Exploring the Spectral Clustering Analysis of the Surface Composition of a Known Asteroid.

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Introduction: This project was completed as part of the requirements for graduation at STAR Academy at The Arecibo Observatory as a high school level investigation with the purpose of exposing students to real scientific research. The main goal for this project was to explore the spectral clustering analysis of the surface of an asteroid. On September 8, 2016, NASA launched a space mission OSIRIS-Rex. The mission had the goal of sending and landing a spacecraft on the surface of near-Earth asteroid 101955 Bennu (formerly known as 1999 RQ36) to collect a sample of about 2.1 ounces and return it to Earth. On October 20, 2020, the spacecraft successfully landed on asteroid Bennu. The type of asteroid Bennu (B-Type, containing much carbon) was re-confirmed. The instrument also took a considerable sample from the surface. This undertaking was a significant development for space exploration.

The mission had an expected cost of $1.16 billion [1], being a high cost mission for NASA. Due to these high costs, missions of similar nature are not likely to be frequent. Therefore, a safe and reliable alternate method of analyzing known asteroid surfaces must be found to carry this type of research. Further developing alternate methods is of utmost importance to prevent future studies of asteroid surface composition to diminish due to economic matters; if this happens, our knowledge of space itself will lessen. Our project explores a technique that is a consistent, steadfast, and an economically viable alternative.

Spectral Clustering: General space study is usually linked to complex data processing, for which great number of researchers turn themselves to machine learning. Being a method of artificial intelligence foundations, here one uses computer arrangements to study and simplify data without ensuing explicit commands by creating algorithms and arithmetical models to examine and draw conclusions from patterns. Although extremely useful, the practice of machine learning is a multifaceted and advanced platform of coding. K-means clustering is the technique under the machine learning macro that we explored in this project. This clustering technique is a method to divide an image's properties into clusters, or groups with similar properties, to determine a pattern in the color image [2]. With k-means, one can establish the type and surface composition of an asteroid with the pre-created code that analyzes the images effortlessly.

To learn the past of our solar system, humans rely heavily on working with the sources around us as relics of the past. One source of this information are asteroids. These objects contain information of the early solar system, can be exploited as potential mineral sources, and can be considered as prospects for future space exploration and colonization. Understanding the surface composition of asteroids is essential for the continuation of space exploration and the expansion of our knowledge of the universe itself.

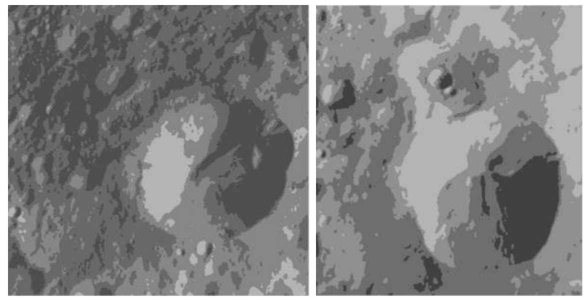

Figure 1: Clustered image of Octavia and Oppia Craters from Asteroid 4 Vesta

This project's primary goal was to use spectral clustering to determine any specific asteroid surface composition using its luminosity and characteristics from known materials. These two variables along a 2D plane use a celestial object's topography with its reflectivity and show where certain materials are located on the surface [3]. Using a K-Means clustering algorithm in Python, we were able to process any given image into colored cluster regions representing different concentrations of the materials located along the surface, as shown in figures 1, 2, and 3.

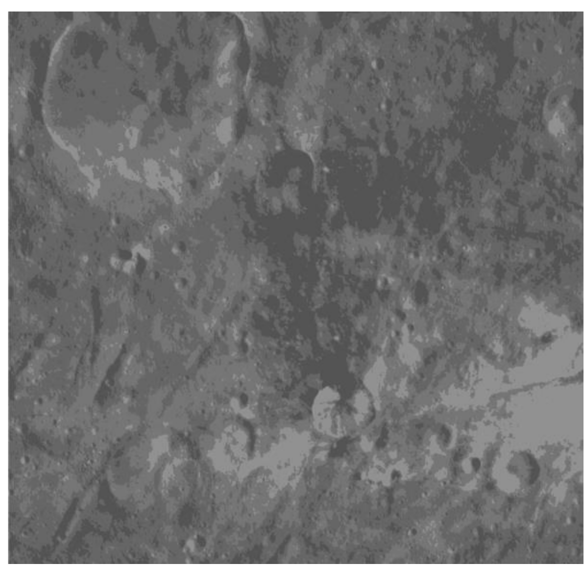

Figure 2: Clustered Image of Sossia Crater from Asteroid 4 Vesta

The program inputs any image and simplifies it to understand what said object is composed of. This method is now an easy gateway to determine the surface composition of an asteroid without directly exploring it. Considering the homogeneity in some areas of the asteroid belt, photos with the least shadowing are most useful as they do not disrupt the light-dark reflectance balance created by the material by casting a shadow on lighter materials. Results show that the brighter areas of a clustered image indicate a more metallic surface composition due to the light reflectance of the material to the image, while the darker the clusters appear to be more silicate or rocky materials are in those regions. By applying this process to a complete asteroid, one will be able to determine its surface composition type in a reliable and economically viable approach.

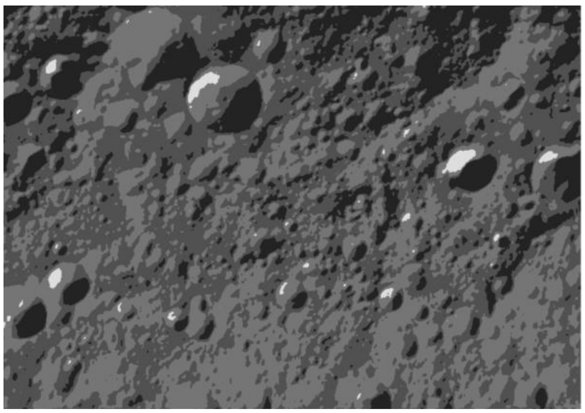

Figure 3: Clustered Image of the Surface of Asteroid 4 Vesta

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