Fast Identification of Streak-shaped NEOs in Astronomical Images through Heterogeneous Computing

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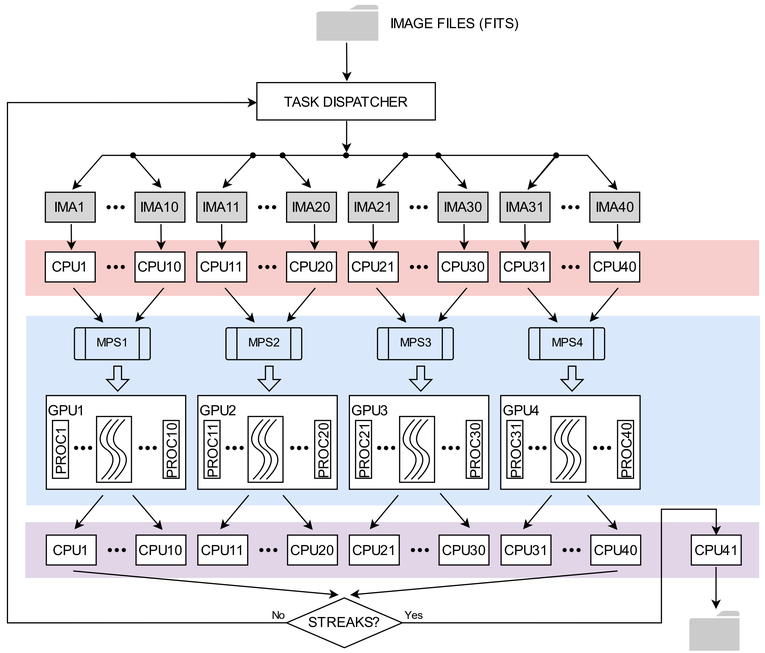
We have developed a fast image processing pipeline to detect and identify “streak-shaped” objects in astronomical images, based on a heterogeneous (multi-CPU, multi-GPU) computing system. Depending on the production rate of images of a particular telescope, the system can achieve real-time performance, meaning that the images are processed faster than they are produced. The fast processing speed can be very useful when there is a massive number of images that need to be processed automatically, or when a fast data handover between follow-up observation sites is required, when observing a particular NEO object.

Heterogeneous Computing

- Many processes are **executed concurrently ≠ multi-tasking** (time-sharing single CPU)
- **Hardware accelerators**: GPU, FPGA
- **Heterogeneous computing**: systems that make use of more than one type of processor or core.
- GPU processing pipelines for graphics processing **were found to fit other fields** needs, such us **scientific computing**, encryption/decryption or physics calculations.



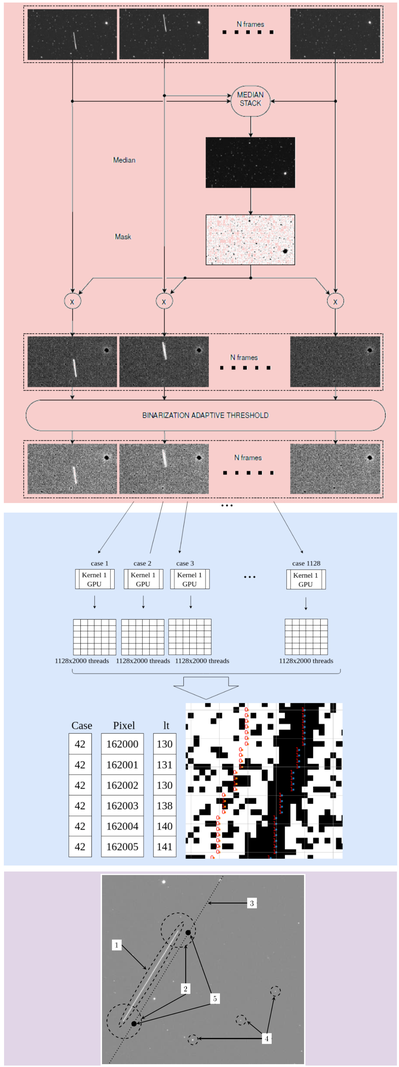
Heterogeneous computing workflow. Each CPU processes one image (IMA). Each GPU processes 10 tasks (PROC) in parallel. CPU41 processes (post) detected streaks

