Analysis of detection limits in event-based cameras for space situational awareness

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ABSTRACT

Event based cameras (EBC) are of interest in Space Situational Awareness (SSA) purposes for its low bandwidth, low power consumption and high dynamic range [1]. Recently, due to the increasing number of orbiting objects efforts to maintain ephemeris has intensified. Previous works have shown night and day detection of satellites with EBC [2], but non approach has focused on finding the most suited optical system in which the capture of objects can be carried optimally. In this work, we study the characteristics in the generation of events by capturing objects in orbit simultaneously with three EBC systems of different optics.

1. INTRODUCTION

In the last couple of years, satellites residing in Low-Earth Orbits (LEO) have greatly increased in numbers and are expected to exponentially grow in the near future. Therefore, it is imperative for Space Situational Awareness (SSA) systems to be up to the task of detecting and maintaining ephemeris of the ever growing number of objects, such as satellites or debris, to help preserve Earth's near space safety, avoiding collision hazards. This duty has been transferred, slowly, from radar sites to optical telescopes to reduce costs while increasing the coverage. Nowadays there are many efforts to design efficient optical-based SSA systems with components-of-the-shelf (COTS), benefiting the community by having more "eyes in the sky" to detect and track objects of interest.

However, observing objects in LEO with optical telescopes also has many restraints. For instance, it can only be done for a few hours every night, weather allowing. Moreover, there are technical showstoppers too. LEO satellite monitoring requires capturing the largest portion of the sky as possible and the longest time without interruptions, considering the amount of objects and their different orbits (inclinations) and speeds. Also, COTS optical telescopes are mostly made for astronomical observations so they often have long focal lengths, meaning small Field of Views (FOV). When coupled to modern CMOS cameras with large pixel counts, the continuous monitoring of the sky at shorter exposures in contrast with astronomical applications, leads to saturation in terms of transmission, processing and storage of data. Therefore, given the size and brightness of the space objects of interest, optical SSA solutions have to be designed with the right balance between FoV, pixel size, pixel count, aperture size, and exposure time. Notice, though, that we are also photographing the stars, which are not necessarily informative for SSA purposes.

On the other hand, event based sensors (EBS) have emerged as a solution to intensity detectors, being more efficient to detect sparse changes in the scenes at higher frame rates and at worse SNR conditions. The asynchronous operation of its pixels avoids the redundant elements of the scene, that is, they record only moving objects in the scene. Also the temporal resolution of 1 microsecond makes them a perfect device for surveillance tasks. Furthermore, the low data rates provided by capturing only the changes in the sky reduce the need for transmission, storage and computer processing.

Even though event based SSA solutions reduce the big data workload associated with traditional imaging detectors, we still have to understand how to properly use them for this task. State-of-the-art works have shown object detections during night and day including stars, planets, satellites and debris [2]. Although, most detections are made using telescopes with large focal lengths, i.e., small FOV which do not solve the needs of SSA. On the other hand, most approaches had focused on the software part of the systems, leaving behind the opportunity to improve the acquisition by tuning the correct parameters and enhancing the implementation setup. At last, another approach assesses the sensitivity of EBSs in capturing night sky objects orienting the workflow towards the comparison between two models of these sensors. However, as far as we know none of the state-of-the-art work analyzes the correct way in which an event-based SSA system must be implemented, meaning, little research has been made to define which are the proper optics to capture determined objects of interest.

For the purposes mentioned, in this work we compare three EBC with the same specifications implemented with three telescopes with different characteristics.

In section 2 we present the method used to compare the generation of the three systems, then in section 3 main results are presented and finally in section 4 conclusions are discussed.

2. METHOD

Three identical EBC are coupled with different optics to compare the difference in the acquisition in each sensor. This characteristics can be seen in the Table 1, also an image of the implemented system it is shown in Fig. 1.

	Sharpstar 13028HNT *(1)*	**Sharpstar 61EDPHII** *(2)*	**Askar FMA180** *(3)*
Aperture [mm]	130	61	40
Focal Length [mm]	364	275	180
IFOV [arcsecs]	8.4999	11.2508	17.1887
FOV [degrees]	1.51 x 1.13	2.0 x 1.5	3.06 x 2.29

Table 1: Optics Characteristics

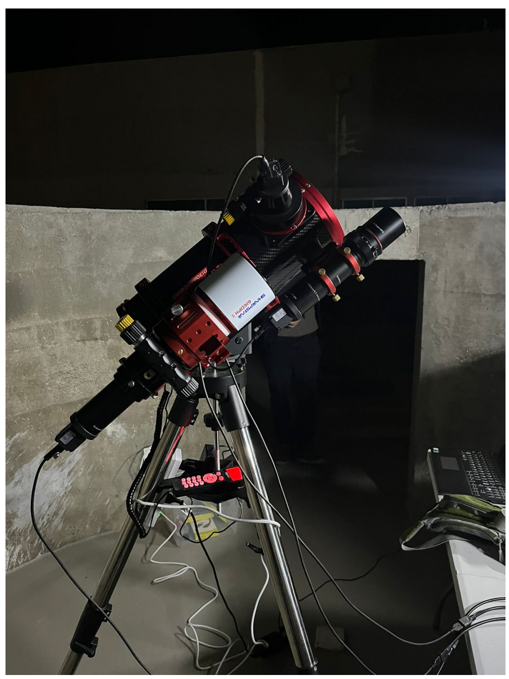

Fig. 1: Implemented system.

In the implementation, due to the mechanics the telescopes doesn't pointo to the same spot completely, so the recordings made with this setup lack full correspondence in between. For this reason, every streak of trajectories of satellites were cropped to facilitate de matching between implementations. The full trajectory of a satellite can be seen in Fig. 2 and the cropped results of the same captured are shown in Fig. 3.

