In flight orbit calculation - Milliways Regulars

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Chosen Theme: Life on Earth
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Introduction

We tried to investigate, the possibility to calculate the orbit and position of the ISS with a Raspberry Pi. This is interesting, because in space it is very important to know the orbit. Without that no one would be able to interact with the space station let alone docking resupply missions. The hardware required for orbit and position determination is cheap and lightweight, and therefore might be useful for CubeSats. We expected to be able to determine the orbit partially during flight, as well as learning about orbit calculation and ways to improve them afterwards.

Method

During flight the program recorded the unixtime, the raw magnet data, the brightness of the IR-Camera and for reference the latitude and longitude and saved them into a csv-file. It also saved 17 Images (Figure 1) to see if the brightness method works. Because the ISS spins once every revolution we expected the magnet-z data to form a cosine wave with a maxima, a minima and turning points representing the corresponding orbit positions. The program executed a Fast Fourier Transform and a Scipy method to fit the cosine over the data. Thanks to the north at the maximum and minimum, the program was able to calibrate the data and then calculate the inclination using the turning points and the arctangent.

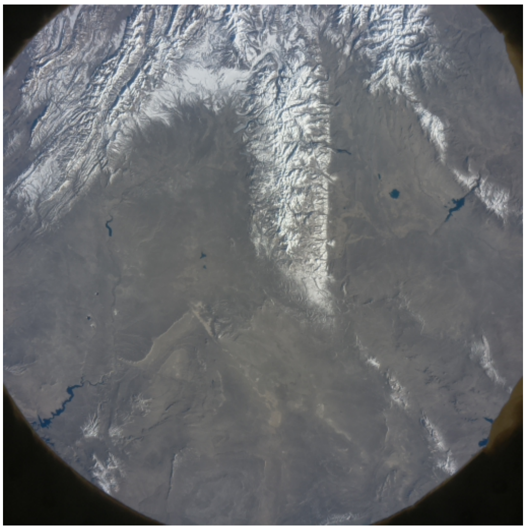

Figure 1: yellowstone nationalpark (reference image)

Finally, the program used the time, the day-night transitions and the normalized cross product to determine the longitude of the minimum and the position at sunrise. The results were saved in a different file. On earth we only illustrated our results.

Results

During flight 461 rows of data were recorded. No exception was raised, the fit worked and the day night transitions were correct. The result was saved in the result-file. As seen in Figure 2 the measurement intervals were quite inconsistent and long, considering that we programmed a Intervall of 10s. The average of 22,8s affected the precision of our calculations. The ISS travels about 200km during that time. We also analyzed if the fit-Method worked well. As seen in Figure 3 there exists a connection between magnet-z (blue) and the inclination (green). One can also see, that the cosine (orange) was fitted quite well even though there where some irregularities in the magnetic field in the southern hemisphere. The calculated inclination was 52,26° and the orbital period was 94,1min which corresponds to an orbit height of 475,7km.

