Mission Space Lab Phase 4 Report

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Chosen theme: Life on Earth

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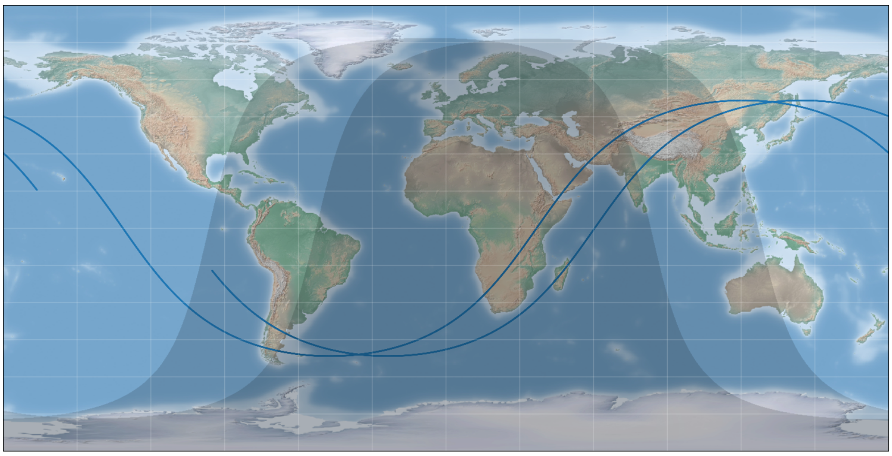
Country: Romania

Introduction

In this project, our goal was to experiment if, based on identifying landmarks and reference points in pictures, we can determine the speed of the ISS (using the altitude and taking into account the camera’s resolution) and the dimension of some natural landmarks in pictures collected by our program. Also, we wanted to experiment and build an algorithm for smoke and pollution detection for land-covered images and cloud patterns detection for land or sea images covered by clouds.



The team expected that two-thirds of the photos would have clouds protecting the Earth from solar radiation.

To carry out our experiments, we developed a code in Python that allowed us to collect data and images to test our hypothesis. For this, we collected data on acceleration, orientation, and magnetic field, along with some parameters from inside the ISS, for three hours on April 24, 2021, from 21:29:33 to 00:24:33.

Method

The program developed by our team used the Astro-Pi's camera and took pictures every 7 seconds (we aimed to get the maximum number of pictures featuring clouds without exceeding memory constraints), and measurements were done every second and the time-stamped data was written in a log file. We collected 1376 images and recorded 29373 data samples from the sensors. Over half of these photos were black and useless, being taken during "nighttime" that happened every 40 minutes. All analyses on data collection were carried out on Earth.

From the set of 1376 images, 675 were taken during the daytime and were suitable for cloud classification. For the ISS velocity on-orbit, we used the OpenCV library with the KAZE 2D Features detection algorithm to identify key points in successive images
and measure the velocity.

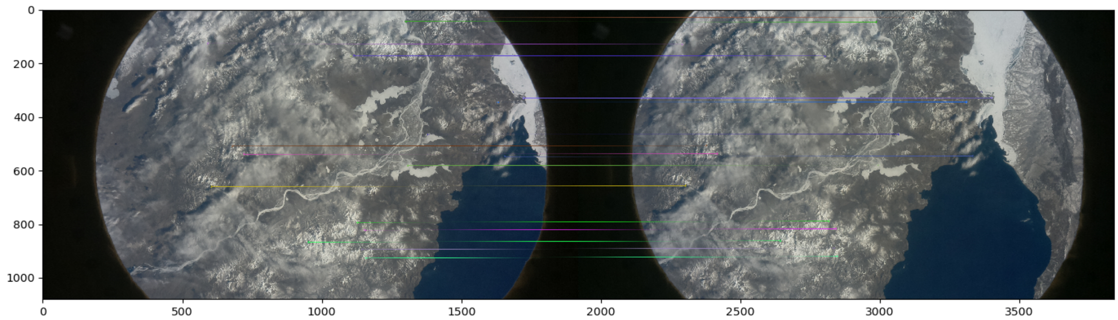


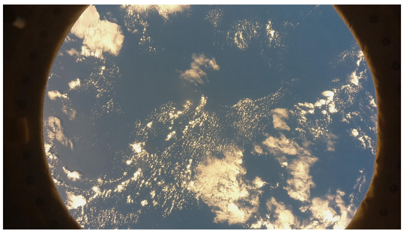
Figure 1: Successive images with reference points identified for the ISS movement measurements.

