Fast Spatial Preprocessing for Spectral Unmixing of Hyperspectral Data on Graphics Processing Units

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***Abstract*—Spectral unmixing is an important technique for hyperspectral data exploitation. It amounts at finding a set of pure spectral signatures (endmembers) of the most representative materials in the scene, and estimating their abundance fractions. The integration of spatial information prior to spectral unmixing of hyperspectral data has attracted much attention in recent years. Several approaches have been developed for the purpose of guiding endmember identification algorithms to spatially representative, yet spectrally pure endmembers. In particular, the spatial preprocessing (SPP) algorithm can be used prior to most existing spectral-based endmember identification techniques, thus promoting the selection of endmembers in spatially representative areas of the scene. However, most SPP techniques are computationally expensive, which adds significant burden to the spectral unmixing process. In this paper, we present three parallel implementations of SPP that have been specifically developed for commodity graphics processing units (GPUs). We perform an evaluation of these techniques using two GPU architectures from NVidia: GeForce GTX 580 and GeForce GTX 870M, which reveals that real-time processing performance can be obtained for real hyperspectral data sets collected by the airborne visible infra-red imaging spectrometer (AVIRIS).**

***Index Terms*—Endmember identification, graphics processing units (GPUs), hyperspectral imaging, spectral unmixing, spatial preprocessing (SPP).**

I. Introduction

SPECTRAL unmixing amounts at estimating the abundance of pure spectral signatures (called endmembers) in each mixed pixel of a hyperspectral image. Mixed pixels arise due to insufficient spatial resolution and other phenomena [1], [2]. A challenging problem is how to automatically identify endmembers, as the presence of mixed pixels generally prevents the localization of pure spectral signatures in transition areas between different land-cover classes. A possible strategy to address this problem is to guide the endmember identification process to spatially homogeneous areas, expected to contain the purest signatures available in the scene [3]–[5].

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For this purpose, several spatial preprocessing (SPP) methods have been used prior to endmember identification [6]–[8]. The SPP in [6] introduces the spatial information in the endmember extraction process, so that the preprocessing can be combined with classic methods for endmember identification [9]. In this way, the endmembers can be obtained based on spatial and spectral features. An extension of this concept was presented in [7], in which the use of fixed spatial neighborhoods adopted by SPP was replaced by the incorporation of regions intended to better characterize the spatial context. However, the RBSPP strongly depends on a prior region growing algorithm that makes the procedure sensitive to the selected technique for region segmentation. Also, region growing algorithms are difficult to implement in parallel due to their irregular nature. Another technique is the spatial and spectral preprocessing (SSPP) presented in [8], which integrates both spatial and spectral information at the preprocessing level. This technique also includes a clustering step that makes the parallelization difficult. Out of the techniques discussed in [6]–[8], the most amenable one for parallel implementation is the SPP in [6] due to the regularity of its computations, which can be exploited in latest-generation hardware accelerators such as commodity graphics processing units (GPUs).

Despite the availability of several techniques to accelerate the performance of spectral unmixing algorithms on GPUs [10]–[13], no efficient implementations of SPP techniques to be used prior to spectral unmixing have been presented thus far in the literature. In this paper we present, for the first time in the literature, three different parallel implementations of the SPP algorithm in [6] using GPUs (with different memory management strategies). These versions have been implemented using NVidia's compute device unified architecture (CUDA),[1] and tested on two different NVidia GPU architectures: GeForce GTX 580 and GeForce GTX870M, using two different images collected by NASA's AVIRIS over the Cuprite mining district in Nevada and the World Trade Center in New York City. We also presented an exhaustive assessment of the performance of these different versions in terms of memory stalls and cache hit rates. Our experimental validation shows that a significant reduction in the execution time can be achieved allowing the integration of this preprocessing step in a fully operational unmixing chain, which exhibits real-time performance with regards to the time that the AVIRIS sensor takes to collect the data.

This paper is structured as follows. Section II outlines the SPP technique considered in this work. Section III describes

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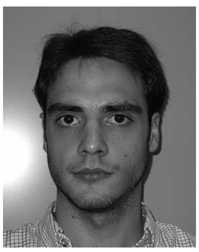

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