Experimental Study to Determine the Best Compression Ratio of High-Resolution Images of Small Bodies for the Martian Moons eXploration (MMX) Mission

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Data transmission rate becomes one of the biggest limiting factors in space explorations; technological advance in increasing pixel numbers of camera images dominates the improvement of the data transmission rate. Yet, high demand exists for high-resolution images especially in geological studies, and thus there is a tradeoff between the spatial resolutions (or pixel numbers) and the number of images to be transmitted to Earth. The telecommunications issue is critical for Martian Moons eXploration (MMX) mission that explore either/both Phobos and Deimos and return samples. Especially, timely transmission of high-resolution images is required for the selection of sampling site both in terms of scientific impacts and of the landing safety. The highest image resolution of the current camera configuration is as good as several tens of centimeters per pixel and the size of image is 3296 x 2472 pixels, which means 7 color (3 bands) images can be up to 1 GB if no compression is considered. During the landing phase, such large data have to be sent at the limited bitrate (< 32 kbps) to select landing and sampling sites, while the landing duration is about 4 hours. Thus, considering the best compression scheme of images is a big issue for landing operation. Lossy compression can significantly reduce the sizes of images, though images can be scientifically worthless when compressed too much. The best compression ratio should make the sizes of images as small as possible without losing scientific importance.

Here, we develop a method of rapidly determining the best compression ratio of high-resolution images of the surface of small bodies. For preparing the image studied in this research, we take an experimental scheme, where we develop a simulated Phobos surface by using a high-quality simulant of Phobos regolith (UTPS-TB) and take simulated images of the surface of Phobos in somehow similar condition with the camera of the MMX mission. The images are compressed by JPEG2000, which is planned to be used in MMX mission, and the influence of the compression is analyzed by objective methods such as Structural SIMilarity (SSIM) and entropy of image. The results shows that they are able to rapidly detect the exact ratio, in which the quality of the images started to be diminished.

Moreover, by defining scientific value of images as detectability of rock gravel on the surface of celestial bodies and showing that the loss of scientific value can be expressed by the change in the value of slope of Cumulative Size-Frequency Distribution (CSFD) of gravel, we carefully confirm whether the decrease in the image quality is truly connected with the loss of scientific information such as for landing operations and conclude that those objective methods can determine the best compression ratio. By using those methods, the spacecraft can autonomously complete the process of finding the best compression ratio, compressing images and sending it to the ground within a few minutes even if it has only a limited transmission rate.

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