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GPU implementation issues for fast unmixing of hyperspectral images

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Space missions usually use hyperspectral imaging techniques to analyse the composition of planetary surfaces. Missions such as ESA's Mars Express and Venus Express generate extensive datasets whose processing demands so far have exceeded the resources available to many researchers. To overcome this limitation, the challenge is to develop numerical methods allowing to exploit the potential of modern calculation tools.

The processing of a hyperspectral image consists of the identification of the observed surface components and eventually the assessment of their fractional abundances inside each pixel area. In this latter case, the problem is referred to as spectral unmixing. This work focuses on a supervised unmixing approach where the relevant component spectra are supposed to be part of an available spectral library. Therefore, the question addressed here is reduced to the estimation of the fractional abundances, or abundance maps. It requires the solution of a large-scale optimization problem subject to linear constraints; positivity of the abundances and their partial/full additivity (sum less/equal to one).

Conventional approaches to such a problem usually suffer from a high computational overhead. Recently, an interior-point optimization using a primal-dual approach has been proven an efficient method to solve this spectral unmixing problem at reduced computational cost. This is achieved with a parallel implementation based on Graphics Processing Units (GPUs). Several issues are discussed such as the data organization in memory and the strategy used to compute efficiently one global quantity from a large dataset in a parallel fashion. Every step of the algorithm is optimized to be GPU-efficient. Finally, the main steps of the global system for the processing of a large number of hyperspectral images are discussed.

The advantage of using a GPU is demonstrated by unmixing a large dataset consisting of 1300 hyperspectral images from Mars Express' OMEGA instrument and uses a spectral library of 41 possible ground components. The parallel implementation proposed requires three days of calculation to unmix this dataset, instead of twenty days for the optimized CPU implementation previously in use.