Deepspace Interplanetary Navigation Operations Colorado Research EXplorer (DINO C-REx)

DINO C-REx Technical Memorandum

Document ID: DINO_C-REx-Image Generation

SYSTEMS ENGINEERING REPORT 4.7: POINT SPREAD FUNCTION AND RASTERIZATION MODEL

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Status: Initial Version
Scope/Contents
Description of the method used by the DINO C-REx camera module to go from decimal-precision star and beacon facet locations to an integer precision pixelated CCD image.

Rev:	**Change Description**	**By**
1.0	Initial Release	Matt Muszynski

Contents

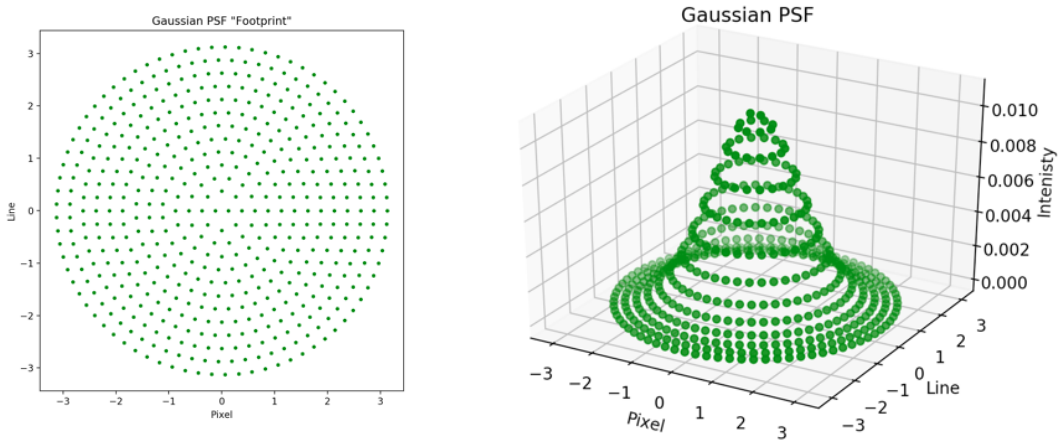

Fig. 1: 2D and 3D representations of the generic PSF for DINO C-REx. Here psfSigma is 1.

1 Overview

This SER describes the conversion from exact (decimal precision) pixel and line location to a more realistic pixelated (integer precision) detector array. The process begins with adding point source stars and wire frames of point sources to an image, continues by applying a gaussian point spread to each imaged point, and ends with binning and summing incident photons on each coordinate of the CCD array. Much like the noise model described in SER 4.5, the model for point spread and rasterization is greatly influenced by Merlene and Howell (1995).[1]

2 Adding Point Sources

After adding stars as described in SER 4.12 and beacon facets as described in SER 4.9, the camera system has a set of arrays describing all point sources that are visible to the camera. Most importantly for the purposes of this document are pixel, line, and I (intensity). The pixel and line arrays describe the position of the star on the detector array with machine precision, and the I array contains the number of electrons created by the CCD in response to that point source.

3 Point Spread

Because of quantum mechanical uncertainties inherent in the process of light from a point source passing through a lens, the light from each source will strike a range of locations on the pixel array. DINO C-REx achieves this by applying a Gaussian point spread function to each point source added by the processes described by SERs 4.12 and 4.9. The point spread function is designed to fall off radially symmetrically with a standard deviation input by the user when initializing the camera via the psfSigma variable, as shown in fig 1.

In effect, the function image.psf() transforms a single point to a set of discrete points. In pixel and line space, the points form concentric circles, and no point is farther than 0.1 pixels from any other.[2] The third dimension of the psf represents the intensity of light striking each discrete point. The sum of intensities of all the points in the PSF sums to 1. This way the intensity of each point source can be multiplied by the intenisty of the PSF array. The output of image.psf() is a python dictionary with three arrays. One describes the physical spread in the pixel direction, one the physical spread in the line direction, and the third the fraction of the total intensity at each discrete point.

[1] Merline, W. J., and Steve B. Howell. A realistic model for point-Sources imaged on array detectors: The model and initial results. Experimental Astronomy, vol. 6, no. 1-2, 1995, pp. 163210

[2] This is done in order to avoid artifacts of this discrete integration process once the image has been rasterized.