The image metrics we used for cloud and aerosol characterization are red versus blue intensity, RBR, R (Shields et al., 1993), and the normalized red-blue ratio, NRBR, proposed by Yamashita et al. (2005) and Li et al. (2011).

$$RBR = \frac{R}{B} = 1 + \frac{R-B}{B}, \text{ and } NRBR = \frac{B-R}{B+R}$$

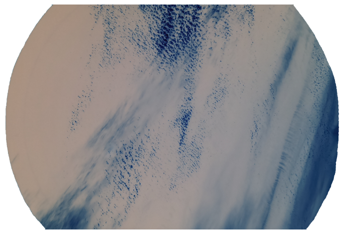
Each image was processed with our program. We split the image on R, G, and B channels and we generated the RBR and the NRBR version of each image. For the cloud classification program, we used the following categories: altocumulus, cirrus, cumulonimbus, cumulus, stratus, and no clouds for our program, and we used the classified images from our 2019-2020 AstroPi mission as the training and validation data.

Some images from the above-mentioned classes are presented below in unprocessed form and also in Red-Blue Ratio and Normalized Red-Blue Ratio, the first one being in shades of blue

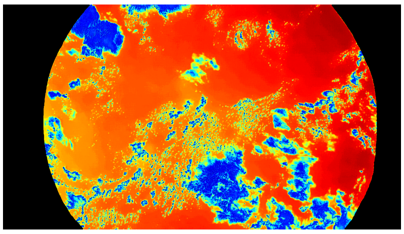


Altocumulus and cumulus

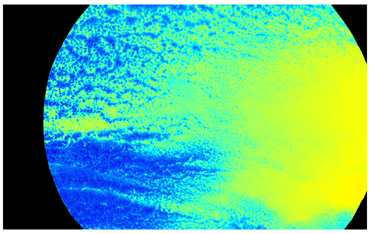
Stratus



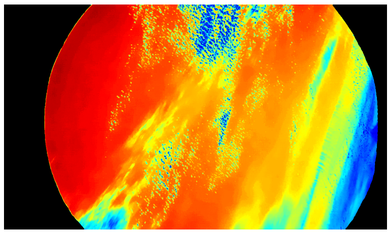
Cirrus



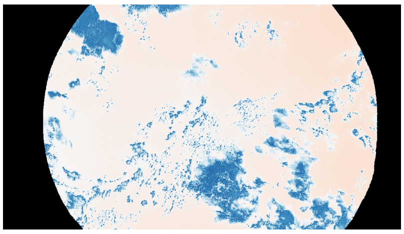
Altocumulus and cumulus in RBR



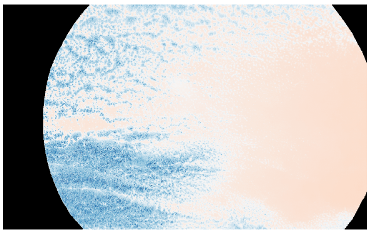
Stratus in RBR



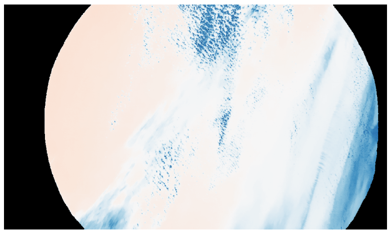
Cirrus in RBR



Altocumulus and stratus (NRBR)



Stratus (NRBR)

