

B₀ Field Optimization of Permanent Magnet Assemblies with Characterized Field Variations in Individual Magnets Using Genetic Algorithms

K. Lavronenko^{1,2}, Marcel Ochsendorf^{1,2}, Volkmarschulz^{1,2}

¹RWTH Aachen University, LfB Institute, Aachen, Germany,

²Fraunhofer Institute for Digital Medicine MEVIS

Introduction: Low-field MRI systems using permanent magnets offer accessible and cost-effective imaging solutions [1]. Yet, achieving uniform B₀ fields remains a major challenge. One of the major reasons for is the remanence variation in individual magnets. This study investigates whether characterizing individual remanence and optimizing magnet placement using genetic algorithms (GA) can improve field homogeneity prior to shimming.

Methods: We studied a ROMA configuration from the OSII project [2], comprising 2320 N52 NdFeB magnets (12×12×12 mm³ inner, 12×12×50 mm³ outer), generating 45–50 mT within a 20 cm spherical FOV.

1. **Magnet Characterization:** Remanence of 318 magnets from multiple batches was measured using an MMC5603 Memsic Inc. ($\pm 0.2 \mu\text{T}$). The remaining magnets were sampled based on the observed distribution, Fig. 1.
2. **Field Simulation:** A Biot-Savart dipole approximation [3,4,5] computed field maps on a 3D mesh grid for fast homogeneity assessment.
3. **Genetic Algorithm Optimization:** We evaluated 10,000 random permutations, then ran 10 GAs for both minimization and maximization of homogeneity (mutation rate: 10%, 500 mating parents, 200 generations) to analyze the possible homogeneity span when constructing the system.

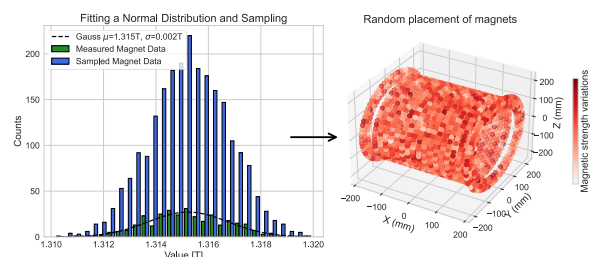


Fig. 1: Upsampling the measured magnet data using a fitted normal distribution. Right: Placement of magnets with sampled properties in the target system.

Results and discussion: Fig. 2 shows the homogeneity variation across random arrangements (4431 ± 65 ppm). Maximization achieved up to 6566 ± 85 ppm, while minimization yielded 4189 ± 85 ppm — a 2377 ppm spread. This suggests that while random arrangements provide consistent average homogeneity, GA optimization can significantly enhance performance before physical assembly.

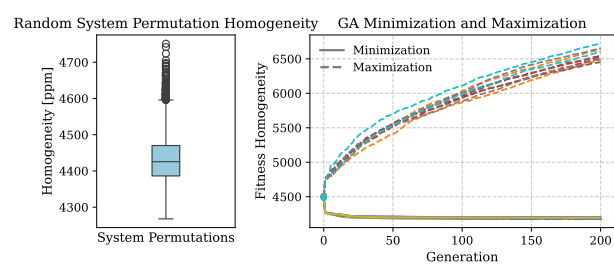


Fig. 2: Left: boxplot visualizing random homogeneity of random system arrangements. Right: development of the genetic algorithm optimizations.

Conclusion: Characterizing individual magnet remanence and applying GA-based configuration can substantially improve B₀ field uniformity in permanent magnet arrays. This approach offers a low-cost enhancement step before traditional shimming, particularly valuable in resource-constrained low-field MRI systems.

References: [1] H. Masaaki, DOI: 10.1097/RLI.0000000000000810. [2] Winter, L. et al. DOI: 10.5281/zenodo.10079541. [3] S. Tewari et al., DOI: 10.1016/j.jmr.2021.106923. [4] T.O'Reilly et al., DOI: doi.org/10.1002/mrm.28396. [5] A.J. Petrushka et al., DOI: 10.1109/TMAG.2012.2205014