,

CS-510
Project Proposal
Testing and Characterizing of the Open Star Tracker

Aakarsh Nair
aakarsh@pdx.edu

January 26, 2023

Abstract

The goal of this project is to increase understanding of the star tracker component of OreSat project by documenting it, providing optimal values for its parameters, looking for possible corrections for speed of movement, and providing basic benchmarks

1 Problem Statement

1.1 Introduction

Oresat0 which was was launched from Seattle, Washington, aboard the Astra LV0009 in a sun-synchronous low earth orbit. It flies at an altitude of roughly 500 km at a velocity of roughly 8 km/sec. OreSat 0.5 is a 2U version of OreSat0 and is tentatively going to launch in Q1 of 2023. The satellite is modularly designed to consist of a series of hot swappable cards on a shared bus built on the OSD335x-SM System-in-Package offered by Texas intruments [**Octavio-OSD335x**] built around the ARM Cortex-A8 processor along with firmware programmable PRU units.

Unlike OreSat0, OreSat0.5 is designed to include an Attitude Determining and Control System (ADCS) a key component of this is the Star Tracker. As a functional component of the ADCS the Star Tracker is required to provide updates to its subscribers of the relative orientation of the satellite, in terms of RA (right ascension), DEC (declination), and ORI (orientation), with respect to the earth. This is achieved by performing some image pre-processing and utilizing the Open Star Tracker interface to solve from camera image pixel to the relative orientation. Internally we use the data from Hipparcos mission which collected and cataloged precise measurements of 118,200 stars including the brightness, relative positions and motions. This catalog is indexed and made query-able by the Open Star Tracker using the relative brightness and positioning of the stars to search for matches in the catalog.

On the hardware side the star tracker card consists of an AR0130CS, 1/3 inch CMOS digital image sensor of size 1280Hx960v which can capture images at up to 45 fps.

2 Proposed Deliverables

2.1 Document Open Star Tracker algorithm and internal data structures

Current implementation of the star tracker is under documented a lacks sufficient framework for testing. The task here would be to generate better documentation for the algorithm functioning as well ass adding greater degree of functional and unit tests. There is also the possibility to prototype key parts of the algorithm in pure python notebook for understanding. Read and summarize background material on blind calibration used by astrometry.net for comparison. Perform, simulate or otherwise justify the expected star tracker camera view based on velocity, elevation or using some star simulation software.

2.2 Describe sensitivity of solver parameters on the Pine Mountain Data Set

Pine mountain Dataset consists a series of the images taken at pine mountain at various exposure settings. The task here would be to characterize the solver on this dataset. Including exposure time dependence. Solving in the presence of motion blur when exposure times are high as well as speed and accuracy of the solver. Use data augmentation techniques to increase the dataset size and noise sensitivity. Write some benchmarks using these datasets. If weather conditions permit we can also consider gathering additional data from other sites.

2.3 Evaluate feasibility of motion blur removal

Evaluate the feasibility and of motion blur removal. Evaluate the trade-off in solver performance in the presence of degrees of motion blur vs the exposure time and gain. Investigate speed and performance of techniques such as the Wiener filter and others.

2.4 Study and propose optimal values for exposure time and other settings with rationale for choice.

Provide a rationale for the optimal values and describe the trade offs using performance common detector metrics such as ROC and precision recall curves. Include these metrics as output of an automated benchmark script so these can be evaluated at different parameter values.

2.5 Investigate Priors

If possible while solving consider how prior satellite images or solving information maybe used to increase solving accuracy under uncertainty, this might involve looking into Bayesian methods.

2.6 Literature Review

Read further literature on star tracking, and review other techniques such as feature based or neural network based methods star tracking. If possible give an account of what they would look like. If we are able to finish writing a bench mark then consider implementing one of them and comparing it against Open Start Tracker.

3 Discussion

We expect to at a minimum be able to accurately describe the solver and be able to test out the solver characterstics to perturbations of the images, these should help us increase confidence in the solver.

We hope that we can also optimize camera parameters or make argument for their current values in tandem once we can test the solver on various data augmented tasks.

We might be able to gather more data by making additional observations weather and place permitting. Motion blur removal and other solving and capture problems are stretch goals based on our observations.

Final stretch goal maybe to either rewrite the star tracker as pure python based implementation, or to compare it with some other reference implementation.

4 References

1. https://www.onsemi.com/pdf/datasheet/ar0130cs-d.pdf
2. Look into the Weiner Filter - https://www.youtube.com/watch?v=l3LMVLbDCi
3. https://github.com/UBNanosatLab/openstartracker
4. https://en.wikipedia.org/wiki/Hipparcos
5. Open star tracker paper.
6. ASTROMETRY.NET: Blind Astrometric Calibration of Arbitrary Astronomical Images, https://arxiv.org/abs/0910.2233
7. Star Tracker: https://www.youtube.com/watch?v=rnFpJ-xxFjM

@URLOctavio-OSD335x, TITLE=Texas Instruments Octavio System, OSD335x-SM System-in-Package, URL=https://octavosystems.com/*sm/*.

@BOOKMG, AUTHOR=M. Goossens and F. Mittelbach and A. Samarin, TITLE=A LaTeX Companion, PUBLISHER=Addison-Wesley, ADDRESS=Reading, MA, YEAR=1994.

References

[1] Texas Instruments *The TEX Book*, Addison-Wesley Professional.

[2] Leslie Lamport (1994) *LATEX: a document preparation system*, Addison Wesley, Massachusetts, 2nd ed.