Team Name: **AstroWarriors**

Chosen theme: Life on Earth

Team members' names: Dawid Domasławski, Julia Kosiek, Kinga Moskal

Organisation name: **Szkola Podstawowa nr 12 w Jasle**

Country: **Poland**

Introduction

Our goal was to study the speed of the space station in orbit through the analysis of images taken with the camera every 6 seconds and their analysis using the functions hidden in the OpenCV libraries. We collected data from other sensors in order to check the changes in parameters connected with the location of the ISS in relation to the Earth. We expected that we would be able to determine the speed of the ISS stations in a correct way and to detect velocity differences at apogee or perigee. We also wondered if we would be able to see bright light sources on the unlit part of the Earth what would be an important experiment for us, defining the possibilities of Picamera.

Method

For the experiment we used NoIR camera, accelerometer, gyroscope, magnetic field, humidity, pressure and temperature sensors. By means of PyEphem module we obtained the location of the station, its height and information about whether the photos will include day or night areas of the Earth. Descriptions of photos, timestamp, calculated station height and data from the sensors were saved in a csv file. During the night flight over the Earth we increased the sensitivity of the camera and extended the exposure time to 6 seconds. Within 2 hours and 49 minutes we gathered1126 images, 665 of which were used for further analysis, including 5 night images. We were pleasantly surprised to see the light images in 7 night shots. After receiving the results and photos, we used the second program on Earth, which allowed us to find common points in the next photos, measure their shifts. Thanks to it, with the use of information about the height of the station above the Earth and camera data we could calculate the speed of ISS stations. For the analysis we used the AKAZE algorithm, because SURF and SIFT algorithms, described as better, were removed from OpenCV libraries due to patent rights.

Results

For the analysis we used 658 daily photos. The results of speed calculations showed a large scattering, caused by wrong matching of corresponding points in the photos in whole or in part covered with clouds. After rejecting the most

inadequate data, we obtained an average ISS speed of 27,356 km/h which corresponds with average theoretical speed of 27,600 km/h. The Station was at apogee during nighttime so we was not able to measure velocity there.

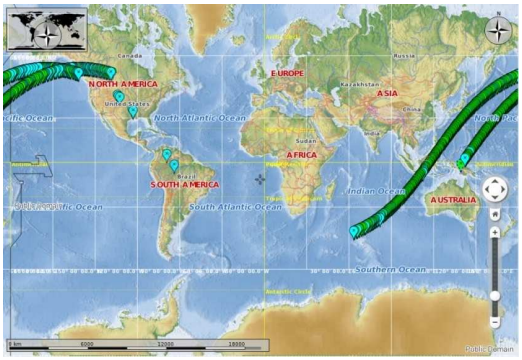

Figure 1: Photos used to analyse the speed of the station

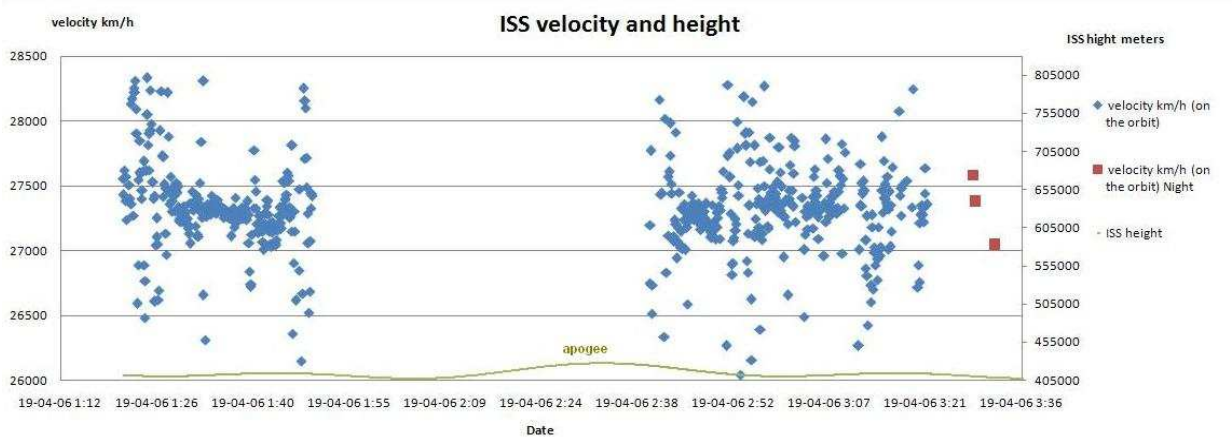

Figure 2: Calculated speed and ISS height versus time

We obtained 7 night pictures, three taken near Albugerque USA show one point, two near Houston show two light sources 56 km apart from each other and two with single lights in Brazil (in the middle of Amazonian jungle) that we couldn't identify. In case of images from the USA, using GIMP, we measured the shift of points in the images and thus calculated the ISS speed. However, our program didn't cope with this because the number of matchpoints was too small. The values similar to the average ISS speed confirmed that these are light sources located on Earth.

