PATTERN EXTRACTION FROM CAVE IMAGES. I. Sandjaja, K. E. Schubert, E. Gomez, and P. J. Boston, 1 Department of Electrical and Computer Engineering, Baylor University, Waco, TX 76798; keith_schuert@baylor.edu 2School of Computer Science and Engineering, California State University, San Bernardino, San Bernardino, CA 92407; 3NASA Ames Research Center Moffett Field, CA 94035.

Search for Patterns of Life: Biosignatures are fundamental to the search for life, but what comprises a biosignature and how do we tell what biosignatures are valid on planets that are not dominated by life, like earth? When a biosignature is selected to be used, how can we guarantee the quality of the measured value?

The first question is a hotly debated issue [1], though a number of potential candidates can be proposed. A potentially universal biosignature common to caves [2] is the characteristic patterned growth behavior of resource constrained life, such as extremophiles, referred to as “biovermiculations” or “bioverms” for short. Bioverms are common in many caves and are also interesting, as all that is needed is a good photograph to identify them. Histogram rule extraction [6], can then be used to attempt to distinguish patterns generated by biology from those generated abiotically.

The second question is more straightforward, but can still provide some unique challenges in cave environments. For example, in caves, light sources are extremely limited and often have a very narrow frequency bandwidth, making glare extremely hard to remove. The glare issue (Fig 1) is exacerbated by the often-moist surface of biofilms in caves, and the source of light is typically located right next to the sensor. A first challenge is thus to obtain clean images that can be used for analysis, which is the subject of this work.

Specular Removal: A number of specular glare removal tools have been proposed [3], but many rely on a broad range of frequencies to distinguish reflections from just light colored areas. Since this not available in most cave environments, multiple image methods [4,5] were used to automatically remove specular glare by taking multiple pictures with variable light positions (Fig 2).

Figure 1: Photo of biovermiculations from Cueva de Villa Luz.

Figure 2: Multiple images of the same feature in Cueva de Villa Luz, with varying lighting used to remove glare.

We observed it took at least 10 images to get a good quality, glare free result (fig 3). This varied slightly, each new light source position had to not produce glare in at least 3 images to provide adequate removal. Flat images would likely be done in 5 images, however, curved rock surfaces that provided many opportunities for reflection required about twice as much on average.

Figure 3: Bioverm pattern with glare removed.
Once glare is removed the image is converted into a three-color image: (red) not in a patterned region, (black) bioverm life, (white) bioverm no-life. The image must be filtered to smooth any noise in the image. A bilateral filter from the OpenCV library is used for this purpose. Image segmentation is augmented by edge detection in regions that are particularly flat to create local groups of pixels. Each pixel in a group is analyzed by examining the statistical variation of other pixels in its local region to determine if it is predominantly a two-colored region or not. Dynamic local thresholding then establishes which color group the pixel belongs to. Resulting images are then ready to have their patterns analyzed (fig 4).

Figure 4: Biopattern converted to a three-color image.

Conclusions: Biopatterns are a potentially universal biosignature, but to utilize them images must be able to be automatically processed into a form that can be analyzed for the patterning. The removal of glare from cave images is a challenging part of this pre-processing, since many methods fail due to the limited light sources and narrow frequency range of the illuminating light. By utilizing multiple images and iterative glare removal, a successful image can be generated. Images can then be processed to separate patterned regions from non-patterned regions and the two colors of the pattern. A method that accomplishes this is presented.