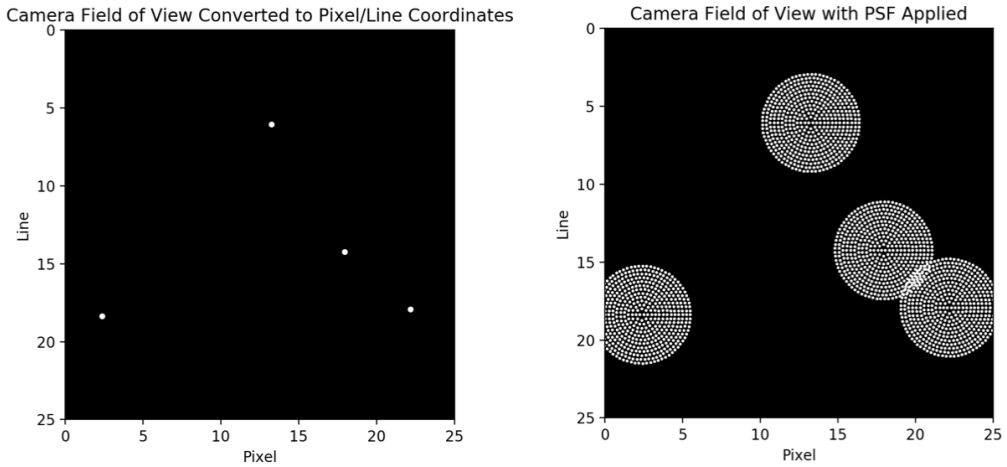

Fig. 2: Side-by-side comparison of four stars represented as point sources and with PSF applied. Note that in this representation, plots do not reflect differing magnitudes of the stars.

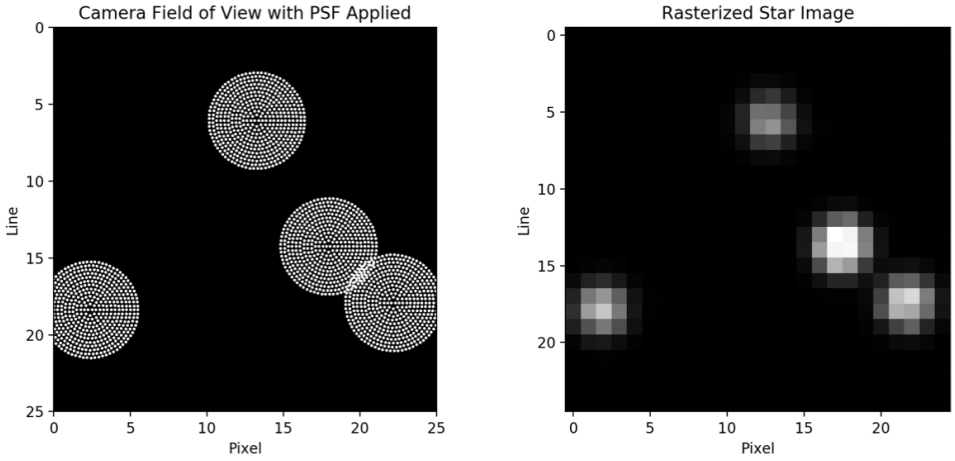

Fig. 3: Side-by-side comparison of four stars represented with PSF applied and with rasterization applied. Here we can see the that stars differ in brightness as the rasterized image takes intensity into account in a way that it can be easily plotted.

Each point source described by SERs 4.9 and 4.12 is then replaced with a full set of points from image.psf() such that the each Gaussian is centered at the true position of the point in pixel/line space, and the sum of the intensities of those points is the intensity of the single point before PSF was applied. Figure 2 shows the process of converting point sources to sets of discrete spread points.

4 Rasterization

Because the pixel array of a real CCD will have far fewer bins than can be described with machine precision, this is achieved rather simply by taking all of the points present after applying the PSF, flooring their pixel and line positions, and summing the intensities of all points that fall in each bin of the detector array. This is shown in figure 3.

5 DINO C-REx Implementation

Point spread and rasterization in DINO C-REx are both achieved by functions within the image object. If directed to by the debug message, the camera model will calculate the PSF arrays via image.PSF()[1] once just before summing each scene. Rasterization is applied via image.rasterize() to the detector_array of each scene just before it is added to the full image. image.rasterize() uses the pandas library's powerful DataFrame to quickly sum intensities that are in each bin.

[1] Which in turn calls image.gaussian()