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2D アレイ状にホールセンサを実装した回路基板と深層ニューラルネットワークを連携した永久磁石の高速磁化推定システム

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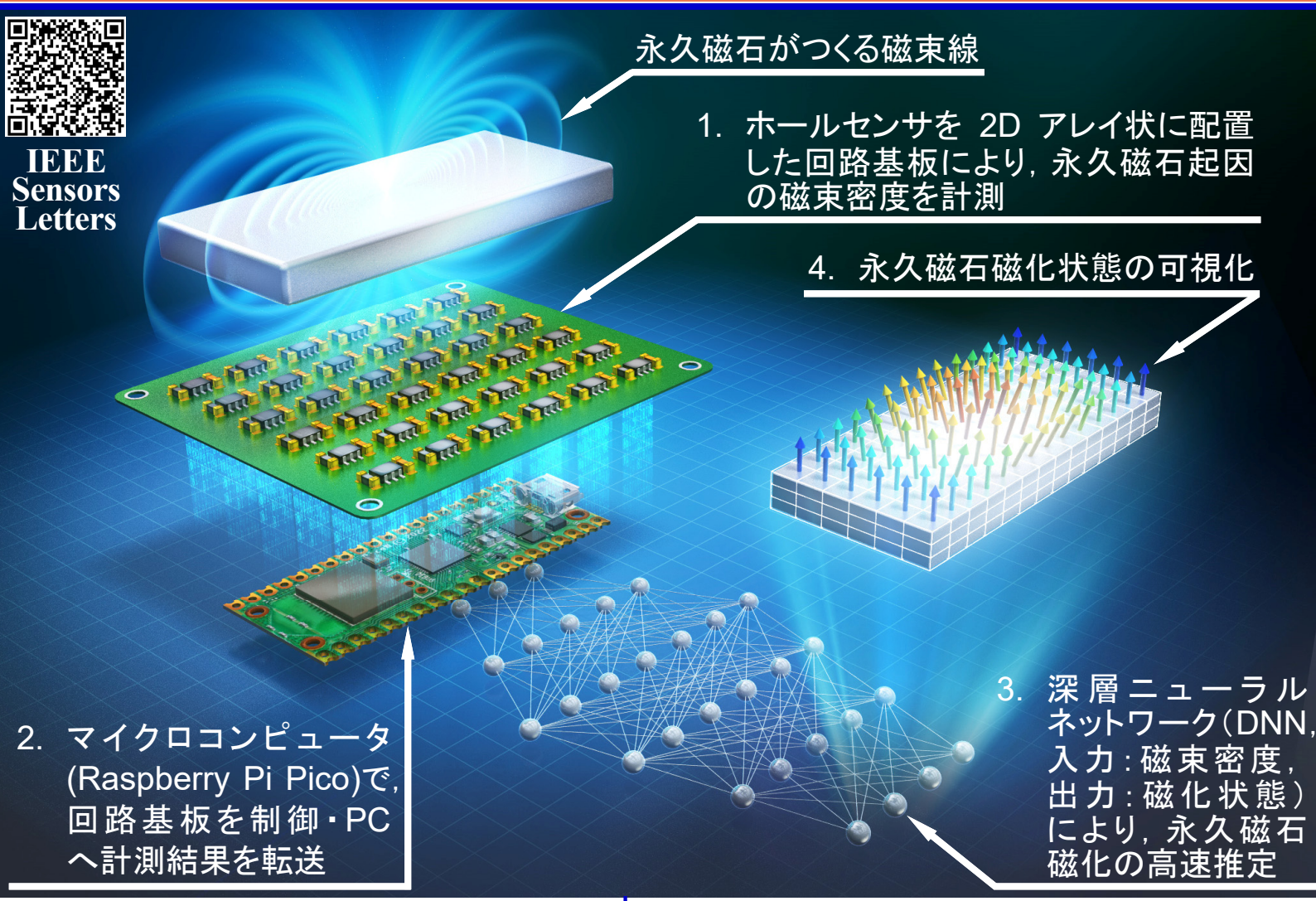
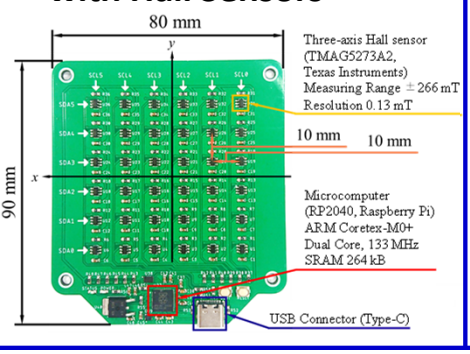


