Image Subtraction & Transient Detection Techniques

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The process of image subtraction drastically changes the characteristics of the signal and noise in the images being analyzed. One or both images are resampled to a fiducial astrometric system; one image is additionally convolved to match PSFs; and one image is subtracted from the other. Without careful propagation of image artifacts and noise, the output image may be littered with false positives and have a poorly defined measure of significance. We outline improvements made to the SuperMACHO/ESSENCE pipeline that have helped us improve the quality of our difference images. These improvements are a significant step along the route to robust image subtraction algorithms for the LSST variability pipeline.

Masking : Bad pixels

In difference imaging, the primary goal is the determination of the convolution kernel that matches PSFs. This requires comparing pixel regions found in both images, which should optimally contain an object or set of objects at high S/N. If there are bad pixels (or variable objects) in these regions, the process can fail. It is of utmost importance to know the quality of the input images and to use only pristine pixels in this calculation. In addition, bad or saturated pixels leave a large footprint in resampled images, and an even larger footprint in difference images where they have been convolved twice. We explicitly propagate the influence of bad pixels through our pipeline, using a bit-wise image mask that tells us if a pixel was found in the detector’s bad pixel mask, was saturated, or received flux from any such pixel during the convolution steps. Our object detection algorithms have been modified to use these masks.

Masking : Diffraction spikes

Features around saturated stars lead to significant numbers of residuals in difference images. To compensate, additional bits are added to our mask to model haloes and diffraction spikes. The image on the right shows the resampled template and input images and their mask, as well as the difference image and its mask.

Noise propagation :

The propagation of noise is important to quantify detection limits in the difference images. The resampling and difference imaging stages both accept input noise images, and produce output noise images. Object detection stages use this information to determine the significance of detected objects. We currently ignore pixel covariance.

Efficiency analysis :

The determination of image detection efficiencies requires the addition of fake stars and an inventory of fraction recovered as a function of brightness. To enable this for our image subtraction pipeline, we save the convolution coefficients in the FITS header of the difference image. In this way, we can use the same kernel that determined the original difference image to yield the efficiency image – otherwise, the efficiency stars may dominate the convolution solution.