Mitigation of Satellite Tracks in LSST Data Processing

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SATCON1 | Virtual Meeting | June 29 - July 2, 2020
LSST Data Release Production

• The Data Release Production is the episodic (re)processing of all accumulated LSST images.

• LSST pipeline development is done using the precursor dataset from the Subaru Strategic Program using the Hyper Suprime-Cam (HSC) instrument.

• Satellite trails are visible in many images in this dataset
  • Satellite mitigation techniques for Rubin Observatory can be developed on this dataset
Example Stacked Image
The Plan for Satellite Mitigation:

- Satellite trails are easy to identify by eye—how do we replicate this algorithmically?
  - The Hough Transform provides an algorithm to detect lines in images automatically.
- Once we have the approximate coordinates of a line, a rough profile is fit.
  - The affected section of the image is masked out.
The Kernel-Based Hough Transform

- Finds clusters of non-zero points and splits them into line-like groups
- Only groups that meet requirements for length and straightness are kept
- Faster, more precise, and fewer false positives than with a traditional Hough Transform.
The Kernel Hough Transform

Standard Hough Transform

Kernel Hough Transform

Original Image

After Canny Filter

Fernandes and Oliveira, 2006
Using the Kernel Hough Transform in the LSST pipeline
A note on the image processing

- For the data release production, we split field into “patches” — quadrilateral sub-regions of about 1.5 degrees on a side.

- Coadds are constructed out of all exposures that overlap with a given patch, warped onto the tangent plane.

\[
\text{Coadd} = \sum \text{of Individual Warped Exposures} + \cdots
\]

- For the data release production, we detect artifacts by looking at the difference between individual exposures and the conservatively clipped coadded image.
**Image Preprocessing**

*Difference Image = individual exposure - (aggressively clipped coadd of many exposures)*
Image Preprocessing

Binary Image (above or below limit for ‘detected’ pixels)
Image Preprocessing

Canny Filtered Image
Kernel Hough Transform Line Detection

Line Detections
Fitting the Line Profile
Masking

\[ \text{Mask} = (\text{Line Profile} > \text{Threshold}) \cap (\text{Detection Map}) \]
Masking

Mask = (Line Profile > Threshold) \cap (Detection Map)
Applying this technique in the original stacked image

Coadd image with no satellite masking

Coadd image with satellite masking
Masking Other Linear Image Artifacts

- Optical ghosts (multiple reflections off of surfaces in the primary optical path)
- Diffraction spikes from bright stars
Masking Optical Ghosts
Masking Optical Ghosts
Masking Optical Ghosts
Conclusions

• Even in current conditions, we can expect data to be frequently affected by satellite trails.

• Nevertheless, satellite trails and other artifacts can be reliably detected and masked out.
  
  • Some data is lost, but contamination is greatly reduced.

• The work shown here is tuned to artifact rejection in coadded data release production images.

• Variations on the same technique will need to be tuned to meet the detection limit for transients and other science cases, though it may remain difficult to mask all low-surface-brightness effects.