Public Abstract
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Title:Semi-supervised Interactive Unmixing for Hyperspectral Image Analysis

In the past several decades, hyperspectral imaging has drawn a lot of attention in the field of remote sensing. Yet, due to low spatial resolutions of hyperspectral imagers, often the response from more than one surface material can be found in some hyperspectral pixels. These pixels are called mixed pixels. Mixed pixels bring challenges to traditional pixel-level applications, such as identification and detection of ground targets. To address these challenges, hyperspectral unmixing is often an important step during analysis of hyperspectral imagery. Hyperspectral unmixing is the task of decomposing each pixel into a set of pure material signatures with the corresponding proportions of each material found in each pixel. In this thesis, novel hyperspectral unmixing approaches are proposed that leverage interactive labeling and semi-supervised approaches to improve unmixing results.

Hyperspectral unmixing is conducted using an unsupervised approach. Fully supervised hyperspectral unmixing approaches are generally infeasible as the number of pixels in a hyperspectral image is often in the tens- or hundreds-of-thousands and obtaining accurate pixel-level labels is prohibitively expensive or simply impossible. Thus, many hyperspectral unmixing algorithms in literature only use the hyperspectral image. However, there are often other ancillary information regarding the image available that could be used to assist the unmixing process and do not add an infeasible amount of labeling tasks. Motivated by this, novel semi-supervised hyperspectral unmixing techniques are proposed. The proposed semi-supervised approaches allow supervision over hyperspectral unmixing to improve the unmixing performance but do not require complete pixel-level accurate labels for a training data set.

For the semi-supervised hyperspectral unmixing, however, there are some challenges. The first one is to identify which pixels need to be (re-)labeled interactively during the unmixing process. We solve this problem by proposing an instance influence estimation approach. This approach estimates the influence of each pixel based on its impact on target endmember estimation and simplifies the job of the analyst by indicating the pixels with the highest influence during unmixing and endmember estimation. This allows an analyst to only (re-)label the data points with the highest level of influence and to refine the target endmember estimation interactively. The second one is to design a new semi-supervised hyperspectral unmixing method which is capable of introducing a semi-supervised learning phase to hyperspectral unmixing. We solve this challenge by proposing a semi-supervised Partial Membership Latent Dirichlet Allocation (sPM-LDA) approach. The supervision in this approach introduces document-level labeling, restricts and allows one to several candidate topics for each document, which leads to more sparse and precise estimation results. The third challenge is how to find available ancillary information regarding the image data set. We address this challenge by incorporating map data (e.g. Open Street Map) to provide the spatial information and imprecise labels.

Results on real hyperspectral data sets indicate that the proposed instance influence estimation methods can effectively identify the instances, of which labels are most influential for target endmember estimation. Furthermore, experiments on semi-supervised PM-LDA show that overall hyperspectral unmixing results are more accurate than the comparison unmixing that also address spectral variability.