Nearest-Neighbor Classification Using Unlabeled Data for Real World Image Application

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ABSTRACT

Currently, Nearest-Neighbor approaches (NN) have been widely applied to real world image data mining. These approaches have the following three disadvantages: (i) the performance is inferior on small datasets; (ii) the performance of approximated nearest neighbor search will degrade for data with high dimensions; (iii) they are heavily dependent on the chosen feature and distance measure. To overcome these intrinsic weaknesses, we propose a novel Nearest-Neighbor method, which improves the original NN approaches from three aspects. Firstly, we propose a novel neighborhood similarity measure, where the similarity between test images and labeled images in the database is calculated jointly by the original image-to-image similarity and the average similarity of their neighboring unlabeled data. Secondly, we adopt the kernelized locality sensitive hashing to effectively conduct the nearest neighbor search for high dimensional data. Finally, to enhance the robustness of the method on different genres of images, we propose to fuse the discrimination power of different features by considering all the retrieved nearest neighbors via hashing systems using different features/kernels. Experimental result shows the advantage over traditional Nearest-Neighbor methods using the labeled data only. Even when the ratio of labeled data is very small, our method could also achieve remarkable results, thanks to the help of unlabeled data and multiple features.

Categories and Subject Descriptors

H.3.1 [**Information Storage and Retrieval**]: Content Analysis and Indexing; I.2.6 [**Artificial Intelligence**]: Learning; I.4.8 [**Image Processing and Computer Vision**]: Scene Analysis

General Terms

Algorithms, Experimentation.

Keywords

image classification, Nearest-Neighbor methods, neighborhood similarity measure, kernelized locality sensitive hashing.

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1. INTRODUCTION

Automatic image classification has drawn considerable attention during the past few decades. The significant endeavors made in the research community have resulted in many novel and effective approaches. For typical dataset such as Caltech-101, the classification accuracies of state-of-the-art methods have been improved from 20% to almost 90% during the past few years [2,9].

Among the existing approaches, a well studied paradigm for image classification is learning based approaches, which requires an intensive training step for classifier models (For example, SVM [4], Boosting [12] and Distance Metric Learning [11]). Another is totally data driven, which requires no training step on model parameters. The most common data driven approach is Nearest-Neighbor Classification (NN), which classifies an image by the class of its most similar images in the database.

Compared with the learning based approaches, data driven approaches have several advantages: (i) no training and learning step is required; (ii) no over-fitting issues should be considered; (iii) they can naturally handle thousands of image classes and millions of images. Furthermore, when the number of labeled images in the database is large enough, the error rate of Nearest-Neighbor approaches converges to the optimal Bayes error rate [1], which provides a theoretical foundation for NN methods.

However, Nearest-Neighbor approaches usually achieve inferior performance than learning based approaches in many scenarios. To bridge the performance gap between NN approaches and learning based approaches, a lot of studies have been conducted from different aspects. Firstly, from distance metric aspect [2, 5, 8], Boiman *et al*. [2] claimed that the previously used image-to-image distance will lead to the degradation of NN approaches and proposed an image-to-class distance measure. Friedman [5] proposed a new local similarity measure based on kernel methods and recursive partitioning techniques. Another similarity measure was proposed in [8] to incorporate the invariance of translations and scaling. From database size aspect [3, 8], Torralba *et al*. [8] found that with extremely large tiny image database, *i.e.*, 80 millions, NN could work significantly well for image annotation, although the tags of the images are very noisy. Deng *et al*. [3] constructed a large scale database with human labeled ground truth. NN approach is more likely to achieve good performance on this large scale database. Next, from image analysis aspect, Boiman *et al*. [2] showed that feature quantization will reduce the discrimination power of local features, which will lead to inferior performance of NN methods. Finally, from learning aspect, Zhang *et al*. [13] combined the efficiency of NN and the effectiveness of SVM.