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Semi-supervised sparse feature selection based on multi-view Laplacian regularization☆

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ABSTRACT

Semi-supervised sparse feature selection, which can exploit the large number unlabeled data and small number labeled data simultaneously, has placed an important role in web image annotation. However, most of the semi-supervised sparse feature selection methods are developed for single-view data and these methods cannot naturally deal with the multi-view data, though it has shown that leveraging information contained in multiple views can dramatically improve the feature selection performance. Recently, multi-view learning has obtained much research attention because it can reveal and leverage the correlated and complementary information between different views. So in this paper, we apply multi-view learning into semi-supervised sparse feature selection and propose a semi-supervised sparse feature selection method based on multi-view Laplacian regularization, namely, multi-view Laplacian sparse feature selection (MLSFS).[1] MLSFS utilizes multi-view Laplacian regularization to boost semi-supervised sparse feature selection performance. A simple iterative method is proposed to solve the objective function of MLSFS. We apply MLSFS algorithm into image annotation task and conduct experiments on two web image datasets. The experimental results show that the proposed MLSFS outperforms the state-of-art single-view sparse feature selection methods.

1. Introduction

Web images, most of which are unlabeled, have shown continuous explosive growth. As an important means, semi-supervised sparse feature selection [1–4] has the ability to improve the performance of web image annotation. It has extensively shown that semi-supervised sparse feature selection approaches can overcome the drawbacks of supervised feature selection methods and unsupervised feature selection methods. On the one hand, semi-supervised sparse feature selection approaches can save human labor cost for labeling a large amount of training data, and on the other hand, they can make full use the reliable labeled data and the accessible unlabeled data simultaneously to improve the sparse feature selection performance.

Among different semi-supervised learning methods, graph Laplacian regularization based method is one of the most representative works [5]. The graph Laplacian can determine the geometry of the underlying manifold in Laplacian regularization. Now, the graph Laplacian regularization based semi-supervised learning has been widely applied into semi-supervised sparse feature selection [1,2]. In [1], Ma et al. have proposed a structural feature selection with sparsity frame based on graph Laplacian semi-supervised learning to select features with considering the correlation between them. In [2], Shi et al. have proposed a semi-supervised sparse feature selection method based on graph Laplacian and $l_{2,1/2}$-matrix norm to select more sparse and discriminative features for image annotation. In this paper, we also exploit graph Laplacian regularization to construct our semi-supervised sparse feature selection frame.

As we know, images are usually represented by different types of features, such as color correlogram, wavelet texture, and edge direction histogram. Each type of features characterizes these images in one specific feature space and has particular physical meaning and statistic property. Conventionally, the data represented by multiple types of features are named as multi-view data to distinguish from the single-view data represented only by one type of features [6]. However, most of the existing semi-supervised sparse feature selection methods are developed for the single-view data and these methods concatenate multiple views features into a long vector once they confront with multi-view data, such as [1,2]. This concatenation strategy cannot efficiently explore the complementary of different view features because it improperly treats different view features carrying different physical characteristics. In addition, this concatenation strategy ignores the

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[1] MLSFS: Multi-view Laplacian Sparse Feature Selection.

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physical interpretations of different features and results in an over-fitting problem when the size of the training set is small.

Recent research has shown that multi-view learning can address the above problems and leverage the correlated and complementary information between different views, thus multi-view learning has obtained more and more research interest and it has been explored in variety of applications. Xu et al. have finished a survey on multi-view learning in their paper [7]. In [8], Liu et al. have applied multi-view learning in the sparse coding for image annotation. In [9], Liu et al. have proposed multi-view regularization to support vector machines for image annotation. In [10], Xu et al. have proposed large-margin multi-view Gaussian process for image classification. In [11], Luo et al. have proposed vector-valued multi-view semi-supervised learning for multi-label image classification. In [12], Xia et al. have proposed multi-view spectral embedding for image retrieval, video annotation, and document clustering. In [13], He et al. have introduced multi-task multi-view learning for complicated learning problems with both feature heterogeneity and task heterogeneity. In [6], Feng et al. have proposed an adaptive unsupervised multi-view feature selection for visual concept recognition. However, as far as I know, multi-view learning has not been widely used in semi-supervised sparse feature selection. Therefore, we apply multi-view learning into our method to boost the semi-supervised sparse feature selection performance.

