Name: Neha Nair

Project Advisor: Whit Smith

Group Name: Operation J.A.G.A.N

Detection of Space Debris Using Nocturn XL CMOS Camera

Introduction

There is an exponential increase in space debris which could potentially hamper space operations in the next few decades. Some major applications of debris detection include avoiding satellite collisions with floating space objects and detecting uncatalogued space objects [1]. The location of space objects can be tracked using optical methods. A Nocturn XL CMOS Camera attached to a Kowa LM60JS5MA lens is used to capture images of space objects. This paper will discuss how multiple images of the same space object are used to determine its position relative to the satellite.

Commercial Applications

The optical method for detecting space objects requires two major hardware components – the Nocturn XL CMOS Camera and the Kowa LM60JS5MA lens.

Nocturn XL CMOS Camera

The Nocturn XL CMOS Camera, manufactured by PHOTONIS, is used because it has a Lynx CMOS imaging sensor that was designed specifically with night vision. There is no need for additional illumination for low light imaging. The camera can operate in a temperature range of -40ºC to +60ºC. It has a sensor resolution of 1280x1024 pixels and a pixel pitch of 9.7 µm x 9.7 µm. The read noise of the sensor is <4e- median at 60 Hz and the dynamic range is greater than 60 dB. It has an SNR (signal to noise ratio) of 42 dB. The camera is very compact with dimensions 34.1 mm x 36.6 mm x 37.4 mm and its weight is approximately 85 g. The sensor takes less than 5 seconds for startup and has automatic gain and exposure control. Power used by the camera depends on the frame rate selected by the user (50, 60 or 100 Hz). In the 50/60 Hz mode, approximately 1.8 W power is used and in the 100 Hz mode approximately 2.25 W power is used. The manufacturer provides the price quote on request [2].

Kowa LM60JS5MA Lens

The Kowa LM60JS5MA lens is attached to the camera. It is manufactured by Kowa Optimed based in Japan. It is a high-speed lens with focal length 60 mm and iris range f/0.80 – f/360. It has a high resolution of 6 Megapixel. The lens is compact and lightweight. It has dimensions 78.4 mm x 124 mm and weighs approximately 1000 g. It can operate in a temperature range of -10ºC to +50ºC. Currently, the lens costs approximately $1429 [3].

Underlying Technology

Once the satellite is deployed in low earth orbit, the camera captures several image datasets. There are multiple visible objects in each dataset. The main objective is to distinguish between stars and resident space objects. An intensity distribution of the image is described by a discrete mapping. The maxima of this mapping indicate the presence of stars or RSOs (resident space objects). Calculating the area centroid of each object provides the location of the object in the image [4]. The centroid extracted from the image is slightly distorted because light passes through the lens before reaching the camera sensor. The Brown Distortion model provides a relationship between distorted coordinates and undistorted coordinates [5]. The undistorted coordinates are then calculated using the Newton-Raphson method.

Multiple image datasets are analyzed and stars are removed from consideration. This done by making a few assumptions. According to orbital mechanics, RSOs are free to move in space whereas stars are fixed in the inertial reference frame. It is known that the satellite is at the inertial origin and has only rotational degrees of freedom. The images are then corrected for rotation of the satellite. Using the image datasets, if the angular separation between the detected objects is near zero, it is most likely a star and can be removed from consideration; this leaves behind only the RSOs [4].

Building Blocks

The technology to detect space debris using optical methods requires the use of a Nocturn XL CMOS Camera that has a Kowa LM60JS5MA lens attached to it. The object detection sets from the images are transferred to the on-board Raspberry Pi 2B processor which calculates the positons of space objects observed in the images. This information must be downlinked to the ground. The data is converted to an analog signal (470 MHz). The signal is transmitted into space using the satellite antenna. The signal is received by the ground station and then demodulated into digital data [6].

References

[1] A. Ciurte, A. Soucup, and R. Danescu, "Generic method for real-time satellite detection using optical acquisition systems - IEEE Xplore document," in ieeexplore.ieee.org, 2017. [Online]. Available: http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6936971. Accessed: Mar. 5, 2017.

[2] "Photonis Nocturnal XL Technical Specifications," in http://www.nocturncamera.com/, 2014. [Online]. Available: http://www.nocturncamera.com/pdf/Nocturn_XL.pdf. Accessed: Mar. 5, 2017.

[3] "LM60JS5MA Datasheet," in http://www.kowa.eu/lenses/en/data/LM60JS5MA.pdf, 2013. [Online]. Available: http://www.kowa.eu/lenses/en/data/LM60JS5MA.pdf. Accessed: Mar. 6, 2017.

[4] J. Lee, L. Zubair, S. Virani, T. Murphy, and M. J. Holzinger, "HARDWARE-IN-THE-LOOP COMPARISON OF SPACE OBJECT DETECTION AND TRACKING METHODOLOGIES," 2016. [Online]. Available: http://www.ssdl.gatech.edu/sites/default/files/papers/conferencePapers/AAS-16-266.pdf. Accessed: Mar. 6, 2017.

[5] D. C. Brown, “Decentering Distortion of Lenses,” Photometric Engineering,Vol. 32, No. 3, 1966,pp. 444–462.

[6] Jefferson, Andy, and Agrawal, Varsha. Satellite Technology: Principles and Applications (3rd Edition). Somerset, NJ, USA: Wiley, 2014. [Online] Available: ProQuest ebrary