During the experiment we noticed systematic, periodic changes in the yaw and roll values, associated with station's position towards the Earth. We didn't detect any changes caused by events such as mooring the ship to ISS, which is consistent with the reported data on activity at the station and data from gyrometer and accelerometer.

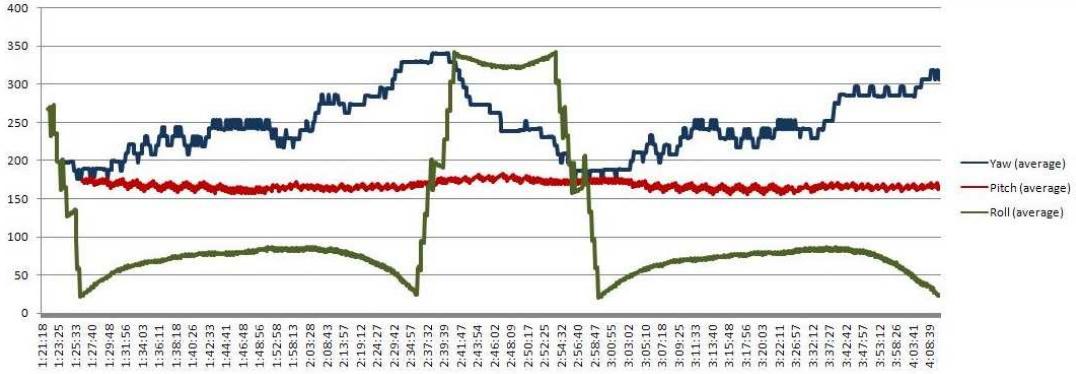

Figure 3: The values obtained from the position sensors

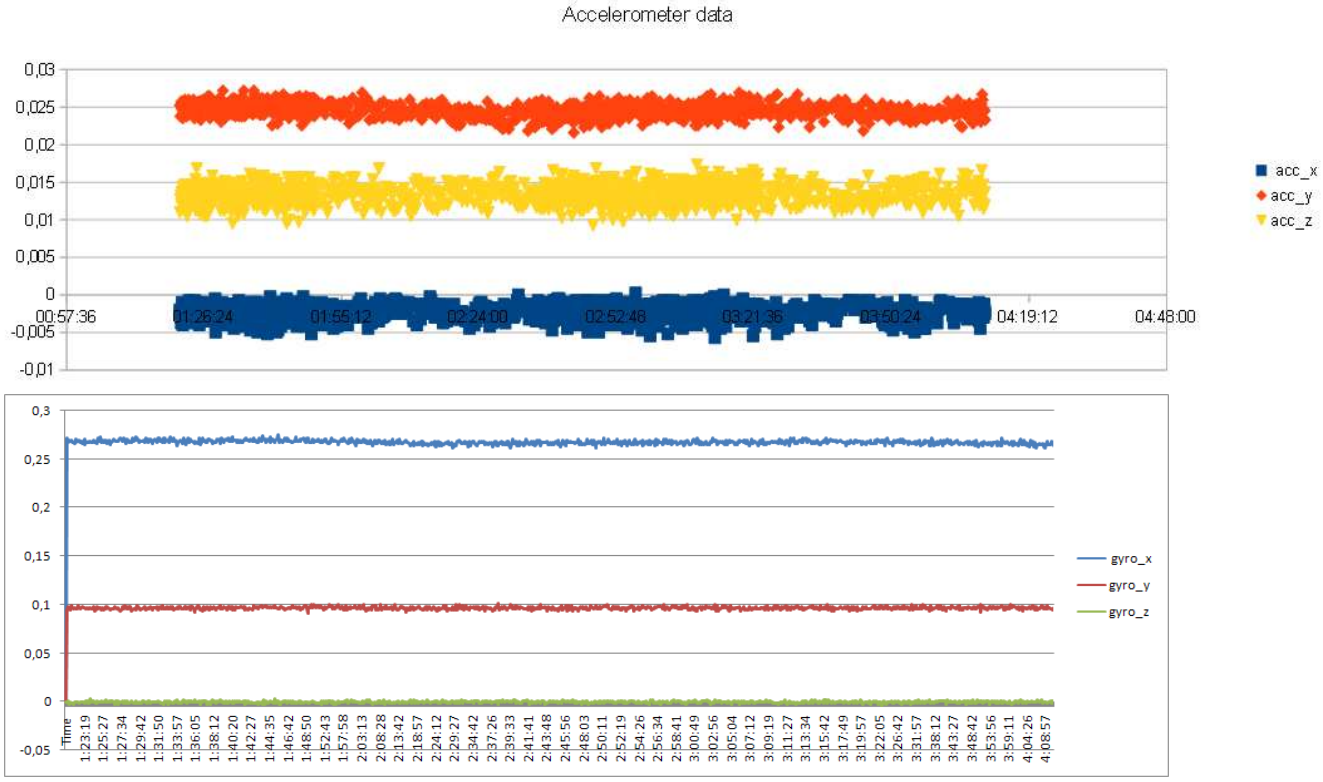

Figure 4: The values obtained from the gyrometer and accelerometer

We spotted slight changes in temperature. The station heated up in sunlight while in the shade its temperature decreased. Besides, we observed changes in humidity and pressure, not related to the ISS location but probably to work at the Station and presence of astronauts near AstroPi.