4 x NVIDIA Quadro RTX8000
4 x 48 GB memory
CPU Intel i9-10940X 3.3 GHz
28 CPU cores
4 x 4608 CUDA cores

2 x NVIDIA RTX A6000
2 x 48 GB memory
CPU AMD Epyc 7502 2.5 GHz
64 CPU cores
2 x 10752 CUDA cores

Current JAXA platforms used in heterogeneous computing tasks

Image Processing



PREPROCESSING

- Image files (FITS files) are stored continuously in a folder.
- The Task Dispatcher assigns Image files as they arrive to available CPUs (1-40).
- Each CPU processes 1 image file, in parallel with the rest.
- Removal of stars: to avoid detection of false positives of streaks created by diffraction spikes of bright stars or other astronomical objects.
- Binarization: global or local (adaptive thresholding).

DETECTION

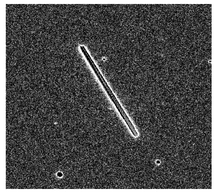
- 4 MPS (Multi-Process Service) instances are executed in each GPU respectively.
- MPS allows concurrency of processes in GPU, which increases GPU utilization.
- Pixel binary values (0/1) are accumulated over segments of length 200/100/50 pixels
- Casefile includes 1128 possible directions.
- Cases over threshold (~130/200; 33/100; 33/50) are considered candidates of streaks.

POSTPROCESSING

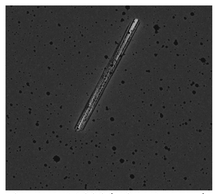
1.Elliptical area surrounding the detected streak to compute photometry.
2.Comparison error with TLE database.
3. SGP3 propagated trajectory of real object.
4. Photometric stars
5. (RA,Dec) coordinates of object streak ends.

Results

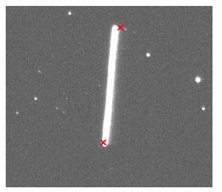
21.084 FITS files analyzed ~ 3.4 Tbtyes (Tomo-e Gozen Camera Kiso Observatory)
In 2 hour observation time, streaks were detected in approx . 3% of the images
From these streaks, ~18 were non cataloqued objects (space debris, meteors, …)



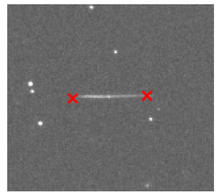
SL-8 R/B (NORAD 16766)
(detected streaks superimposed in black)

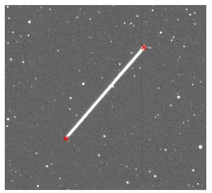


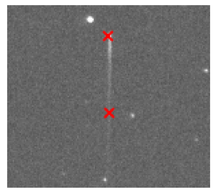
STARLINK-1336 (NORAD 45557)



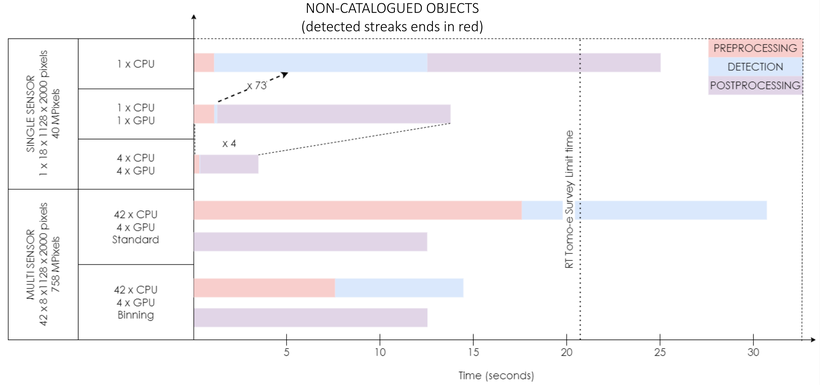
THORAD DELTA 1 DEB (NORAD 42608
(detected streak ends in red)







NON-CATALOGUED OBJECTS
(detected streaks ends in red)



- Heterogenous computing dramatically improves timing performance even reaching real time.
- GPU-based STREAKS detection can detect a percentage of non-catalogued objects (~18/hour) using Tomo-e camera at Kiso Observatory.
- The system can be used for LEO space debris detection and NEOs, provided that exposure time of the camera and slant range are adequate to imprint streak shapes in the image sensor.

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