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# FAST IDENTIFICATION OF STREAK-SHAPED NEOs IN ASTRONOMICAL IMAGES THROUGH HETEROGENEOUS COMPUTING

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## Abstract

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.

## I. INTRODUCTION

Telescopes tracking at the sidereal rate usually detect Earth-orbiting objects as streaks with lengths that depend on the exposure time of the camera and the slant range to the object. Shorten the time to detect these objects can be very beneficial in some situations: when the data rate of produced images in the observatory is large, or when it is needed to follow up observations of a particular detected object from another observatory. To achieve this fast process we can leverage in acceleration hardware such as multi-GPU or multi-CPU systems.

## II. HETEROGENEOUS COMPUTING

Parallel computing is a technique to accelerate image processing algorithms, where many processes are executed concurrently. To achieve this, multi-CPU-GPU systems can be used, which nowadays are becoming more common. Image processing techniques are usually based on the same operations performed over a large amount of pixels, and for these tasks, GPUs are well suited, as they basically consist of a larger amount of cores when compared to standard CPU cores. In this work, we have developed an image process technique, based on a previous technique used by some of the authors of the present work for other purposes, that can achieve a fast processing time, even reaching real-time results, depending on the production rate of images by a particular telescope system.

## III. IMAGE PROCESSING

The processing pipeline consists of three stages: multi-CPU preprocessing, where star removal and binarization are performed; multi-GPU detection, which is a variation of the Stacking Method(1), previously developed by some of the authors of this work, which successfully can detect very faint "dot-shaped" NEO objects; and multi-CPU postprocessing, where astronomical coordinates and apparent magnitude of each detected streak are obtained.

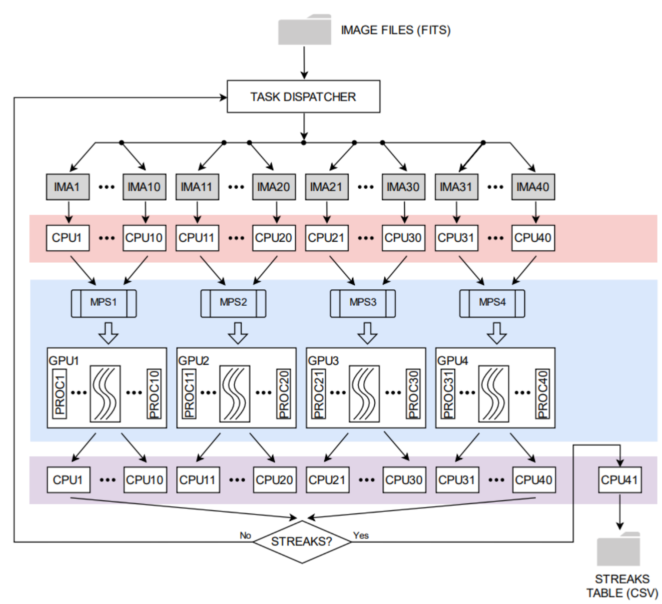


Figure 1: Heterogeneous computing architecture.

In figure 1 is shown a schematic of the heterogeneous computing architecture used in this work. In the preprocessing stage ("orange" background in figure 1), it is performed the removal of stars, a variation of the method used in (2), and a subsequent binarization of the image, so only “0”s and “1”s are sent to next stage. In the detection stage (“blue” background in figure 1), the multi-GPU system processes the binarized images, performing over each pixel “add and accumulation” operations over certain number of pixels (typically 100) in 1128 possible directions. The cases where more than approximately 2/3 of the pixels are “1”s, are considered candidates to be a streak. In the postprocessing stage, only in the images with detected streaks, three tasks are performed: astrometry (to obtain the coordinates of the streak ends), identification (comparison with a large up-to-date database of catalogued objects, typically space-track.org), and differential photometry (to have an estimation of the brightness of the streak).

## IV. RESULTS

We have assessed our processing pipeline with observations during five nights using the Tomo-e camera of the 1M Schmidt Telescope at Kiso Observatory in Japan. These tests were focused on the detection of “streak-shaped” objects in LEO Orbit, ranging from 350 to 2000 km, but we plan to extend the observations with different exposure time/field-of-view ratios, which will give us the chance to detect NEOs at higher slant ranges as “streak-shaped” objects. From the results of these tests at Kiso Observatory, during 2 hours observation time after sunset, streaks were detected in approximately 3% of the images, which corresponded to 35 real objects in LEO orbit, where 27 of them were identified in the NORAD catalog from a space-track.org database. The minimum detectable streak had an apparent magnitude of +11.3 in the GAIA G-band.

In figure 2 is shown two examples of catalogued (left) and non-catalogued (right) objects respectively.

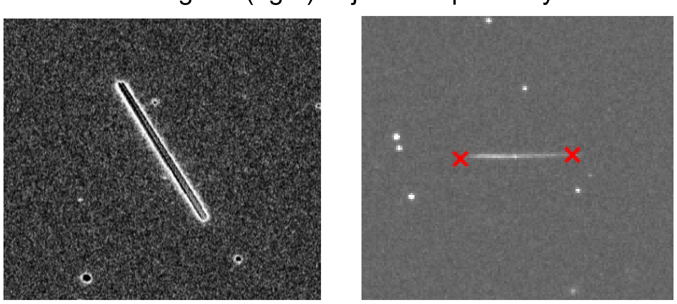

Figure 2: (Left) SL-8 R/B (NORAD 16766) (black lines within the streak are segments detected by the algorithm). (Right) Non-catalogued object (red crosses are the streak ends coordinates detected by the algorithm).

In figure 3 is shown the timing performance, where it can be observed that the GPU computations improve the detection stage by x73 when compared with a standard CPU. When a multisensor camera is used (such as the Tomo-e Gozen camera at Kiso Observatory(3)), the system can achieve real-time behavior, that is, the images are processed faster than they are produced.

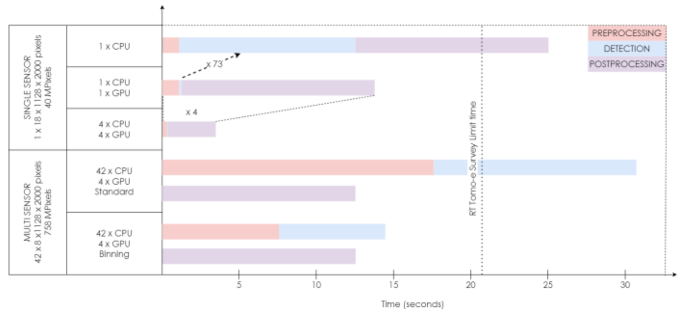


Figure 3: Timing performance.

## V. CONCLUSIONS

In this work we show that our heterogeneous computing system can achieve remarkably high processing speed of astronomical images, currently 28.4 MPixels/second, and high detection sensitivity, +11.3 apparent magnitude. We believe this system can help in establishing optical observations as a fast and sensitive technique to successfully detect and track LEO and NEO objects, when aided by automatic heterogeneous computing.

**Acknowledgments**

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**References**

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