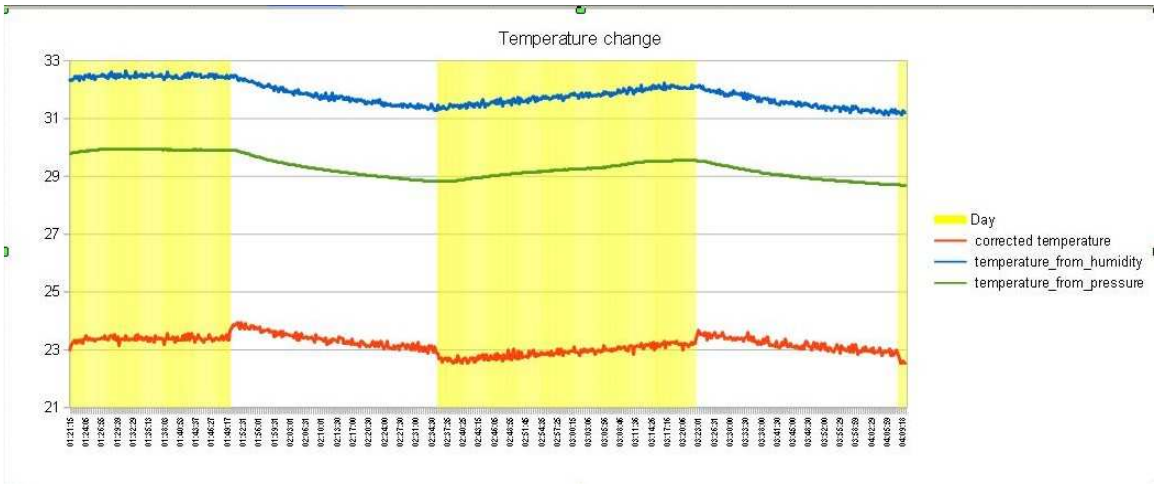

Figure 5: Temperature changes

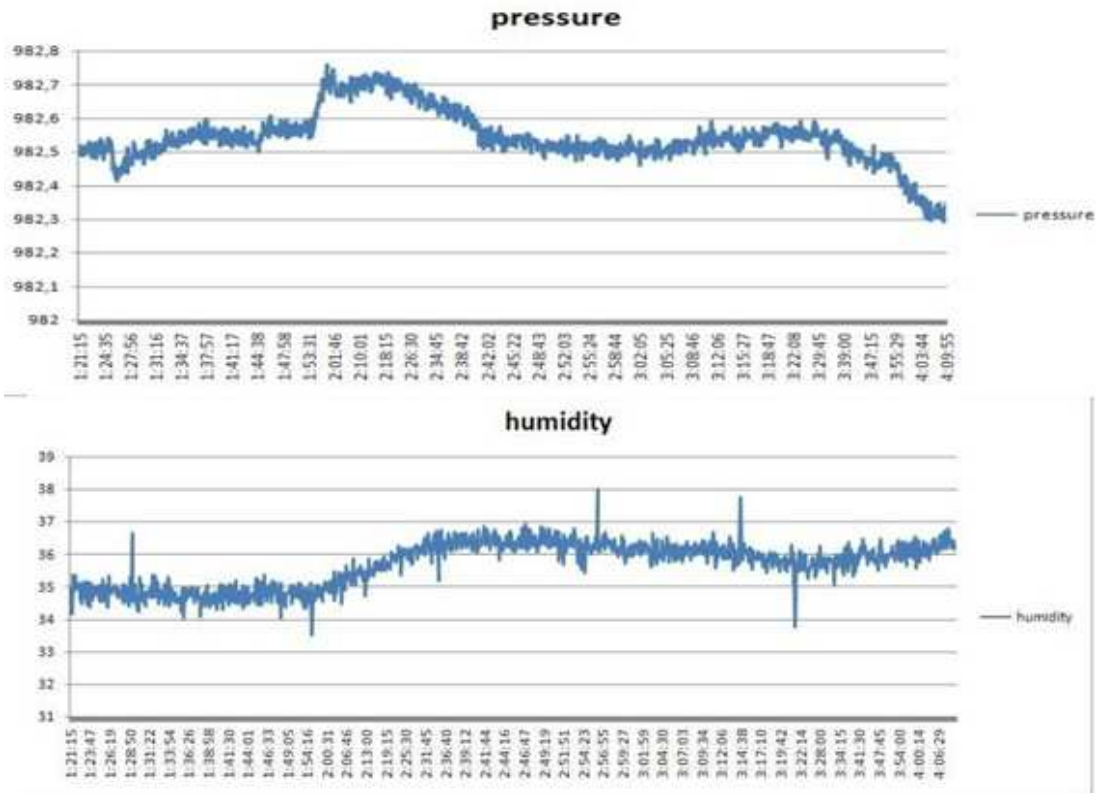

Figure 6: Pressure and humidity changes

We observed a clear periodicity of magnetic field intensity connected with the ISS position in relation to the Earth's magnetic poles. Unfortunately we were not able to detect a flight over the Magnetic South Atlantic Anomaly.

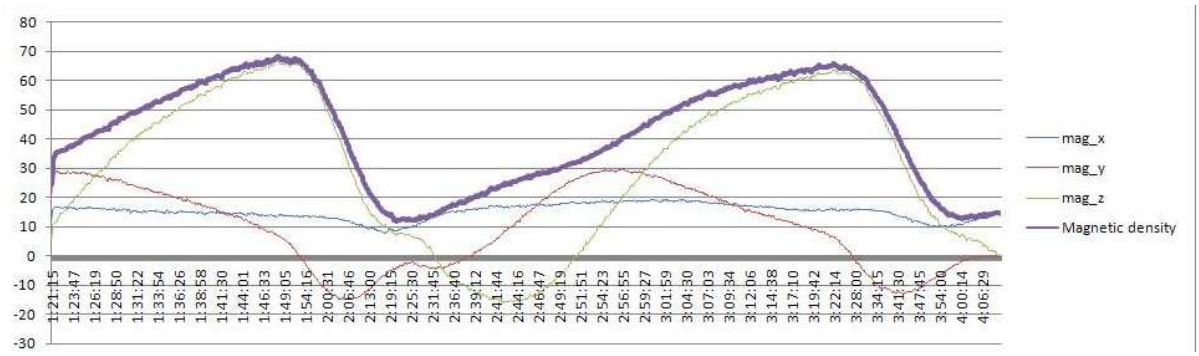

Figure 7: Magnetic field changes

Conclusion

We had a lot of fun during the experiment. We consider it to be very successful, it allowed us to confirm the validity of our assumptions. While we were analyzing the results on Earth, we tried to find out why some results of speed measurements were so different from the others, and concluded that our program wasn't doing well with photos showing clouds. We selected a data around 1:48 AM on April 4, 2019, decided to investigate the shifts of characteristic points (we choose them based on minimal relative shape changes) manually using GIMP and thus calculate resulting ISS velocity in a spreadsheet. This way we obtained results that were less chaotic, but still showed a large

dispersion. The biggest problem were fast dynamic changes in the layout and appearance of clouds. We didn't think they would be so big in such a short period of time.