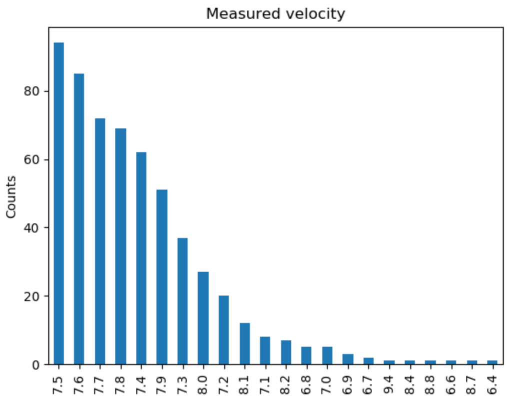


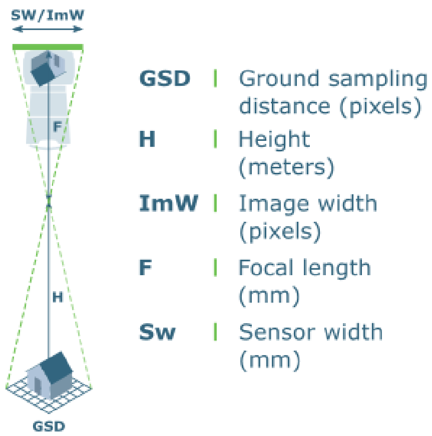
Cirrus (NRBR)

Figure 2: Clouds in different color compositions (unprocessed, RBR, and NRBR).

Result

For the velocity measurements, through the previously described techniques, for each pair of images, the KAZE algorithm detected several pairs of the same feature in the image and we measured the velocity by measuring the displacements on each pair of reference points, using the Ground Sampling Distance (GSD) method (presented in the figure on the right), and after averaging these distances, knowing the altitude of the ISS, the focal length of the camera and the time delta between two consecutive images we obtained very close values to the ISS speed, our measurements being between 6.4 and 8.8 km/s





The photos obtained are mostly over the Pacific ocean and have a medium and large cloud cover percentage, which is good for our classifier program. The majority of the images were classified as stratus and cumulus.

We used a CNN classifier built with Keras for classifying the image data set. Out of the 675 images, 74.8% were classified as Cumulus, 20.7% as Stratus, 2.3% as Cirrus, 1.9% as "no clouds", and only one image was classified as Cumulonimbus for the raw image classification.
As for the NRBR images, 62.6% were classified as Cumulus, 27.4% as Stratus, 7.3% as Cirrus, 2.0% as "no clouds" and 4 images as Cumulonimbus, which makes 0.5% for this cloud type.

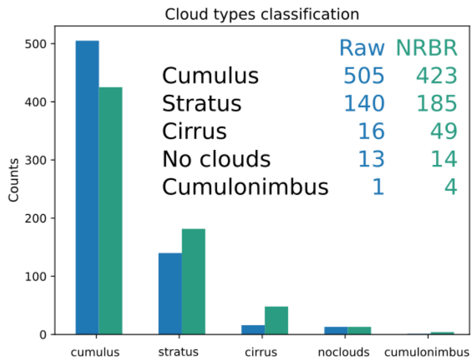


Figure 3. Classification results for raw and NRBR images using Convolutional Neural Networks (CNN).

Conclusion

Overall, the code did exactly what we wanted it to do. The data we collected with our project surpassed our expectations: high-quality images with a lot of cloud patterns. The volume of the data and clear images are impressive, we succeeded in collecting enough data to perform our intended analysis and classification.

The NRBR classification results were good. It would be interesting to use the Euclidean geometric distance (EGD) in the color space to transform the images and perform the same classification and compare the results. A further improvement would be to detect smaller patterns of different cloud types in each image and measure how much are these formations relative to the whole image. In a lot of pictures, the classifier gave mixed results with at least one class with over 10% probability.

Regarding the accuracy of the ISS velocity on orbit, the method we used to measure distances makes some assumptions such as flat Earth surfaces, vertically aligned cameras facing the Earth, therefore we are glad that our results came very close to the real speed value. We can conclude that this method is a feasible means for the small-scale aerial monitoring process. But even if we collected enough data to perform the intensive analysis we would need more data from different geographical regions and maybe from another season (the images we used to train the model being also from April), to build better models with higher accuracy and to validate our assumptions.

Bibliography

1. Shields, J. E., Johnson, R. W., and Koehler, T. L.: *Automated whole sky imaging systems for cloud field assessment*, Fourth Symposium on Global Change Studies, American Meteorological Society, 1993
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4. Ground Sampling Distance (https://support.pix4d.com/hc/en-us/articles/202559809-Ground-sampling-distance-GSD-in-photogrammetry)