Investigating and Improving Ensemble Learning of Deep Neural Networks for Image Classification

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論　文　内　容　の　要　旨

N-ary error correcting output codes (ECOC) is one of the latest techniques in ensemble learning, which employs multiple base classifiers to achieve high accuracy. N-ary ECOC obtains its multiple base classifiers by each time partitioning the original classes into N disjoint meta-classes and then learning a base classifier. N-ary ECOC is known to exhibit high accuracy when a base classifier is either a Support Vector Machine or a decision tree. However, little is known about N-ary ECOC with Deep neural networks (DNNs) as base classifiers, probably due to the extremely long computation time. This situation is unfortunate because DNNs have exhibited the highest accuracies for various image classification tasks in recent years.

In this thesis, we first show by experiments that N-ary ECOC with DNNs as base classifiers generally exhibits superior performance compared with several state-of-the-art ensemble learning methods. Moreover, based on the experiments, we propose a more efficient setting of the two crucial hyperparameters of N-ary ECOC: the value of N and the number of base classifiers to train. We also explore valuable strategies for further improving the accuracy of N-ary ECOC.

Then we propose a new ensemble learning method called "retraining" to overcome the flaws of snapshot ensemble, which controls the learning rate to obtain an ensemble of DNNs as its base classifiers in a time-efficient manner. Our retraining consists of multiple rounds of training, each of which learns a DNN. It regards the upper-layer parameters, which are directly responsible for making predictions, as more important than the lower-layer parameters, of which features represent lower-level patterns. Unlike snapshot ensemble, we propose to reinitialize only the weights of the last layer from the second round of training. Experiments on eight DNN models show that our retraining generally outperforms snapshot ensemble, Bagging, AdaBoost, ECOC, N-ary ECOC and horizontal voting.