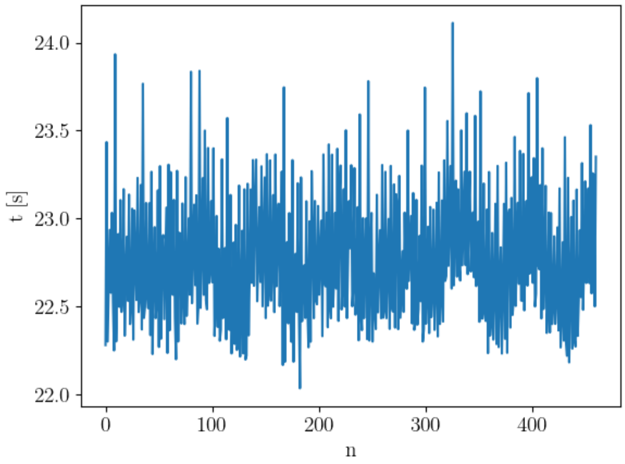

Figure 2: measurement intervals

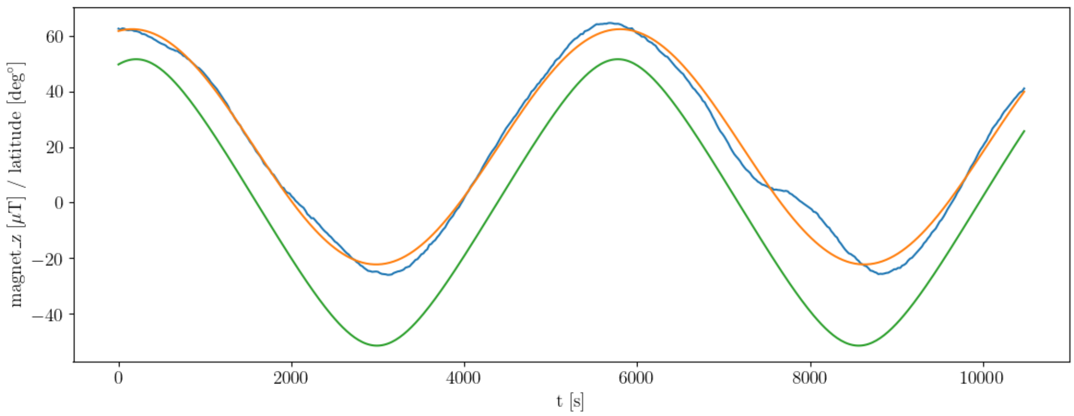

Figure 3: magnet-z and fit-method

Next we analyzed, if the brightness-Method worked. As seen in Figure 4 the day night transitions (orange) were calculated well using the brightness data (blue). The calculated longitude of the minimum was 96,25°, wich was in the expected range

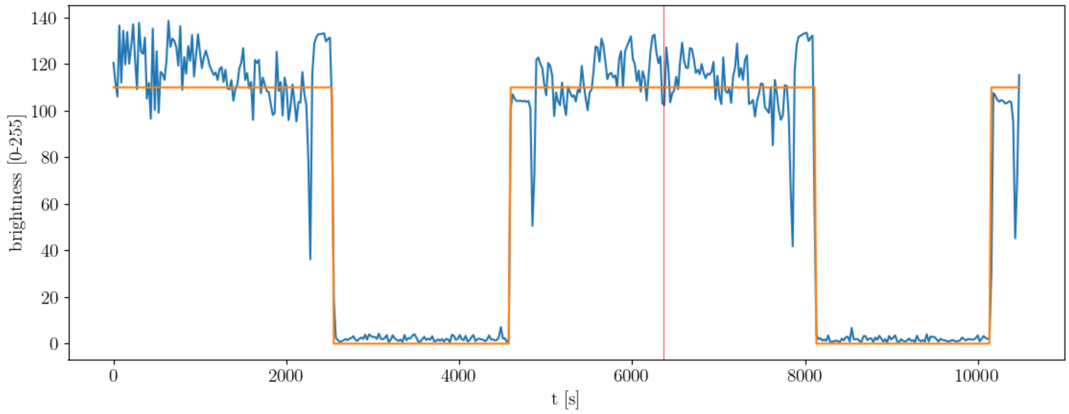

Figure 4: day night transitions

between 92° and 136°, although we underestimated the rotation of the earth wich caused this vague range. The earth rotates about 45° during flight time.

In Figure 5 we put the calculated orbit (red) on a equirectangular projection of the earth and also highlighted the actual position (gray). One can see, that the orbit calculation worked surprisingly well. The only mayor inaccuracy is because of the rotation of the earth, wich we did not considered in our calculations.

