Real-time synthetic tracking for NEA discovery

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Who we are?

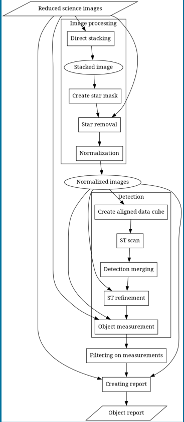
ParaSOL project (UEFISCDI funding) under EURONEAR

- Research network in NEA discovery
- Collaborators in many european countries (and Chile)
- Umbrella:
  Stănescu and Văduvescu 2021 [1]

- ParaSOL: UEFISCDI-funded project to complete the suite
- Reference blink pipeline
- STU (Synthetic Tracking on Umbrella)
- IPP (Image Processing Pipeline)
- Webrella

Synthetic Tracking with STU

- Modern computers feature increasing compute power
- Gains particularly in "accelerator" hardware: GPUs
- Synthetic Tracking [2][3][4][5]: improve SNR by stacking across all possible motion vectors
- Portable: .NET Framework (Linux, Windows maybe others) + OpenCL



Runtime

- Real-time synthetic tracking
- Example: Wide Field Camera on Isaac Newton Telescope
- 4 CCDs of 9 Mpx each, $0.33\,''\,\mathrm{px}^{-1}$
- Readout 30 s, exposure 30 s, total 1 min cadence
- Search cone of $10\,''\,\mathrm{min}^{-1}$, stack of 12 images.
- Runtime: 26 s per CCD, with 2 s for actual ST scan
- **ST** (2 min) $\ll$ **acquisition time** (12 min)

Validation

- Tested on telescopes: TCS, INT, T025; over 100000 images in total
- Detected all objects in the TCS dataset that have no pre-processing issues
- Bulk detection rate on INT WFC of 50%
- Validated real-time processing on 3 nights of INT observations

The good

- Real-time synthetic tracking for the masses
- All objects detected when input images are free of defects
- Validated against a large dataset
- End-to-end pipeline available
- Theoretical model for tuning the detection threshold

The dangerous

Object Designation	Year Range	Potential Impacts	Impact Probability (cumulative)	$V_{infinity}$ (km/s)	H (mag)	Estimated Diameter (km)	Palermo Scale (cum.)	Palermo Scale (max.)	Torino Scale (max.)
(2023 DZ2)	2026-2121	123	2.3e-3	7.35	23.9	0.056	-1.16	-1.17	1
101955 Bennu (1999 RQ36)	2178-2290	157	5.7e-4	5.99	20.6	0.490	-1.41	-1.59	
29075 (1950 DA)	2880-2880	1	2.9e-5	14.10	17.9	1.300	-2.05	-2.05	

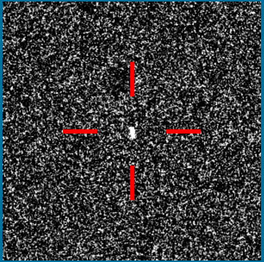


Figure: **2023 DW**, follow-up on 1st of March. Detection as reported by STU, from the observation archive. Detection stamp from trimmed mean of 4 images with stars masked, width 300px.

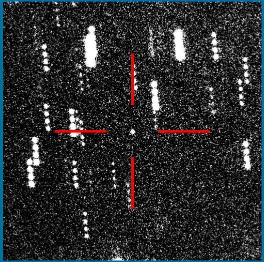


Figure: **2023 DZ2**, detected on 27th of February. Detection as reported by STU, with reporting stage re-ran for press release. Detection stamp from mean of 4 input images, width 500px.

Next steps

Current activities

- Improving reporting and validation
- Decreasing image pre-processing (IPP) runtime
- Continue validation efforts on corner cases

Planned activities

- Acquiring and validating on space debris dataset
- Improving handling of many-chip cameras
- Moving other expensive operations to GPU and eliminating processing bottlenecks

Q&A

Question time

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