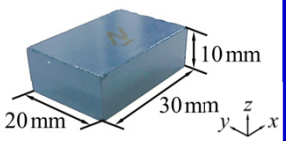
Introduction

On the manufacturing process of permanent magnet (PM) synchronous motors, a fast nondestructive estimation instrumentation for PM magnetization is substantially required. In this paper, to estimate the PM magnetization quickly and accurately, a special instrumentation comprising the 2D-arrayed Hall sensors and deep neural network is developed.

In-house Circuit Board with Hall Sensors

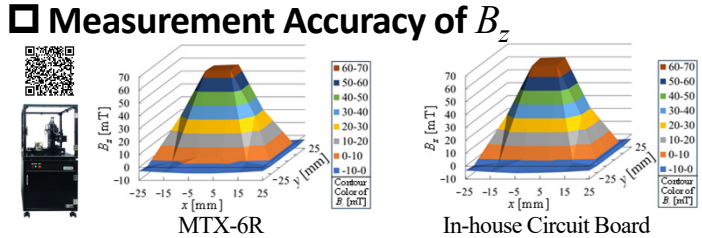


Target PM

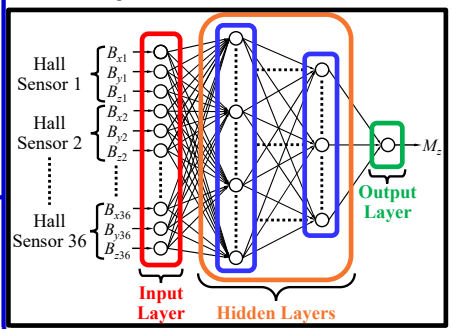


- Ferrite PM Spec.
  - ✓ Material: Y35
  - ✓ B_r: 400 – 440 mT
  - ✓ H_c: 176 – 224 kA/m
  - ✓ Parallel Orientation in the z-direction

Measurement Accuracy of B_z



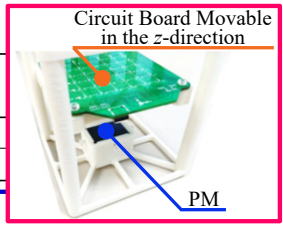
Deep Neural Network



➢ Training Datasets

Biot-Savart Law: $AM_z = \boldsymbol{B}$

By changing M_z from −500 mT to 500 mT in the increments of 25 mT for the specified airgap between the circuit board and the PM, 41 ($\boldsymbol{B}$, M_z) patterns of datasets were generated. Furthermore, by changing its airgap from 1 mm to 20 mm in the increments of 1 mm, 20 patterns of datasets were generated. Thus, a total of 820 (= 41 × 20) datasets were generated using Biot-Savart law. Finally, a total of 15,580 (= 820 × 19) datasets which were generated by adding the random noise to the datasets derived from Biot-Savart law. Consequently, a total of 16,400 datasets is applied to DNN.



Hyperparameters of DNN

Layer Type	Input	Hidden Layers			Output
		1st	2nd	3rd	
Number of Neurons	108	100	100	100	1
Activation Function	–	SELU	SELU	SELU	Linear

Estimation Results

Instrumentation		MTX-6R + SiGrad[1] (ratio)	m-axis L[2]	Proposed System (ratio)
Elapsed Time [s]	Measurement of Magnetic Flux Density	60 (1.00)	10.0	0.066 (0.001)
	Magnetization Estimation	4.1 (1.00)		0.1 (0.024)
	Total	64.1 (1.00)	10.0 (0.156)	0.166 (0.003)
Estimated M_z of PM [mT]		372.8 (1.00)	373.1 (1.00)	373.7 (1.00)

CPU：Intel Core i7-9700K 3.6 GHz，RAM：64 GB

References

1. N. Nakamura, Y. Okamoto, K. Osanai, S. Doi, T. Aoki, and K. Okazaki, “Magnetization estimation method for permanent magnet based on mathematical programming combined with sigmoid function,” *IEEE Trans. Magn.*, vol. 58, no. 9-6000704, Sep. 2022.
2. Matesy GmbH ，https://matesy.de/en/products/m-axis