Learning from Complementary Labels
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Machine learning is the process of extracting important hidden patterns and trends from electronic data. The demand of machine learning and its applications has been growing rapidly ever since we have entered the 21st century, both in industry and academia due to the growing amount of size and type of digital information that is stored in databases.

One of the most successful machine learning methods is called *supervised learning*. It has a long history and has been studied intensively in the past few decades. In supervised learning, with our prepared input-output paired dataset, our goal is to learn the relationship between the input and output, so that we can predict the output value for future input data.

In real-world tasks, however, the assumption of having enough input-output paired data for training is often not satisfied. In spite of the fact that we are in the age of *big data*, labeled data is still very costly, mainly because of the human annotation costs.

To cope with this problem, weakly-supervised learning has gained growing attention rather recently. Weakly-supervised learning challenges to learn under the scenario with weaker supervision. Some examples are *semi-supervised learning* (learns from labeled and unlabeled data), *positive-unlabeled learning* (learns from positive and unlabeled data), *label proportion learning* (learns from only unlabeled data with class priors), and *pairwise constraints* (cluster into groups with pairwise similarity and dissimilarity).

In this thesis, to contribute to the line of weakly-supervised learning, we consider a different approach with a *complementary label*. A complementary label only specifies a class that a pattern does *not* belong to. Collecting complementary labels would be less laborious than ordinary labels since users do not have to carefully choose the correct class from many candidate classes.

However, complementary labels are less informative than ordinary labels and thus a suitable approach is needed to better learn from complementary labels. In this thesis, we show that an unbiased estimator of the classification risk can be obtained only from complementary labels, if a loss function satisfies a particular symmetric condition.

Theoretically, we establish the estimation error bounds for the proposed method, showing that learning from complementary labels is also consistent. Finally, we experimentally demonstrate the usefulness of the proposed algorithms.