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Testing the Cyborg Astrobiologist at the Mars Desert Research Station (MDRS), Utah

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Introduction:

Future planetary rover missions will travel long distances from their safe landing site to the exploration targets. Adding more autonomy to the rover´s image interpretation system would therefore be an advantageous step in preventing the rover from passing by interesting outcrops without due examination.

Herein, we present a computer vision algorithm, based in part on an artificial neural network capable of identifying novel, previously unseen, areas of geological or astrobiological scenery. Other recent processing and software enhancements to our system include: (i) full-color image segmentation and (ii) Bluetooth communication with a local server. The system is easy to operate in the field and was intensely tested during the EuroGeoMars campaign in the Utah desert at the Mars Desert Research Station (MDRS).

Previous work:

In previous work, we have developed a wearable-computer platform for testing computer-vision exploration algorithms in real-time at geological or astrobiological field sites [1][2]. We concentrated in particular on the concept (and the algorithm) of uncommon mapping, in order to identify contrasting areas in an image of a planetary surface. Recently, we have made this platform more ergonomic and easy to use by porting the system into a phone-cam platform connected to a remote server [3].

In many remote areas investigated here on the Earth by geologists, there is no mobile-phone network coverage, therefore, the Cyborg Astrobiologist phone-cam platform, which utilized the mobile-phone network, would not function. With an opportunity to test the Cyborg Astrobiologist phone-cam at the Mars Desert Research Station (which did not have mobile-phone network coverage) near Hanksville in Utah, we would have needed to use the full wearable computer system instead of the more ergonomic phone-cam system. Herein, we test this phone-cam system (i) at the MDRS and (ii) much more extensively/economically by adding a Bluetooth communication mode. Also, herein, we test a second computer-vision exploration algorithm in the field at the MDRS, which uses a Hopfield neural network [4] in order to remember aspects of previous images and to perform novelty detection. These tests of the novelty detection system by the Cyborg Astrobiologist at the MDRS are much more extensive than previous unpublished tests at

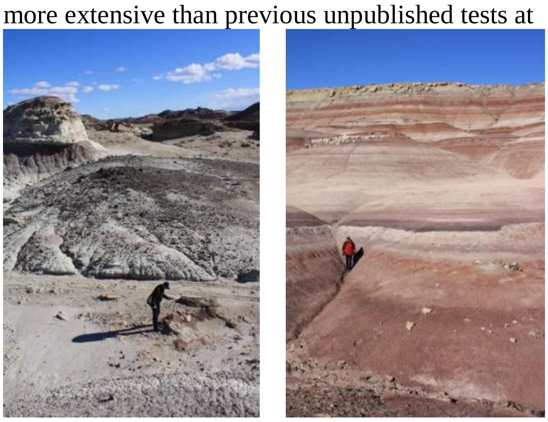

Figure 1: Two examples of the geological scenery surrounding the Mars Desert Research Station. *Left:* Large fan-shaped structure in the Salt-Wash Member with reddish blocks in the foreground. *Right:* Typical layered strata in the Morrison Formation, a perfect playground for full color image segmentation

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Rivas Vaciamadrid in Spain in 2005, and serve to validate the novelty-detection technique further.

Techniques:

The uncommon mapping technique [1][2] searches for uncommon areas of each color layer (Hue, Saturation or Intensity) of an image, based upon grayscale image segmentation of each of these layers and then weighting the image segments by the number of pixels in each segment.

The novelty detection technique (not yet published for this application, but the Hopfield neural network (HNN) technique is from Bogacz [4]) takes the mean colors (<Hue>, <Saturation>, and <Intensity>) from the image segmentation of each image sequentially in real time, and then feeds each of these three numbers as 6 binary bits (3×6=18 bits) into an HNN. If the HNN has observed another 18-bit vector similar to the example, then that pattern is regarded as familiar and it is discarded. On the other hand, if the HNN has not observed the vector before, then the vector is stored in the HNN. The corresponding novel image segment is marked in the result image, which is sent back to the mobile phone. With this technique, novel regions of each image are identified by remembering the colors of regions of previous images.

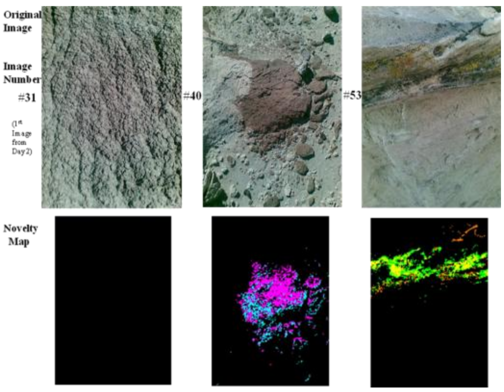

Figure 2: Examples of successful novelty detection during the field tests: The system recognized the colors in image #31 as known and sends back a black image. Image #40 shows a mudstone outcrop, a color unknown to the system. The returned image indicates the novelty in cyan and magenta. Image #53 shows yellow to orange lichen, growing on sandstone. The system clearly indentifies the lichen as novel, whereas the surrounding rock is known and therefore colored black in the result image.

Results:

The hardware and software performed very well and the novelty detection system robustly separated images of rock or biological units it had already observed before from images of surface units which it had not yet observed. This shows that color information can be used successfully to recognize familiar surface units, even with rather simple camera systems like a mobile-phone camera.

Future work:

Following this promising test, we plan to improve the system in the following ways:

1) Texture detection and recognition: We plan to implement a texture recognition algorithm to be able to discriminate between rocks with similar colors. This algorithm will both recognize textures it has seen in previous images and detect predefined structures characteristic of certain rock types, such as layering.
2) Expand wavelength domain: The existing system is capable of treating multispectral images with further channels in the near infrared without major adaptations.
3) Processing speed: The system will benefit from an increase in processing and transmission speed from the current 120 sec/picture to 30 sec/picture.
4) Ergonomic improvements: The screen of the phone camera turned out to be hard to read with the bright daylight experienced during the test campaign.

References:

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