In this paper, we present a semi-supervised sparse feature selection method based on multi-view Laplacian regularization, namely, multi-view Laplacian sparse feature selection (MLSFS). The framework of MLSFS for web image annotation is illustrated in Fig. A. Multi-view learning, which can effectively explore the complementation of different features from different views, is introduced to MLSFS for forming the multi-view Laplacian regularization to improve the performance of semi-supervised sparse feature selection. An effective iterative algorithm is proposed to optimize the objective function. We apply the proposed MLSFS into web image annotation and some experiments are conducted on two large-scale web image datasets, namely, NUS-WIDE dataset [14] and MSRA-MM2.0 dataset [15]. The results demonstrate that MLSFS outperforms state-of-the-art single-view semi-supervised sparse feature selection methods and unsupervised feature selection methods.

The main contributions of our work are as follows:

- Multi-view Laplacian sparse feature selection (MLSFS) method is proposed, which exploits the multi-view learning to build multi-view Laplacian regularization for boosting the semi-supervised sparse feature selection performance.
- An effective iterative algorithm is proposed to optimize the objective function and its convergence is analyzed.
- Some experiments are conducted and the results indicate that MLSFS have better performance than single-view semi-supervised sparse feature selection methods and unsupervised feature selection methods.

The rest of this paper is organized as follows. Section 2 reviews the multi-view learning and semi-supervised learning. Section 3 elaborates MLSFS framework and its convergence. Section 4 conducts extensive experiments on two datasets to evaluate the performance of MLSFS. Lastly, Section 5 concludes this paper.

2. Related work

In this section, we review the related work of our MLSFS algorithm, including multi-view learning and semi-supervised learning.

2.1. Multi-view learning

Recently, multi-view learning has obtained extensive research interest and the existing multi-view learning algorithms can be grouped into the following four categories: co-training, multiple kernel learning, subspace learning, and graph-based learning.

Co-training [16] is one of the earliest schemes for multi-view learning. It trains alternately to maximize the mutual agreement on two distinct different views of the unlabeled data. Co-training method effectively exploits unlabeled data to improve the performance, especially when the two views are conditionally independent of one another

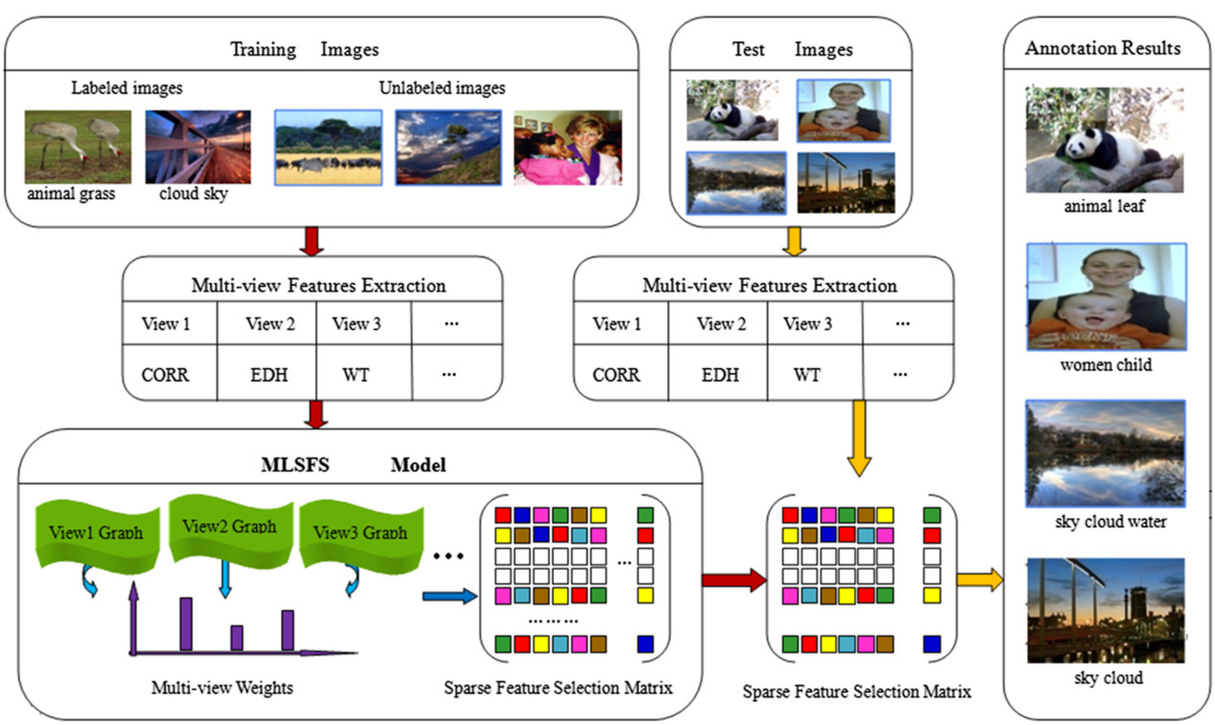

Fig. A. The MLSFS framework for web image annotation.