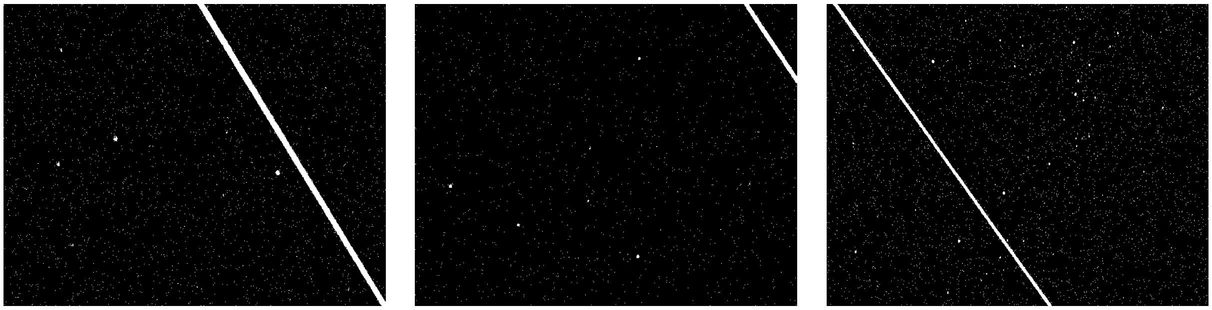

Fig. 2: Simultaneous capture of an object made with the three telescopes. Full trajectories.

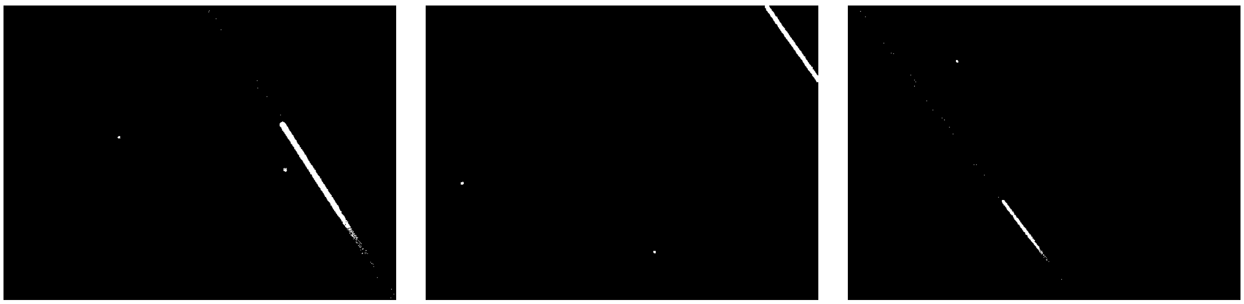

Fig. 3: Simultaneous capture of an object made with the three telescopes. Cropped trajectories.

In the Fig. 3, it can be seen that the cropped trajectories are of different sizes due to the different magnification that each of the images have in each sensor. This cropped sections were coordinated by the time in which were recorded.

3. RESULTS

Every event of the cropped trajectory is then extracted from the file, obtaining the quantity of ON and OFF events generated, Fig. 4. This values are normalized by the magnification of each image, taking as a reference the spot in the telescope with wider FOV (3).

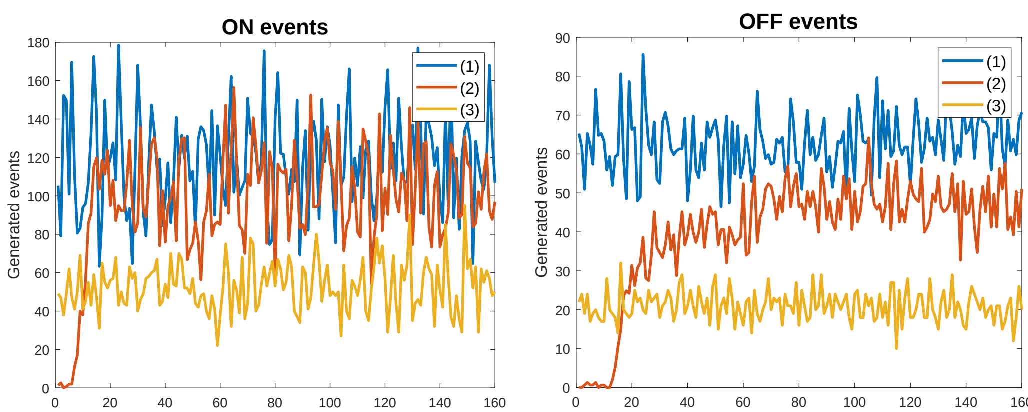

Fig. 4: On and OFF events generated of the cropped trajectories normalized by the magnification.

4. CONCLUSIONS

Results doesn't show substantial difference between the narrowest-FOV telescopes on the generation of ON events, meaning there is little to non turbulence affecting the generation of events in these captures. Then, the election between one or another telescope is dependent of the necessity on the coverage of the sky, so a trade-off is needed to be made between getting more contrast in captures and a bigger FOV. OFF events that are generated due to a negative difference of photons have a more clear difference between implementations.

These results need to be verify with a bigger quantity of satellite captures. Future work must be in line to optimize sky coverage of the system, a possibility it could be to implement an array of EBCs.

5. REFERENCES

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[2] Cohen, G. et al. (2019). "Event-based sensing for space situational awareness," The Journal of the Astronautical Sciences, vol. 66, no. 2, pp. 125–141,.

6. ACKNOWLEDGMENTS

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