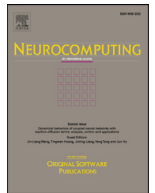




Contents lists available at ScienceDirect

Neurocomputing

journal homepage: www.elsevier.com/locate/neucom

Robust multi-view data clustering with multi-view capped-norm K-means

Shudong Huang, Yazhou Ren, Zenglin Xu*

SMILE Lab, School of Computer Science and Engineering, University of Electronic Science and Technology of China, Chengdu 610031, China

ARTICLE INFO

Article history:

Received 11 August 2017

Revised 1 April 2018

Accepted 20 May 2018

Available online xxx

Communicated by Ivor Tsang

Keywords:

Multi-view clustering

Capped-norm

Robust clustering

ABSTRACT

Real-world data sets are often comprised of multiple representations or views which provide different and complementary aspects of information. Multi-view clustering is an important approach to analyze multi-view data in a unsupervised way. Previous studies have shown that better clustering accuracy can be achieved using integrated information from all the views rather than just relying on each view individually. That is, the hidden patterns in data can be better explored by discovering the common latent structure shared by multiple views. However, traditional multi-view clustering methods are usually sensitive to noises and outliers, which greatly impair the clustering performance in practical problems. Furthermore, existing multi-view clustering methods, e.g. graph-based methods, are with high computational complexity due to the kernel/affinity matrix construction or the eigendecomposition. To address these problems, we propose a novel robust multi-view clustering method to integrate heterogeneous representations of data. To make our method robust to the noises and outliers, especially the extreme data outliers, we utilize the capped-norm loss as the objective. The proposed method is of low complexity, and in the same level as the classic K-means algorithm, which is a major advantage for unsupervised learning. We derive a new efficient optimization algorithm to solve the multi-view clustering problem. Finally, extensive experiments on benchmark data sets show that our proposed method consistently outperforms the state-of-the-art clustering methods.

© 2018 Elsevier B.V. All rights reserved.

1. Introduction

Real world data sets are usually with multiple modalities or represented by different views which capture different aspects of data and can be complementary to each other. This is due to the fact that data may be collected from different sources or be represented by different kind of features for different tasks [1–3]. For example, in image analysis, images can be represented by different visual descriptors like GIST [4], CTM [5], LBP [6], SIFT [7], and HOG [8]; in text analysis, documents can be written in different languages [9]; and in web page categorization, web pages can be classified by page content or linkage [10]. Therefore, it is critical for learning algorithms to integrate these heterogeneous features to improve its accuracy and robustness. Multi-view clustering provides a natural formulation for clustering with such data in the unsupervised setting. Instead of relying on a single view [11–13], multi-view clustering aims to integrate compatible and complementary information provided by the multiple views such

that a better performance can be obtained [14,15]. The key of learning from multiple views is to utilize each view's complementary knowledge in order to outperform simply concatenating views.

In recent years, a number of approaches have been designed to tackle the multi-view clustering problem. Roughly speaking, these approaches can be categorized into subspace approaches and graph-based approaches. The subspace approaches generally try to uncover the common latent subspace shared by multiple views [15–22], while the graph-based approaches were derived from traditional spectral clustering with the help of some similarity measures [2,23–26]. Although several multi-view clustering methods were reported with good performance, they suffer from the following one or more drawbacks: (1) Traditional multi-view clustering methods are usually sensitive to noises and outliers, which greatly impair the clustering performance in practical problems; (2) Multi-view clustering methods based on Nonnegative Matrix Factorization (NMF) cannot be utilized to tackle the data matrix with mixed signs [18,27]; (3) For graph-based methods, the application of different kernels to build the graph will greatly affect the clustering performance [28]. Thus we have to consider the impact of the choices of parameters for some specific kernels,

* Corresponding author.

E-mail address: zlxu@uestc.edu.cn (Z. Xu).

such that the final clustering results are sensitive to the parameters tuning; (4) More importantly, the graph-based methods are not applicable to real-world problems since both the kernel construction and eigendecomposition will involve heavy computation.

In this paper, we propose a novel robust multi-view clustering method to integrate heterogeneous representations of data. By applying the capped-norm based residual calculation for the objective, the proposed model is robust to the noises and outliers, especially the extreme data outliers. Furthermore, We also show that the time complexity of the proposed method is similar to that of the classic K-means algorithm. To efficiently solve the corresponding optimization problem, we derive a new efficient alternating minimization algorithm. In contrast with the competitive multi-view clustering methods, the proposed method consistently achieves better clustering performances on several benchmark data sets.

It is worthwhile to highlight our contributions in this paper as follows:

- We propose a novel robust multi-view clustering method to integrate heterogeneous representations of data. We also derive an efficient updating algorithm to solve the optimization problem.
- The proposed method is robust to the noises and outliers by utilizing the capped-norm based residual calculation. Thus it can achieve more stable clustering results with different initializations.
- The computational complexity of our method is much smaller than the competitive methods, and is as effective as the classical K-means clustering algorithm. Our method avoids the heavy computational burden since it does not require the graph construction as well as the eigendecomposition step.
- Extensive experiments on benchmark data sets demonstrate that our method achieves significant improvement over the state-of-the-art multi-view clustering methods, suggesting the effectiveness of the proposed method.

