IP2 ISAAC Parallel Image Processing

Fast image subtraction using multi-cores and GPUs

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Abstract

The image differencing technique known as Optimal Image Subtraction (OIS)[1], is very useful for detecting and characterizing transient phenomena. Utilizing many-core graphical processing unit (GPU) technology, in a hybrid conjunction with multi-core CPU and computer clustering technologies, this work presents early results from a new astronomy image processing pipeline architecture. The chosen OIS implementation focuses on the 2nd-order spatially-varying kernel with the Dirac delta function basis (DFB)[2], a computationally intensive method with desirable detection capabilities. This new tool can process standard image calibration operations and OIS image differencing in a fashion that is scalable with the increasing data volume.

Challenge

The spatially-varying OIS compensates for point spread function (PSF) changes across the field of view (FOV) in order to match images sufficiently for a high quality subtraction. The second order bivariate fit is necessary to adapt to both lateral and rotational translation. For the 2nd-order DFB the following polynomial must be evaluated for every convolution kernel pixel at every image pixel.

$$a_{x,y,i} = a_{00} + a_{01}y + a_{02}y^2 + a_{11}xy + a_{10}x + a_{20}x^2$$

Where the convolution kernel with i pixels is generated by,

$$K_{x,y} = \sum_i \left(a(x,y) \right)_i$$

at each *x,y* image pixel. Allowing the subtraction of an image I and a convolved reference R to produce a difference image of all photometric changes.

$$I - (R \otimes K) = D$$

The era of gigapixel images, and terabyte archives are too much for existing serial code implementations, requiring minutes to hours for convolution of a single image. IP2 leverages recent advances in parallel computing to restructure and distribute these calculations using off-the-shelf CPU and GPU hardware, accelerating 2nd-order DFB OIS for large image sets by more than two orders of magnitude over currently available implementations [3].

