

Proceedings Article

Image Reconstruction Based on a Cascaded neural network for Magnetic Particle Imaging

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Abstract

The performance of image reconstruction method is critical in magnetic particle imaging (MPI), as it greatly affects the quality of MPI images. In this study, an image reconstruction method based on a cascaded neural network is proposed to obtain high-quality MPI images. In the initial stage, the measured signal is processed by the first network module to reconstruct a preliminary image that captures the global structural information of the imaging target. The preliminary image is then passed to the second network module to generate the final reconstructed output. The cascaded structure ensures that each subnetwork can focus on a specific subtask to improve overall reconstruction quality. Numerical simulations are performed to evaluate the performance of the proposed method based on different loss functions. We envisage that the proposed method is of great significance in advancing biomedical applications of MPI.

I. Introduction

Magnetic particle imaging (MPI) is an emerging biomedical imaging technology, which measures the non-linear magnetization response of magnetic nanoparticles (MNPs) to determine the spatial distribution of the MNPs [1]. As a tracer-based modality relying on superparamagnetic nanoparticles, MPI enables accurate quantification of particle concentration [2]. It also offers notable advantages such as high sensitivity and superior spatial and temporal resolution [3]. The ability to generate high-quality images is essential for expanding the biomedical utility of MPI in applications including tumor diagnosis and targeted drug delivery.

Image reconstruction in Magnetic Particle Imaging (MPI) is an ill-posed inverse problem that transforms measured raw data into images. This process is highly sensitive to noise and perturbations in the data. In the past several years, the regularization methods have been widely used for MPI image reconstruction, including alternating direction method of multipliers (ADMMs) and

the algebraic reconstruction technique (ART) methods [4]. In addition, deep-learning-based methods have received increasing attention in recent years and have been applied to image reconstruction, image enhancement and system matrix recovery [6]. In this study, we propose a new end-to-end image reconstruction method based on a cascaded neural network, which consists of two network modules.

II. Method

The amplitude of a specific harmonic of a dot superparamagnetic iron oxide nanoparticle (SPION) sample versus position of field free point (FFP) is considered as the point spread function (PSF) of narrowband MPI. The relationship between measured 3rd harmonic $u_3(r)$ at different FFP position and the PSF of the 3rd harmonic $PSF(r)$ can be expressed as:

$$u_{3rd}(r) = h_{3rd}(r) * PSF_{3rd}(r_{FFP}) \quad (1)$$

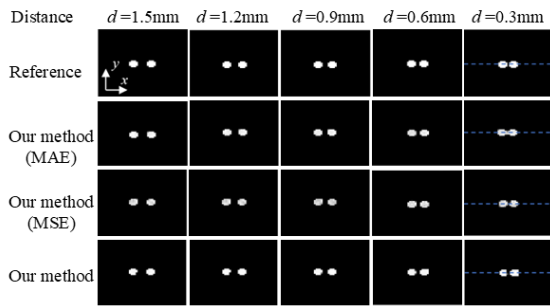


Figure 1: MPI images reconstructed by different training strategies with different distances d in x -direction.

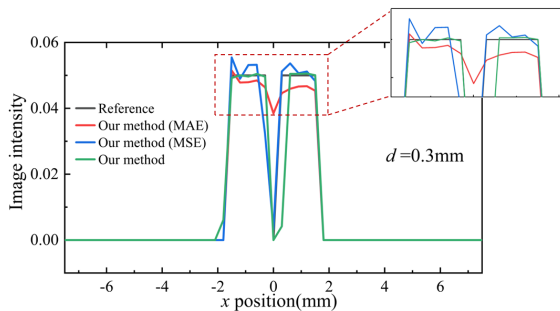


Figure 2: Pixel values on the blue lines using the proposed method with different loss functions in x -direction when $d = 0.3\text{mm}$.

where $h(r)$ is the 3rd harmonic generated by the local SPIONs at position r .

As the FFP moves across the entire field of view (FOV), the obtained magnetization response signals are discontinuous, after discretization, the relationship between the measured signal and the particle concentration can be formulated as a linear integral equation, which can be further expressed in matrix form:

$$Sc = u, \quad (2)$$

where S denotes the system matrix, c is the distribution of SPIONs concentration, and u is the voltage vector.

In this work, a cascaded neural network is proposed to reconstruct MPI images which consists of two network modules. The voltage vector is fed to the first network module to output the preliminary image, which will be used as an input to the second network module for further quality improvement.

III. Results

In the simulation, the proposed method based on different loss functions were used to reconstruct the images of

the point phantoms with different distances d in the x -direction, as shown in Figure 1. The image reconstructed by the proposed method can fully distinguished the two objects at 0.3 mm distance in x -direction with good uniformity.

The pixel values extracted from the blue lines in Figure 1 were shown in Figure 2. The 1-D curves reconstructed with MSE showed more fluctuations in the point region. Conversely, those reconstructed by the proposed method demonstrated better uniformity in the point region.

IV. Conclusion

In this work, an image reconstruction method based on a cascaded neural network was proposed to reconstruct high-quality MPI images. Simulation results exhibited that the proposed method improves the spatial resolution and image uniformity.

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Author's statement

Conflict of interest: Authors state no conflict of interest. Informed consent: Informed consent has been obtained from all individuals included in this study. Ethical approval: The research does not involve any animal experiments.

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