IMPROVED ASTEROID ASTROMETRY AND PHOTOMETRY WITH TRAIL FITTING. P. Vereš[1], R. Jedicke[1], L. Denneau[1], R. Wainscoat[1], M. Holman[2]. [1]Institute for Astronomy, University of Hawaii at Manoa (2680 Woodlawn Drive, Honolulu, 96822 HI, USA veres@ifa.hawaii.edu), [2]Harvard-Smithsonian Center for Astrophysics, Harvard University (60 Garden Street, Cambridge, MA 02138).

Introduction: The performance of current telescopic surveys requires robust and automatic pipeline for image processing and moving object recognition. Detection of fast moving object like NEO causes a trail on the CCD detector for which the PSF photometry does not provide the optimal photometric and astrometric solution. We present the trail fitting algorithm and its application on synthetic and real asteroid trails detected by the Pan-STARRS PS1 telescope. The description and recognition of the trailed asteroid in the image will increase NEO search efficiency.

Trail equation: The trail equation is derived as a convolution of two-dimensional Gaussian with r.m.s. σ, total flux f, image background b stretched along the trajectory L, angle θ and the center at x_0,y_0:

$$g[x',y'] = b + \frac{f}{L}\frac{1}{2\sigma\sqrt{2\pi}}\exp\left[-\frac{((x-x_0)\sin\theta+(y-y_0)\cos\theta))^2}{2\sigma^2}\right]$$

$$\left(erf\left[\frac{(x-x_0)\cos\theta+(y-y_0)\sin\theta+\frac{L}{2}}{\sigma\sqrt{2}}\right]-erf\left[\frac{(x-x_0)\cos\theta+(y-y_0)\sin\theta-\frac{L}{2}}{\sigma\sqrt{2}}\right]\right)$$

where x,y are coordinates of the pixels and f represents the pixel saturation. The trail could be also approximated by the 2-D Gaussian. The trail length can be derived from this Gaussian as a function of σ *and* σ_a (r.m.s along the trail):

$$L=\sqrt{[12(\sigma_a^2 - \sigma^2)]}$$

Trail fitting: We applied the trail fitting algorithm based on Levenberg-Marquardt least-square fit [1,2] of the trail function and the 2-D Gaussian on the synthetic trails generated with the synthetic noise (Figure 1) and observed trailed asteroids (Figure 2).

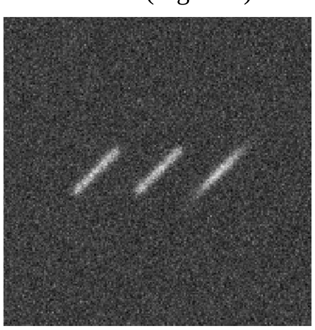

Figure 1: Synthetic trail, fitted trail and Gaussian fit (L=40 pix, θ=45 deg, σ=2.2 pix, centroid [60,100],[100,100],[140,100].

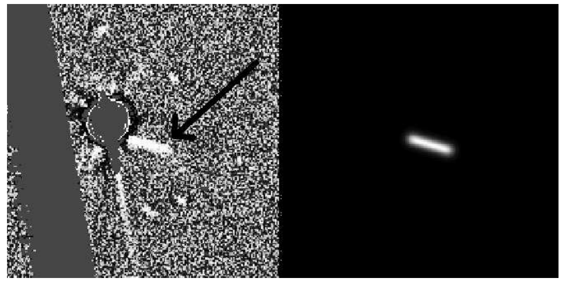

Figure 2: PS1 detection of fast moving asteroid (arrow) interacting with the masked star and gap pixels (left) and the trail reconstruction (trail fit).

Trail fit provides b, f, L, σ, θ, x_0, y_0, s/n and reduced chi-square of the fit. Additional aperture photometry is performed by use of rectangular aperture with the length of L$\pm$3σ and width $\pm$3σ aligned and rotated with respect to the trail. We compare the trail fit with the 2-D Gaussian fit.

Results: Trail length (Figure 3), flux, orientation and centroid derived from the trail fitting give more accurate results as the Gaussian fit. The s/n of the trail is higher by using rectangular aperture instead of circular or square aperture. However, the computation time required for the trail fitting is 3-times as more expensive. Precise photometry, astrometry and recognition of the trailed detections will dramatically decrease the number of false streak-like detections that mimic fast moving asteroids in the automatic surveys.

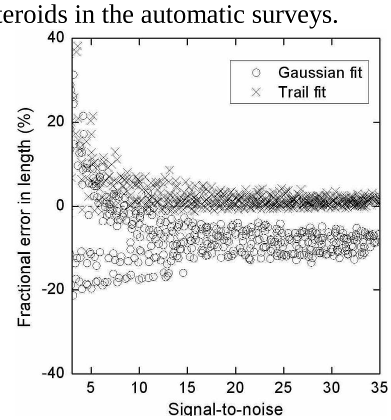

Figure 3: Trail length derived by trail and Gaussian fit as a function of signal-to-noise ratio.

References: [1] Levenberg K. (1944) Quart. Of Appl. Math, *2:* 164–168. [2] Marquardt D. (1963) MSIAM J. on Appl. Math. 11: 431-441