Mission Space Lab Phase 4 Report

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Chosen theme: Life on Earth
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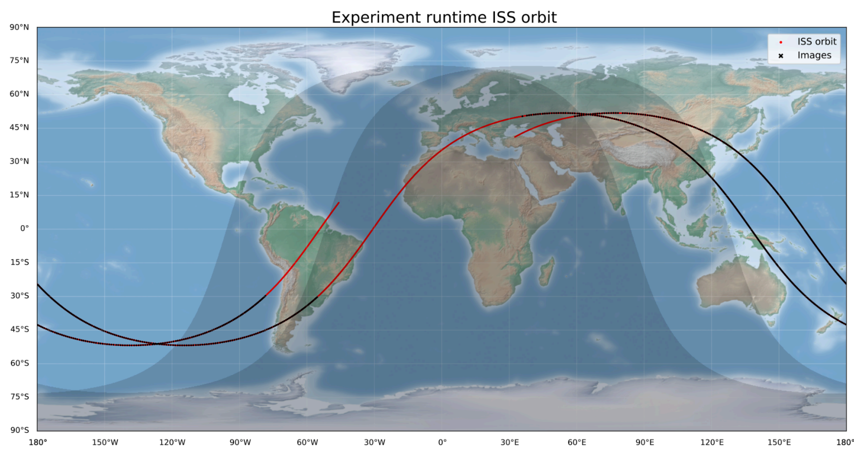
Introduction



Last year, our team was interested in experimenting with identifying landmarks and reference points on pictures taken by Earth-observing satellites. We wanted to see if it is possible for us — based on these detected features — to determine the speed at which an object moves through space (using altitude), as well as distinguish snow from clouds when classified under certain conditions, such ones where there might be storms or hurricanes forming over oceanic areas.

This year's experiment will explore the possibility of using artificial intelligence to analyze pictures taken by satellite. The objective is not just rerunning speed measurements. Still, also we would like to extend and improve our mission by measuring and differentiating snow from the clouds in image classification, detecting possible storm or hurricane formation over the oceanic images, and measuring the albedo level in the pictures. Measuring and classifying cloud formations is essential for understanding many weather phenomena, including precipitation, air circulation, and climate change. Furthermore, studying clouds can also give us clues about conditions on other planets.

Many factors affect Earth’s climate, but one of the most important is Albedo, which measures how much light is reflected by an object. It depends on the type and coloration or surface materials an object has, so surfaces with lighter colors, such as snow and ice, for example, will reflect more than darker ones like grass or forest areas since these have deeper tones which tend to be absorbers rather than transmitters in our world's spectrum. If our global albedo increases by just 0.05%, more energy will be reflected into space, and temperatures on planet Earth will drop by an average of up to 1 degree Celsius.

To carry out our experiments, we developed 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 for three hours on May 07, 2022, from 21:25:04 to May 08, 2022, 00:20:03.

Method

The program developed by our team used the Astro-Pi's camera and took pictures every 10 seconds, measurements were done every second, and the time-stamped data was written in a log file. We collected 740 images and recorded 28620 data samples from the sensors. 76.6% of these photos are suitable for our analysis and image classification tests. All analyses on data collection were carried out on Earth. First, we took our original satellite images and filtered them to enhance their contrast and saturation. We also corrected their blue shift using the OpenCV library. We used a Contrast Limited Adaptive Histogram Equalization (CLAHE) algorithm[1] and a Brightness-Contrast enhancement for a better quality image set[2].

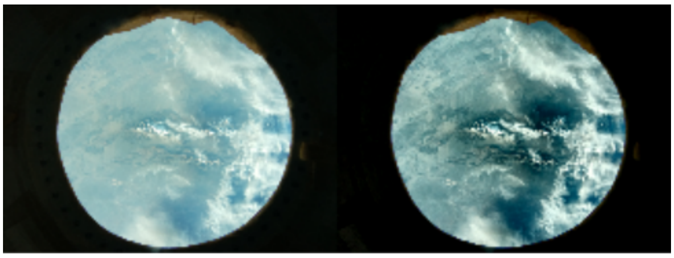


Figure 1. Original image vs. Enhanced Image with CLAHE Method

In our first quick experiment (the ISS velocity on-orbit), we used the OpenCV library with the KAZE 2D Features detection algorithm to identify critical points in successive images and measure the velocity.

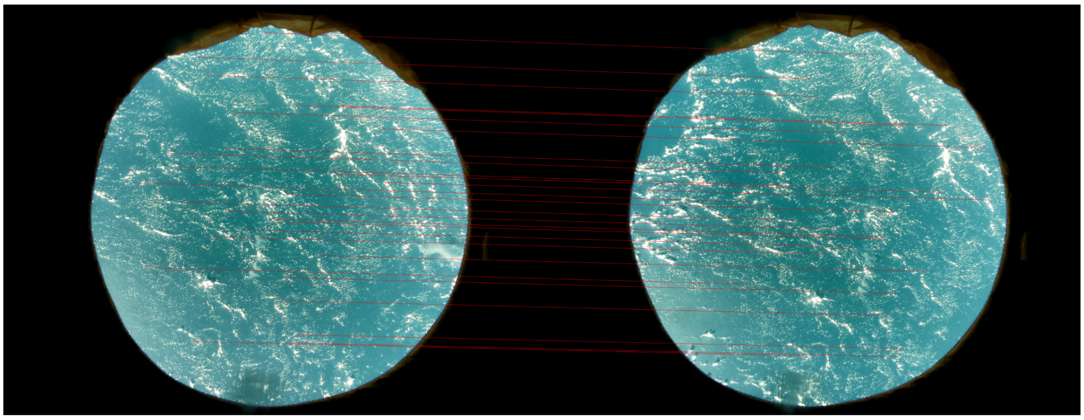


Figure 2. Successive images with reference points were identified for the ISS movement measurements.

