Optical Correlator based Image Classifier

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1. Introduction

In data recognition systems with large capacity databases, it is very important to improve the speed of the identification process. Recently, a system with dedicated hardware based on field-programmable gate array was proposed for speeding up this operation [1], and there is a high expectation for further high-speed verification. We have developed and optimized an optical correlation system that can retrieve matched images from a large number of databases at high speed [2, 3]. So far, data transfer rates exceeding 140 Gbps have been achieved experimentally [4]. However, there is a problem that conventional optical correlation system is applicable only for the k-nearest neighbor method. Therefore, it was necessary to introduce a new method to apply high-speed optical correlation system for another data analysis method.

In this study, we experimentally demonstrate an optical classifier based on the optical correlator.

2. Vector decomposition

In general, the decision function in the classifier is expressed as

$$f(x) = \boldsymbol{w}^{\mathrm{T}}\boldsymbol{x}.$$

Here, $\boldsymbol{w} \in \mathbb{R}$ is the weight vector, and $\boldsymbol{x}$ is the input vector. The optimization of the weight vector using the training data is called learning, and the weight vector is determined by the learning process. Our optical correlator adopts a binary modulation spatial light modulator (SLM), which is not suitable for dealing with weight vectors that are real numbers. In this study, we approximate the weight vector by the product of the binary vectors and real number coefficients. The above equation is obtained by binary decomposition of the weight vector as follows:

$$f(x) \approx \sum_{i=1}^{N} \beta_i \, \boldsymbol{b_i}\boldsymbol{x}.$$

After the vector decomposition, the binary vectors are recorded in the hologram. Decomposing the real weight vector into binary vectors makes it possible to apply the conventional optical correlator to some data analysis method.

3. Optical correlator based optical classifier

The proposed optical classifier has two processes: the hologram recording process of the weight vector and the classification process. Figure 1 shows a schematic of the identification process of the proposed optical classifier. In the hologram recording process of the weight vector, feature amount extraction is first performed on the training data for classifier creation, and a weight vector for identification is generated by a machine-learning algorithm such as support vector machine (SVM). After that, the obtained weight vector is binary decomposed by an approximate calculation, and binary vectors are obtained. These binary vectors are multiplex recorded to a hologram medium in the optical correlator. At the time of the classification process, feature quantity extraction is performed on the target data similar to that during the learning process, and the operations with previously recorded decomposed weight vectors are performed based on the optical correlator. The light intensity is modulated by the intensity mask based on the real number coefficient. Finally, the output value of the decision function is obtained, and the two-class classification problem is solved by taking the decision using a threshold.

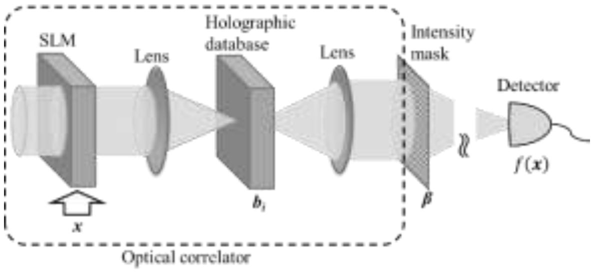

Fig. 1 Schematic of the optical correlator based optical classifier.

As an experimental evaluation of the proposed optical classifier, the operation $\boldsymbol{b_i}\boldsymbol{x}$ in the two-class image classification task was performed by our holographic optical correlator, and the output of the decision function was calculated. Based on the obtained output, two-class classification is executed, and the usefulness of the proposed method is confirmed.

4. Conclusions

It was shown that the optical correlator could be used as a classifier of SVM by introducing binary vector decomposition. Based on the results, the possibility of expanding the application of the optical correlator was demonstrated.

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