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Pattern recognition using FRET networks: a preliminary study

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Abstract—Energy transfer networks between nanoparticles due to Förster resonance energy transfer (FRET) are called FRET networks, which are promising physical phenomena for realizing high-speed, high-efficient, and compact information-processing devices. FRET networks can generate rich spatiotemporal signals, which are helpful for information processing and, in fact, capable of time-series prediction, as shown in our previous studies using a mathematical model. This study proposes a pattern recognition scheme using FRET networks based on their nonlinearity. Numerical results using the mathematical model show that FRET networks are capable of pattern recognition, such as MNIST handwritten digit recognition.

1. Introduction

Förster resonance energy transfer (FRET) is a mechanism of energy transfer caused by dipole-dipole interaction between two neighboring nanoparticles [1]. FRET networks are energy transfer networks due to FRET in a spatially distributed fluorescent particles, for example, quantum dots (QDs). An experimental study [2] using actual QDs revealed that FRET networks generate diverse spatiotemporal signals, which can be helpful for information processing. Our previous study [3] developed a mathematical model for FRET networks as a continuous-time Markov chains [4]. Furthermore, our previous numerical studies [5, 6] using the mathematical model showed that FRET networks can predict time series, thanks to their nonlinearity and some memory. This study using the mathematical model will show that FRET networks are also capable of pattern recognition, such as MNIST handwritten digit recognition.

2. Methods

We propose a pattern recognition scheme using FRET networks. We consider a simple network structure with a single hidden layer consisting of QD-FRET networks. We input excitation light encoded a pattern to the hidden layer and use its output fluorescent signals to perform the pattern classification. Because of the nonlinearity between input/output of FRET networks, we consider that the pattern classification using FRET networks effectively works. Like the extreme learning machine (ELM) [7], our scheme only learns output weights by linear regression.

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3. Results

We apply the proposed pattern recognition scheme using FRET networks to MNIST handwritten digit recognition tasks. We assume irradiating the input excitation light at 784 locations corresponding to the pixels and observing the output fluorescent signals at 10 locations corresponding to the digits. We examine the influence of several hyper parameters against the accuracy and set appropriate values to those hyper parameters. We finally obtain the dependency on the number of FRET network nodes against the accuracy. Our numerical results show that the accuracy is more than 95% when the number of FRET network nodes is more than 3000.

4. Conclusion

We proposed a pattern recognition scheme using FRET networks. The proposed scheme has a simple network structure with a single hidden layer consisting of QD-FRET networks and only learns output weights as with ELM. Our numerical results showed that the proposed scheme certainly has the capability of MNIST handwritten digit pattern recognition. We believe that the proposed scheme may contribute to realizing high-speed, high-efficient, and compact pattern recognition devices.

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