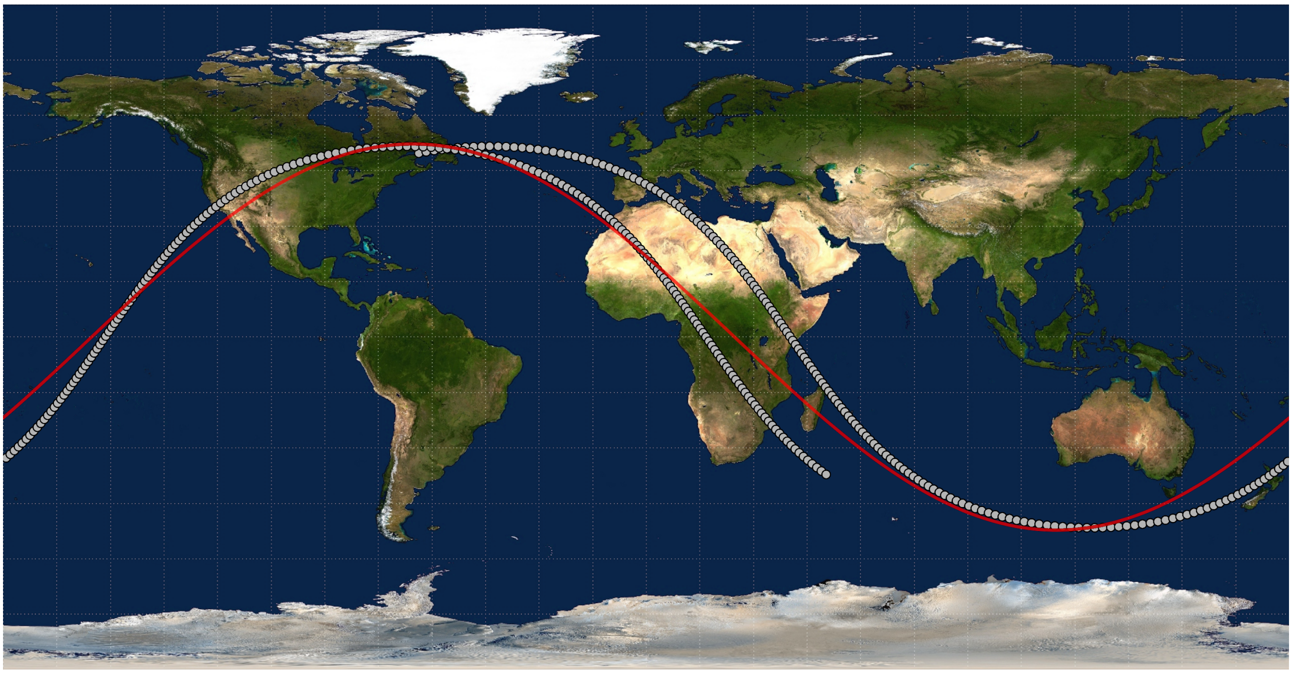

Figure 5: calculated orbit versus real orbit

Conclusion

Our program ran flawlessly over the 180 minutes. The data were saved in the csv-file, evaluated during the flight and the orbit parameters were saved in the result-file. The fit-Method worked well, and so the orbital period and the height were determined approximately. Furthermore, the assumptions could be confirmed that the inclination is related to magnet-z and that you can easily determine day and night with the camera. The earth's rotation was responsible for the biggest inaccuracy, which it should be taken into account in the future. In addition, an improvement would certainly be possible if the magnetic field is not assumed to be a bar magnet, considering the anomaly in the southern hemisphere. To conclude, one can say that the Astro Pi can determine the orbit of the ISS surprisingly well. However, due to the high speeds, the smallest inaccuracies in space already lead to significant position deviations, which is why the accuracy of the program is not precise enough to use it for rendezvous or other interactions.

parameter	true	calculated
orbital period	93min	94.1min
height	320-410km	475,7km
inclination	51.5°	52.26°
longitude of the minimum	92-136°	96.25°

Figure 6: result

If you want to find out more about our project you can find all source code and data here: https://github.com/lucas56098/astropi/tree/master/Data
and a detailed projet report
here: https://github.com/lucas56098/astropi/tree/master/Report