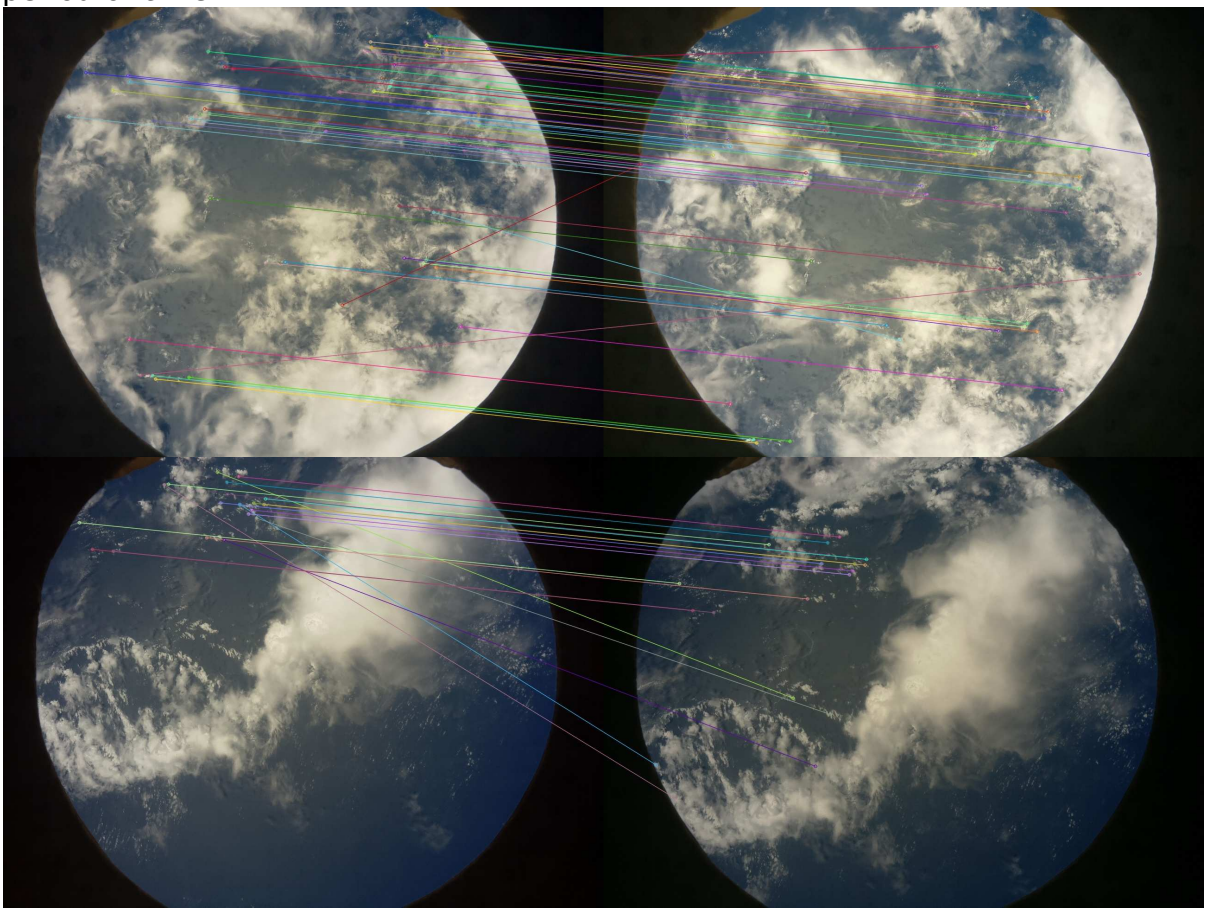

Figure 8: Examples of keypoints with matches example. See some matches are not right.

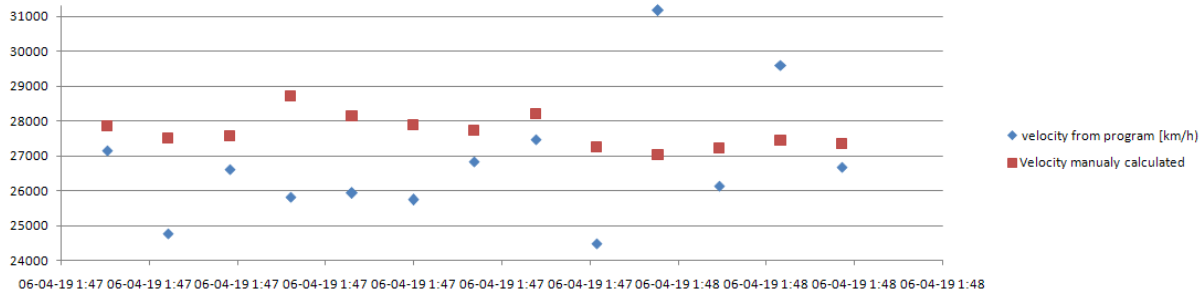

Figure 9: Speed calculated by program and manually calculated versus time

We used the photos obtained during the mission to create a video: https://youtu.be/z9gxUA4QawM .
Programs used during mission, photos, and more detailed studies are available at: https://github.com/JadwigaM/AstroWarriors-2019
We would like to thank ESA and AstroPi Team for the opportunity to participate in such an extraordinary adventure. We would like to thank our parents and teachers for help.

Figure 9: AstroWarriors Team