The LSST Image Processing Pipeline

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Large Synoptic Survey Telescope

We highlight three stages of the LSST Image Processing Pipeline (IPP) that are expected to drive its computational budget, and detail the science requirements on their performance. We examine computational requirements for existing solutions to these stages, and discuss our plans for comparison of PSF modelling and photometry algorithms. While existing software appears inadequate in terms of speed, robustness, and/or accuracy, we see no fundamental roadblocks to successful implementation of the IPP. LSST software design and development will be an area of active research over the next several years.

Science Requirements

These requirements are constraints on the engineering design and software performance necessary to jointly achieve the 4 main science goals of the LSST project.

Science Requirements Definitions:

Minimum Specification : Minimum system capability required to reach science goals
Design Specification : System design point used for engineering tolerance
Stretch Goal : Desirable for enhanced science but unnecessary for successful implementation

Estimated Computational Resources

The reference design for the LSST focal plane includes 25 rafts of 9 CCDs. Each CCD will have 4096 x 4096 pixels. The entire focal plane will have 3.5 Gpixels (6.4 GB). The design specification for latency in taking the raw science images to transient alerts is 60 seconds. In terms of raw computing power, this requires the reduction of 0.06 Gpixels per second (0.1 GB/s). We are profiling current image processing algorithms on modern computers and estimating the required TeraOps per LSST image.

Computational Resources Definitions:

Tera-Ops / Image : Total floating point operations required to reduce one entire image from the LSST focal plane
Scaled From : Algorithms used to estimate computational requirements from modern software
Reference Value : Total floating point operations per pixel from reference algorithm

Determine World Coordinate System (WCS) For Image :

There are 2 astrometric operations in the IPP. The first involves a rough (pointing) correction that is undertaken after bright object detection. This will allow for the use of photometric and astrometric catalogs in subsequent stages. After PSF generation and centroiding of astrometric standards, a fine (distortion) correction will be undertaken.

Science Requirements:
Design (minimum) relative astrometry
10 (20) mas @ 20 arcmin separation
Design (minimum) absolute ICRS astrometry
50 (100) mas

Computational Resource Estimates:
MSCCMATCH : Runs in IRAF. Does its own object detection and centroiding.
B.Schmidt : Unpublished. Determines TNX-format distortion terms given input catalogs.
Platais et.al (2002) : Determines distortions and chip gaps given input catalogs.

Scaled From	Reference Value (TeraOps/Image)
MSCCMATCH	10
B.Schmidt	4
Platais et.al (2002)	0.2

Issues:
What is the functional form of an image's astrometric distortion?
What is the scale of WCS model (chip, raft, or focal plane)?

Determine Point Spread Function (PSF) Model :

This stage is arguably the most important in the IPP. In the initial observations of a field, PSF stars will be selected and a master star list generated for use in subsequent observations. Choosing the appropriate functional form of the PSF model and its spatial variation will require extensive image simulations.

Science Requirements:
Design (minimum) RMS about mean mag
0.005 (0.008) mags
Design (minimum) internal photometric calibration
0.010 (0.015) mags
Design (minimum) external photometric calibration
0.020 (0.050) mags

Computational Resource Estimates:
SDSS Photo : Uses Karhunen-Loéve decomposition for basis functions and a spatially variable PSF. Reference value is for building PSF only.
DaoPhot : Uses functional form plus lookup table for PSF model, and spatially variable coefficients. Reference value includes multiple iterations of PSF generation.
SExtractor : No PSF model. Reference value includes photometry.
C DoPhot : Implementation of DoPhot in C. Uses functional form for PSF, with no spatial variation. Reference value includes photometry.

Scaled From	Reference Value (TeraOps/Image)
SDSS Photo	10
DaoPhot	372
SExtractor	3.1
C DoPhot	89

Build Difference Imaging Kernel :

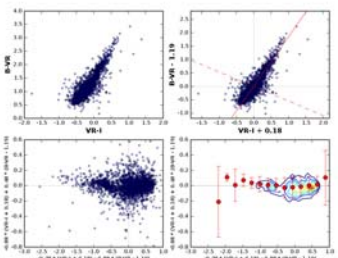
Difference imaging requires both the *astrometric* and *photometric* (depth and seeing) registraton of two images. Currently this is done in separate steps implemented computationally as convolutions. It is important to propagate pixel masks and variance in these convolutions.

Science Requirements
None explicitly defined in SRD

Computational Resource Estimates:
Swremap : Astrometric registration. Similar to SWARP (Bertin), but propagates pixel masks and variance. Accepts input distortion terms.
WCSremap : Astrometric registration. Similar to Swremap, but uses the WCStools package to register images based upon their WCS-model distortions.
HOTPANTS : Photometric registration. Implementation of Alard (2000) PSF-matching algorithm. Propagates pixel masks and variance.

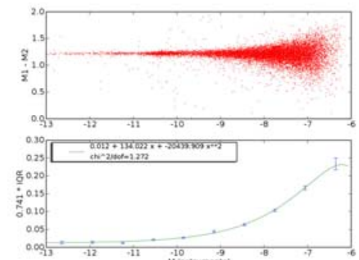
Scaled From	Reference Value (TeraOps/Image)
Swremap	32
WCSremap	111
HOTPANTS	159

Issues:
Can we integrate astrometric and photometric registration into a single computation?
Can we ignore the pixel covariance introduced by convolutions?



Evaluation of PSF Algorithms : We are currently comparing the results of running these photometry algorithms on sets of time-series data. In particular, we will compare the widths of color-color loci derived from multi-color images (left). We will also compare the envelope of differences in stellar magnitudes measured in multiple epochs (right). At the bright end, this width reflects the systematic floor present in the data and/or algorithms (LSST SRD = 0.005 mags at the bright end).

To include SDSS Photo in this comparison, we will also run these algorithms on SDSS images. In particular, equatorial Stripe 82 has multiple epochs of observation, and a range of crowding conditions (including globular cluster M2)



The LSST research and development effort is funded in part by the National Science Foundation under Scientific Program Order No. 9 (AST-0551161) through Cooperative Agreement AST-0132798.
Additional funding comes from private donations, in-kind support at Department of Energy laboratories and other LSSTC Institutional Members.

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