Randomly generated magnetic wire for reservoir computing

Osaka Univ.[1], CSRN Osaka Univ.[2], OTRI Osaka Univ.[3], SRIS Tohoku Univ.[4]
K.Enju[1], M.Goto[1,2,3], Y.Suzuki[1,2,3], H.Nomura[1,2,4]
E-mail: hikaru.nomura.d6@tohoku.ac.jp

With the spread of IoT devices, edge computing, in which information is preprocessed by a device near the IoT device and the preprocessed information is processed by a server, is attracting attention. Many IoT devices are designed to operate remotely, so it is difficult to provide large-scale computing equipment due to limited power and computing resources. Therefore, information processing mechanisms near IoT devices need to pre-process information with less power consumption and fewer computing resources. As an information processing mechanism, neural networks (NNs) are promising because of their superior capabilities in various fields such as image recognition and anomaly detection, but they have problems of power consumption and computational resources.

To address this problem, a technique called reservoir computing (RC), which optimizes only on the output layer of the network, has attracted attention. RC is a type of recurrent neural networks (RNNs) that can treat time-series data. General NNs and RNNs require a large amount of computational resources to optimize the weights of all input, intermediate, and output layers. RC, on the other hand, optimizes only the weights of the output layer, so it can reduce many of them. Since the parameters of the intermediate layer are fixed, important feature of RC is that it can use physical systems as the intermediate layer network, and RC using physical phenomena is called physical reservoir computing (PRC).

PRC using various physical systems have been studied, including electric circuits, optical systems, magnetic materials, mechanical systems, and biological systems [1]. In this study, we focus on magnetic devices, which are considered suitable for remote devices because of their non-volatility, which enables intermittent operation and ultra-low power consumption. Prior PRC research using magnetic materials can be classified into two types: those using dynamic magnetization states [2, 3] and those using static magnetization states [4, 5]. The former has been experimentally demonstrated, howerver the latter has been proposed by simulation and has not been experimentally studied sufficiently.

Previous studies have suggested that the static magnetization state in a magnetic wire with a combined magnetic shift-register structure has high performance as a reservoir element [5]. In this study, we fabricated a magnetic wire element with a random maze structure and evaluated its performance as a reservoir element in order to investigate an element with high performance as a reservoir element. In the evaluation, the data processed by this device are binary values of 0 and 1. By applying an external magnetic field corresponding to the input, the physical input and state were updated, and the MOKE microscope image reflecting the magnetization state was used as the output of the reservoir element. From the measurement results, we evaluated the performance of this element as a reservoir and examined the element that contribute to its performance as a reservoir. This research was supported by JSPS KAKENHI Grant No. 20H05655 and JST CREST JPMJCR20C6.

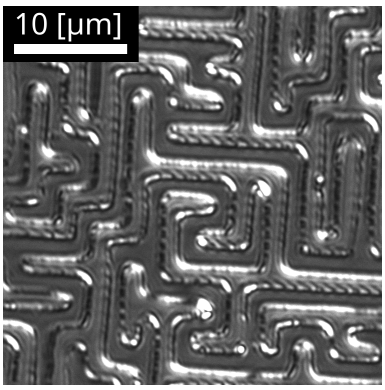

Figure 1: Optical microscope image of maze shaped magnetic wire

References

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