Compression Ratio as Indicator of Scientist Preference for Rover Images

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Remote exploration spacecraft can generally capture far more images than they can transmit over their bandwidth-constrained downlinks to Earth [1]. This suggests that onboard image analysis might improve the quality of returned science data: remote spacecraft gathering images at a high rate can select the most interesting data products for transmission [2]. Here we investigate statistical correlates of desirable image content to inform automatic image selection procedures. We focus on images' compressed size, which functions as a rough measure of the amount of "visual information" present in the image. This study examines a 2003 survey on planetary scientists' preferences for surface rover images. Scientists ranked images according to their assessment of the images' science value, professing a wide range of rationales for their decisions. Nevertheless we find a consistent rank correlation relationship between preference orderings and the images' compression ratios. This raises the possibility that explorer spacecraft could use this or similar measures of visual information as a cue for selective transmission decisions.

Data Acquisition

We consider a dataset from a series of rover experiments conducted in summer 2002 at the Jet Propulsion Laboratory [3]. Researchers collected a set of 25 images using the Field Integrated Design and Operations (FIDO) rover at a field site near Flagstaff, Arizona. FIDO is an experimental platform designed to emulate the basic size and mobility of the Mars Exploration Rovers. The dataset consisted of two image categories. The rover cameras pointed directly at the horizon (zero elevation) for 17 images. For the remaining 8 the cameras pointed downward at the near field terrain in front of the rover so that no horizon was visible. All images had a resolution of 640×480 pixels.

The original study aimed to evaluate the agreement between scientist judgments about images' science value. 16 individuals participated in the study, of which 7 were planetary geologists. Researchers queried each participant about which image they felt was most important (e.g. the image they would like to receive during remote science operations if the rover could transmit only one). Then, the participant added new images to the downlink in the order of decreasing science value until none of the original 25 remained. The procedure resulted in nine rank orderings of the 25 images. The study compared different scientists' preferences and found statistically significant correlations. While several outliers exhibited dramatically different preferences due to differences in background or their ideas about mission goals, the overall picture was one of general agreement among the individuals. Here we extend this analysis to quantify relationships between scientist preferences and objective statistics of the images themselves.

Method

One can describe the correlation between image features and scientists' preferences using the Spearman rank correlation coefficient [3]. The Spearman coefficient measures the codependence between rank-ordered variables. The statistic, commonly represented by ρ, is a nonparametric analog of the classic Pearson correlation coefficient for linear relationships. It measures of the ability of an arbitrary nonparametric function to describe the relationship between two variables. It is computed as follows, where d_i is the difference between rank of each of the values of the "compressed size" and "mean preference ranking" variables and n is the number of images in the dataset.

$$\rho = \frac{6 \sum d_i^2}{n(n^2-1)} \tag{1}$$

Here our image attribute consists of the data products' physical size (in kilobytes) after compression using the JPEG compression standard [4]. The wavelet compression routine exploits regular structures in natural images, so the compression ratio is a rough measure of the visual information that is present. However, imaging conditions such as range, scale, and the amount of sky in an image can affect this compression ratio in ways that have little to do with the image features themselves. To control for these imaging conditions we evaluate ρ separately for the two sets of farfield and nearfield images.

Results

Information content, measured by the compressed image size, strongly correlates with favorable rankings by scientists. The associated ρ value of -0.91 suggests a

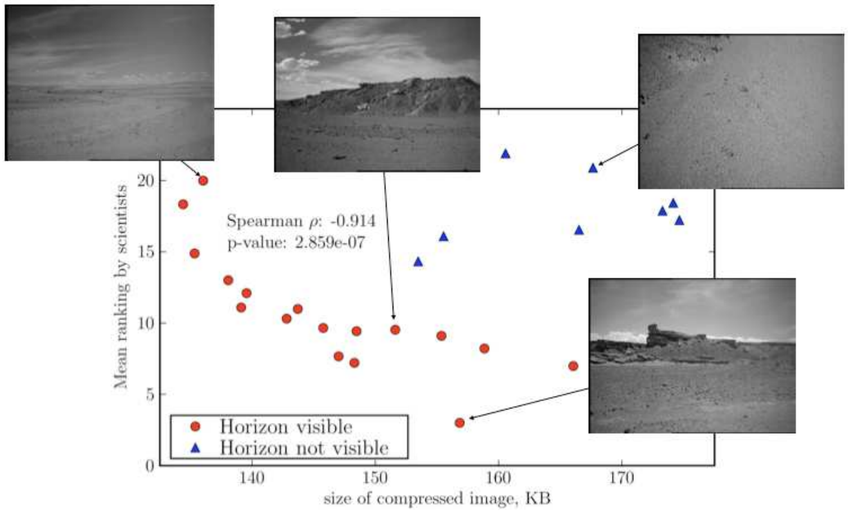

Figure 1: Scientist rank preferences correlate strongly with the compression ratio for farfield images in the FIDO survey. Scientists broadly prefer images that compress poorly; these are more likely to contain interesting geomorphology. Here the ρ and p values refer only to those images which display the horizon. Desirable images have low rankings.

Participant	Spearman ρ	p-value
1	-0.69	0.002
2	-0.55	0.02
3	-0.82	0.00005
4	-0.79	0.0001
5	-0.39	0.11
6	-0.62	0.007
7	0.10	0.68
8	-0.28	0.26
9	-0.88	0.000002

Table 1: Preferences show a significant correlation between preference ordering and compressed image size for 6 of 9 participants.

highly significant relationship (p-value $< 1e - 6$). In other words, the compression ratio accounts for a significant portion of the variance among the mean preference rank. Figure 1 illustrates this trend with red circles signifying the farfield images. The correlation is also significant for the individuals' independent preference rankings for 6 out of 9 individuals (Table 1). This suggests that an explorer agent could use the image compression ratio to determine the best images for transmission. For the FIDO farfield dataset, where images are captured under similar range, lighting and scale conditions, the JPEG compression ratios appear to correlate with images' semantic contents. Low compression signifies irregular structure like broken outcrops and other geomorphological features of interest. Regardless of whether or not the images are actually compressed for downlink, the JPEG reduction constitutes a proxy measure of the visual structure in the scene. It is simple to compute and germane to images' science content.

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