To measure the albedo, we have categorized the surfaces into three categories for each photo: cloud, land, and sea. The selection between these categories was made according to the RGB values of each pixel. The RGB values were used because we found it the most reliable method to differentiate between the classes. We took average albedo values for each surface: 0.25 for land, 0.10 for sea, and 0.7 for clouds. Thus, knowing the percentage of each of the surfaces and the corresponding albedo, we were able to go back to an average albedo for the Earth.

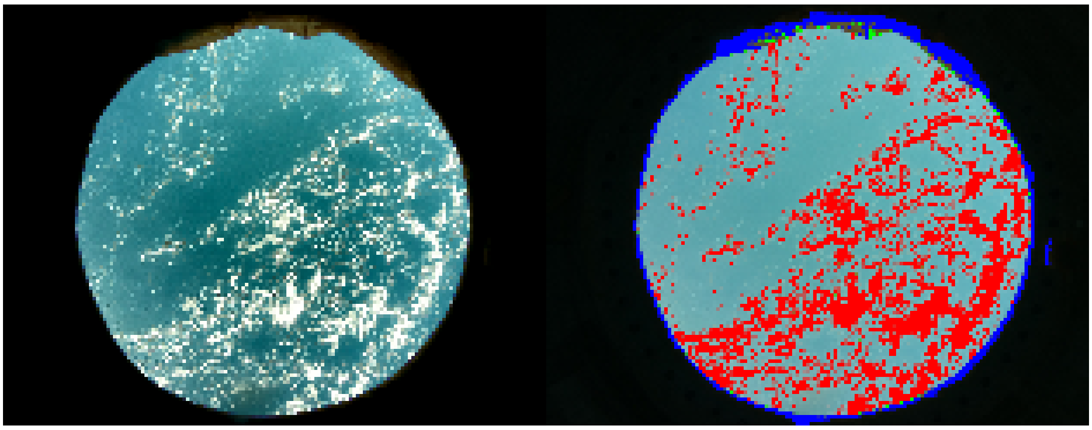


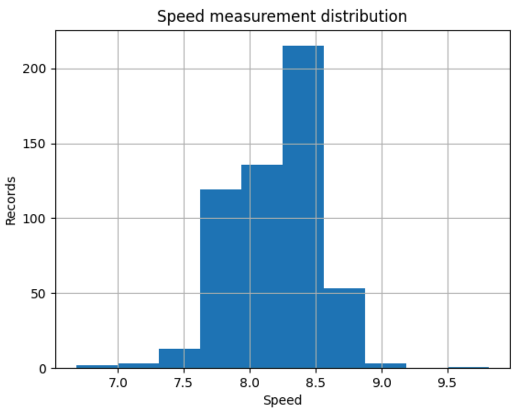
Figure 3. CLAHE Enhanced Image (left) and segmented image for albedo measurements (right) with the sea in light blue and the clouds in red.

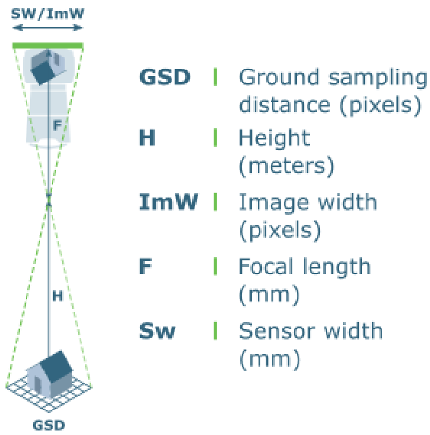
Running a descriptive statistic on the measured albedo series, we found out that the average measured albedo was 00.099543 with a standard deviation of 0.068216.

Our experiment also includes a comparison study between the data recorded from the magnetic sensor and a theoretical off-centered dipole model. By doing this, we can better understand how the Earth's magnetic field affects our measurements.

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 picture, 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 6.68 and 9.82 km/s





The photos obtained are mainly over the Pacific Ocean and have a medium towards significant cloud cover percentage, which is suitable 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. Since most of our pictures are from above the Pacific Ocean and most are cloudy, Cumulus represents 88.1% of them, while 8.5% are Stratus, 2.3% are Cirrus, and 1.1% are classified as Cumulonimbus. In contrast, none of them were classified as "no clouds" for the raw image classification.

Conclusion

Overall, the code did exactly what we wanted it to do. The data collected were below our expectations: many low contrasted images with a lot of cloud patterns. The volume of the data however is impressive. We succeeded in collecting enough data to perform our intended analysis and classification.

Regarding the accuracy of the ISS velocity in orbit, the method we used to measure distances makes some assumptions, such as flat Earth surfaces and vertically aligned cameras facing the Earth. Therefore we are glad that our results came very close to the actual speed value. We can conclude that this method is feasible 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. https://arxiv.org/pdf/2109.00886.pdf
2. https://github.com/CNME-LionTech/AstroPi-2022
3. Ground Sampling Distance (https://support.pix4d.com/hc/en-us/articles/202559809-Ground-sampling-distance-GSD-in-photogrammetry)