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The Cyborg Astrobiologist: Image Compression for Geological Mapping and Novelty Detection

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Abstract

We describe an image-comparison technique of Heidemann and Ritter [4,5] that uses image compression, and is capable of: (i) detecting novel textures in a series of images, as well as of: (ii) alerting the user to the similarity of a new image to a previously-observed texture. This image-comparison technique has been implemented and tested using our Astrobiology Phone-cam system, which employs Bluetooth communication to send images to a local laptop server in the field for the image-compression analysis. We tested the system in a field site displaying a heterogeneous suite of sandstones, limestones, mudstones and coalbeds. Some of the rocks are partly covered with lichen. The image-matching procedure of this system performed very well with data obtained through our field test, grouping all images of yellow lichens together and grouping all images of a coal bed together, and giving a 91% accuracy for similarity detection. Such similarity detection could be employed to make maps of different geological units. The novelty-detection performance of our system was also rather good (a 64% accuracy). Such novelty detection may become valuable in searching for new geological units, which could be of astrobiological interest. By providing more advanced capabilities for similarity detection and novelty detection, this image-compression technique could be useful in giving more scientific autonomy to robotic planetary rovers, and in assisting human astronauts in their geological exploration.

1. Introduction

In prior work, we have developed computer algorithms for real-time novelty detection and rarity mapping for astrobiological and geological exploration [1][3][6-8][10]. These algorithms were tested at astrobiological field sites using mobile computing platforms originally with a wearable computer connected to a digital video camera, but more recently with a phone camera connected wirelessly to a local or remote server computer. The image features used in the novelty detection and rarity mapping in prior work were based only upon RGB or HSI color. Nonetheless, even with image features limited to color, the mobile exploration systems worked very robustly.

Herein, using data acquired by the Astrobiology Phone-cam at a geological field site (Fig. 1A), we test an image-comparison technique of Heidemann and Ritter [4,5] that uses image compression and is capable of (i) detecting novel (colored) textures in a series of images as well as of (ii) alerting the user to the similarity of a new image to a previously-observed texture. We first implemented this technique in 2010 [2], but we did not test this software at a geological field site until now. See [9] for a more in-depth discussion.

2. Image-Similarity Measure

Following Heidemann and Ritter [4,5], we "calculate the similarity of two images I_1, I_2 as:

$$D_{\mathrm{SIM}}(I_1, I_2) = S(I_1) + S(I_2) - S(I_{12}) \, , (1)$$

where $S(\cdot)$ denotes the bit size of a compressed image. I_{12} is the 'joint' image obtained as juxtaposition of pixel arrays I_1 and I_2". In order to simplify interpretation, we have taken the logarithm of D_{SIM} and added a normalization factor, so that the maximal range of D_{SIM} is 0%-100% for the current database of images. We accomplish this by comparing the newest image to itself and setting the value obtained as the 100% similarity value.

3. Field Tests

Due to its proximity to three of the authors (McGuire, Smosna and Bruner) at the time of the survey, we chose a geological field site near the northern end of the Morgantown Mall in Morgantown, West

Virginia, USA. This mall is the former site of a coal mine, and there are several exposed geological cuts, including one of a coal bed.

Fifty-five images were acquired at the field site, and were processed offline. For those images which were novel, the computer either gave it a low D_{SIM} score (<40%) or it matched it with a higher score with an image which even the human analyst would say is similar. See Fig.1 for examples of the novel images and their best matches in the database. Fig. 1B shows the low D_{SIM} score for the novel yellow sporing bodies of the lichens with the best-match platy-texture with red clast. And Fig. 1C shows the higher D_{SIM} score for the novel coal-bed with the best-match yellow sporing bodies of the lichens. In Fig. 1C, the score is likely higher because the substrate rock for the yellow lichen is black, much like a large part of the coal bed, and because the coal bed has some pale yellow coloring due to sulfur content.

A)


B)

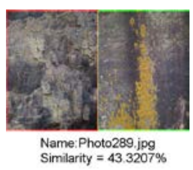

C)


Figure 1: A) Astrobiology Phone-cam studying lichens. B) Novel Yellow sporing-bodies of Lichens and best-matching prior image. C) Novel Coal Bed and best-matching prior image.

6. Conclusions and Future

With a similarity threshold of 40%, the computer correctly classified 64% of the novel images as being novel and 91% of the similar images as being similar to prior images (see [9]). We plan to speed-up the algorithm so that real-time processing of the images is not so time-consuming.

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