The rest of the paper is organized as follows. We present a brief review of previous related research in Section 2. We give a detailed description of preliminaries in Section 3. In Section 4, we illustrate our model in detail. Experimental results are presented in Section 5. The paper ends with a conclusion in Section 6.

2. Related work

Multi-view clustering aims at leveraging information shared by the multiple views to improve clustering performance. In recent years, several multi-view clustering approaches have been studied widely under the framework of different theories and methodologies [29,30].

An important class of multi-view clustering methods is multi-view spectral clustering. Kumar and Daume proposed a co-trained multi-view spectral clustering method (Co-train) [23]. It is based on the assumption that the true underlying clustering would assign a data point to the same cluster irrespective of the view. If two data points are assigned in different clusters in one view, it should be so in all the views. On the other hand, if two data points belong to the same cluster, it should be so in all the views. This is a reasonable approach to take in the light of compatibility assumption of co-training. [24] proposed a co-regularized multi-view spectral clustering (Co-reg). Co-reg enforces the view-specific eigenvectors of different graphs (i.e., views) to look similar by regularizing them towards a common consensus. The objective function of Co-reg consists of the graph Laplacians from all the views and regularizes on the eigenvectors of the Laplacians such that the latent structures resulting from each Laplacian look consistent

across all the views. However, these graph-based methods are usually with high computational complexity due to the kernel/affinity matrix construction as well as eigendecomposition.

Gao et al. [31] proposed multi-view subspace clustering (MVSC). Unlike the traditional subspace clustering methods which performing clustering on a common view, MVSC performs clustering on the subspace representation of each view simultaneously. Furthermore, a common indicator is utilized to guarantee the common cluster structure to be consistent across the views. That is, the points in different views are enforced to be classified into the same cluster. Based on the idea that feature selection is a necessity for further improving the multi-view clustering results, Xu et al. [29] presented a weighted multi-view clustering that can perform multi-view data clustering and feature selection simultaneously. Tzortzis and Likas [32] proposed multi-view kernel K-means clustering (MVKKM). Inspired by unsupervised multiple kernel learning, views in MVKKM are expressed in terms of given kernel matrices, and a weighted combination of the kernels is learned in parallel to the partitioning. Cai et al. [33] proposed a robust multi-view K-means clustering (RMKMC). By utilizing the $l_{2,1}$ -norm, RMKMC is robust to noises and outliers. However, it still suffers from the extreme odd outliers since the $l_{2,1}$ -norm based objective just weakens the effect of the outliers, but it cannot remove the effects of the outliers. Wang et al. [34] presented a novel multi-view clustering algorithm based on max-product belief propagation. It aims to establish a multi-view clustering model consisting of two components, which measure the within-view clustering quality and the explicit clustering consistency across different views, respectively. Zong et al. [35] proposed a multi-manifold regularized NMF framework to preserve the locally geometrical structure of the manifolds for multi-view clustering. With the multi-manifold regularization, this model incorporates consensus manifold and consensus coefficient matrix to preserve the locally geometrical structure of the multi-view data space.

In this paper, we focused on the robustness problem in presence of noises and outliers in multi-view clustering tasks. Our proposed method is robust to the noises and outliers, especially the extreme data outliers by utilizing the capped-norm based residual calculation in the objective.

3. Preliminaries

As one of the most classical clustering algorithms, K-means clustering has been widely used in various areas such as image segmentation and text clustering [36–38]. It is a centroid-based clustering method, which aims to learn C cluster centroids that minimize the within cluster data distances [39–43]. Furthermore, it has been widely applied to real-world clustering problems due to its efficiency and simpleness.

Previous studies have shown that nonnegative matrix factorization (NMF) is equivalent to relaxed K-means clustering [44–46]. Thus the objective function of K-means can be reformulated as follows

$$\min_{\mathbf{U}, \mathbf{V}} \|\mathbf{X} - \mathbf{UV}^T\|_F^2 \quad (1)$$

$$\text{s.t. } \mathbf{V}_{ic} \in \{0, 1\}, \sum_{c=1}^C \mathbf{V}_{ic} = 1, \forall i = 1, 2, \dots, n,$$

where $\|\cdot\|_F$ denotes Frobenius norm, C is the prescribed number of clusters, $\mathbf{X} \in \mathbb{R}^{d \times n}$ is the data matrix with n data points and d -dimensional visual features, $\mathbf{U} \in \mathbb{R}^{d \times C}$ is the cluster centroid matrix, and $\mathbf{V} \in \mathbb{R}^{n \times C}$ is the cluster assignment matrix and each row of $\mathbf{V}$ is coded as 1-of- C scheme. That is, $\mathbf{V}_{ic} = 1$ if data point $\mathbf{x}_i$ is assigned to c th cluster and $\mathbf{V}_{ic} = 0$ otherwise.

However, as shown in Eq. (1), traditional NMF models usually adopt the Frobenius norm, which is well-known to be sensitive to outliers and noises [47,48]. Recently, several robust NMF models have been proposed. [47] proposed a $l_{2,1}$ -norm NMF and the

Download English Version:

<https://daneshyari.com/en/article/6863631>

Download Persian Version:

<https://daneshyari.com/article/6863631>

[Daneshyari.com](https://daneshyari.com)