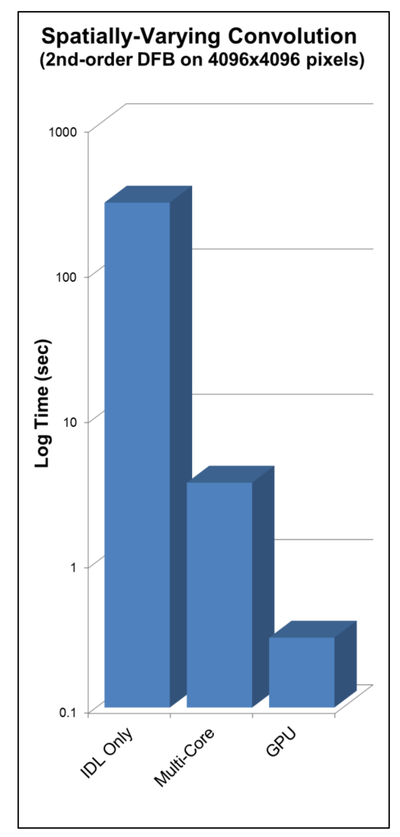
Faster time to results

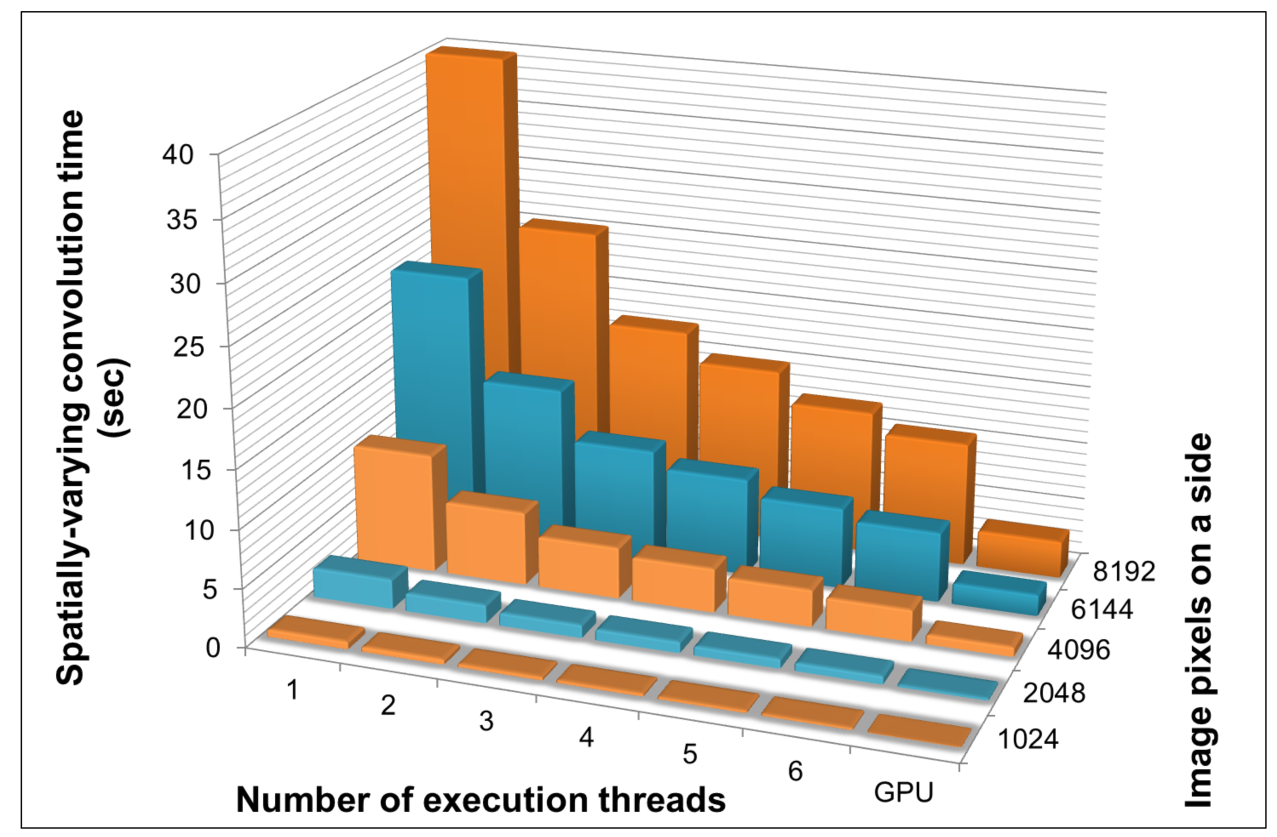
Single node computer performance

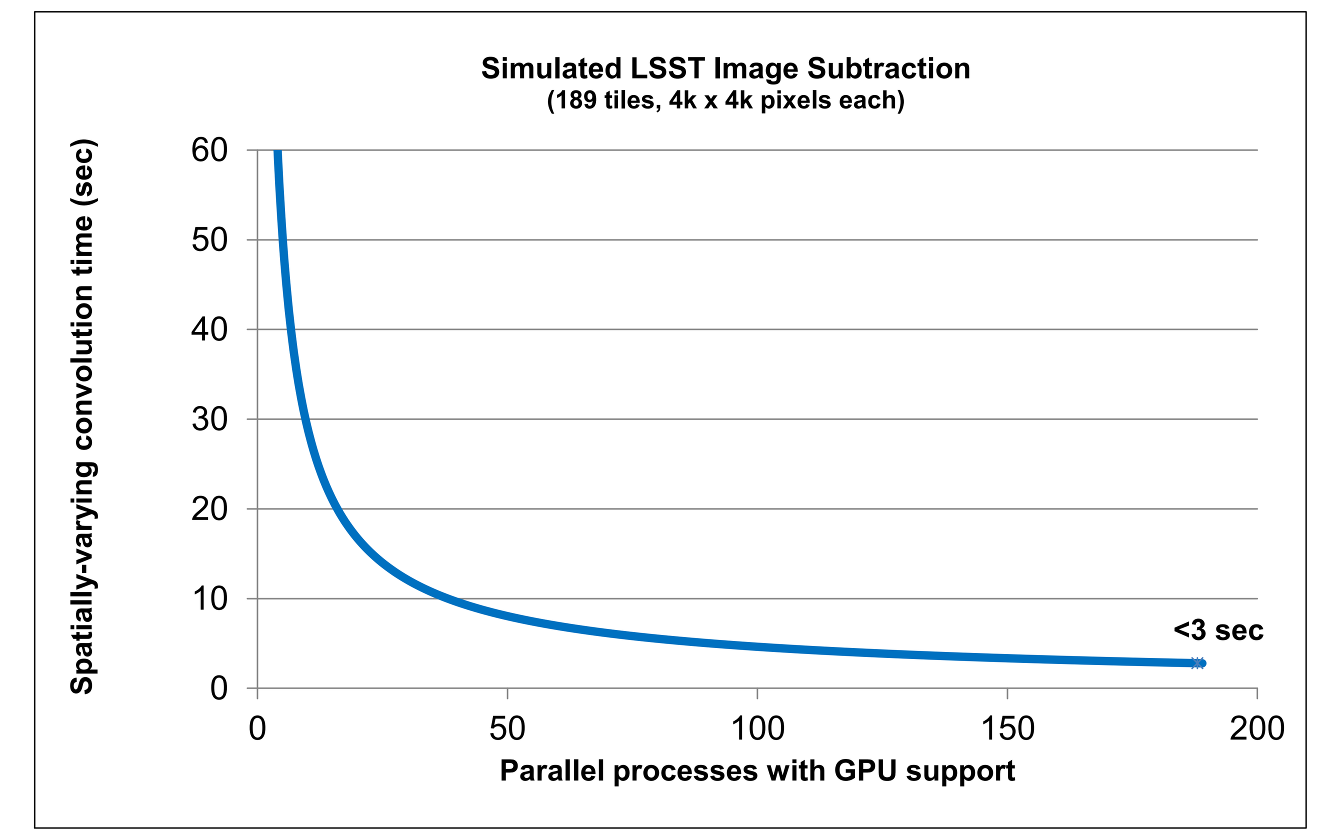
On larger images, the use of multi-core CPUs via OpenMP offers a **50x** improvement for the critical convolution portion of the algorithm over an IDL-only implementation. The use of GPUs with the CUDA language provides an additional **3x-7x** speed-up.

Cluster scalability

For large mosaic camera images, or large archive reprocessing, a multi-node computer cluster can be employed, allowing simultaneous parallel processing of many images pairs.







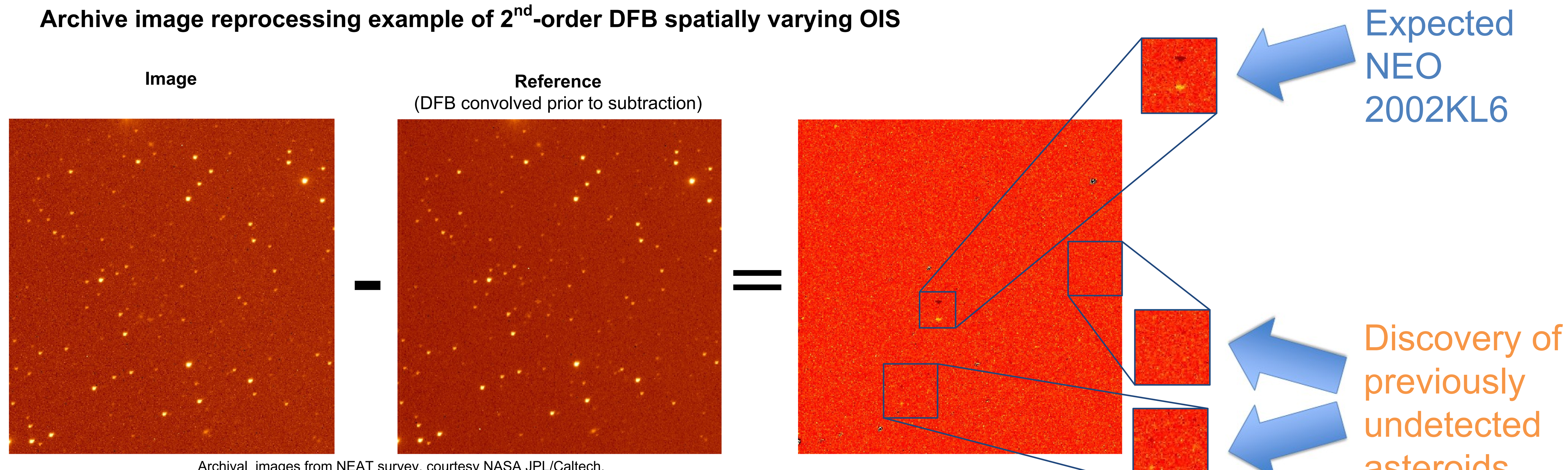
The spatially-varying convolution is responsible for 85-95% of the OIS subtraction time. The plots illustrate the IP2 parallel acceleration and cluster scalability of the 2nd-order spatially-varying convolution kernel derived from the Dirac delta function basis (DFB).

IP2

Enhanced discovery capability

The 2nd-order DFB adapts to asymmetric PSF changes over potentially large FOVs, providing improved variable object detection capabilities in many images. Previously computationally prohibitive for many applications, multi-core and GPU parallel processing provide a practical solution to put this technique within reach. Real-time analysis for large format cameras and archive reprocessing become practical.

Archive image reprocessing example of 2nd-order DFB spatially varying OIS



Archival images from NEAT survey, courtesy NASA JPL/Caltech, obtained from the SkyMorph image server provided by NASA/GSFC

Lawrence Berkeley National Laboratory • University of California • National Science Foundation • James Cook University, Australia

References:

[1]Alard, C. 2000, Astron. Astrophys. Suppl. Ser., 144, 363
[2]Miller, J. P., Pennypacker, C. R., & White, G. L. 2008, Publications of the Astronomical Society of the Pacific, 120, 449
[3]Hartung, S., Shukla, H., Miller, J. P., & Pennypacker, C. 2012, in IEEE International Conference on Image Processing (ICIP) 2012 (Orlando, Florida: IEEE), 1685