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TOWARD AN IMAGE COMPRESSION ALGORITHM FOR THE HIGH-RESOLUTION ELECTRONIC STILL CAMERA

Final Report

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Abstract

Taking pictures with a camera that uses a digital recording medium instead of film has the advantage of recording and transmitting images without the use of a darkroom or a courier. However, high-resolution images contain an enormous amount of information and strain data-storage systems. Image compression will allow multiple images to be stored in the High-Resolution Electronic Still Camera. The camera is under development at Johnson Space Center. Fidelity of the reproduced image and compression speed are of tantamount importance. Lossless compression algorithms are fast and faithfully reproduce the image, but their compression ratios will be unacceptably low due to noise in the front end of the camera. Future efforts will include exploring methods that will reduce the noise in the image and increase the compression ratio.

Background

A conventional camera uses film to store images. Light enters the lens and strikes the film. A digital camera uses a digital recording medium such as memory chips to store images. It converts the light entering its lens into a voltage corresponding to the intensity of the light. The analog voltage is then converted into a number and the numbers are stored in the camera's memory cartridge. A digital camera has the advantage of transmitting images to a remote location without the necessity of physically sending film. Compared to conventional video, a digital camera has superior image quality and provides flexibility and confidence in image transmission. Because the image is represented by a file of numbers, it can be sent at any transmission rate. Further, error detection and correction methods used to transmit digital files virtually guarantee that the images arrive distortion-free.

Developing such a camera is the goal of the Electronic Still Camera project, which is under the direction of Don Yeates at the Johnson Space Center[1]. It will supplement conventional 35mm cameras on the Space Station. Current plans of the Space Station call for long intervals between shuttle visits. Using a digital camera to transmit images to earth will relieve ground support from waiting 60 to 90 days for high quality pictures.

The digital camera will be contained in a housing similar to a conventional 35mm camera body, and crew members on the Space Station will use it in the same way they would use a conventional 35mm camera. After taking pictures, the crew member will remove the camera's memory cartridge on which the pictures are recorded. To preview the pictures, the crew member will use the Feedback/Downlink Unit. (See figure figure 1.) The same unit will transmit images to earth. The ground station will receive the images,

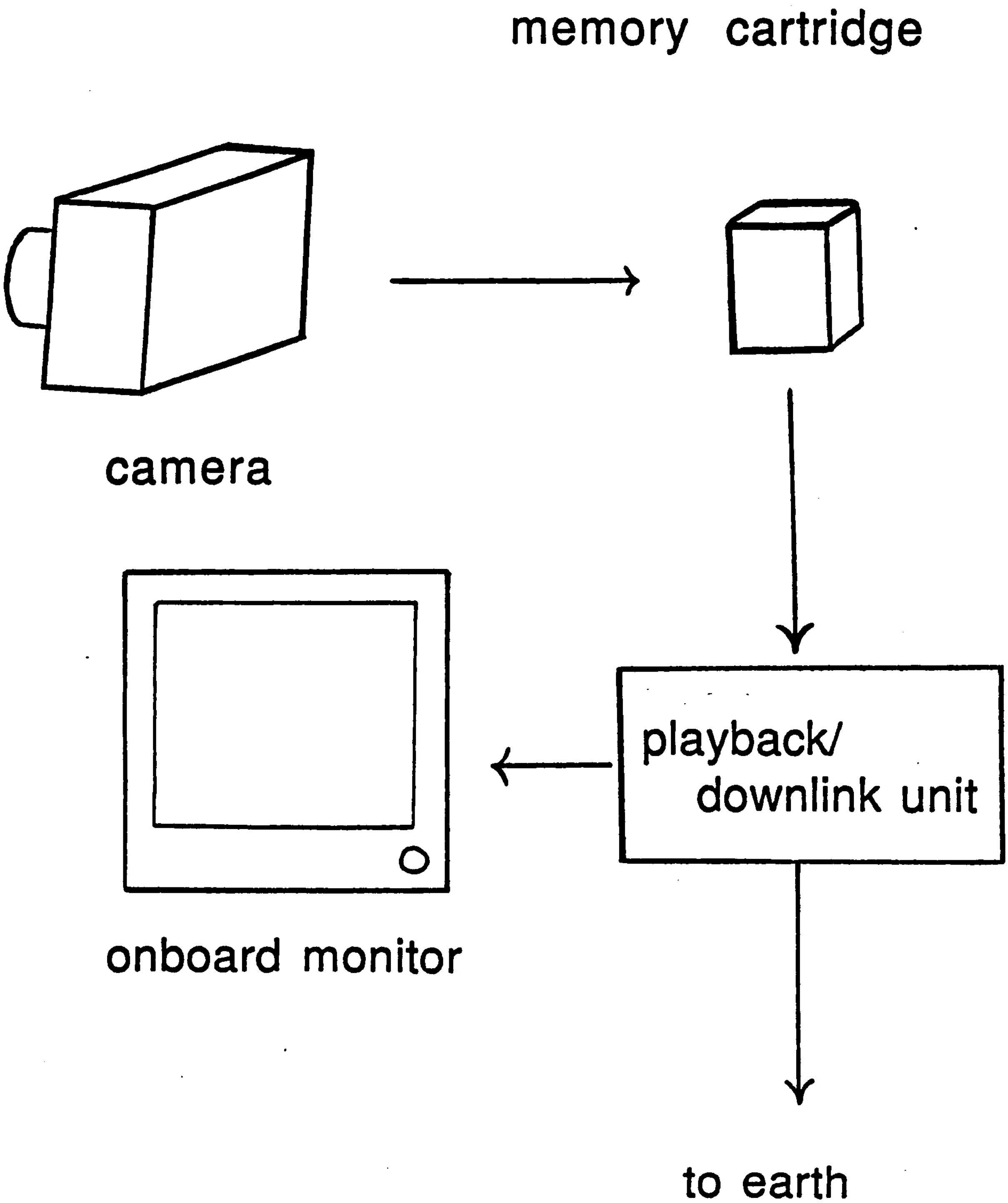

Figure 1.- Electronic Still Camera
Block Diagram

and will have the options of displaying them on a monitor, printing them on film and archiving them for future use.

The amount of memory the camera will need to store an image is tremendous. In order to approach 35mm film quality, the camera's resolution will be 2048x2048 pixels. Proper color response dictates that a pixel have eight bits of information for each of its red, green and blue components for a total of 24 bits. Recording a single image requires 12 Mbytes of memory.

The dimension of the camera body restricts its memory capacity to one image. Even with the one Mbit chips now commercially available, 12 Mbytes of memory requires 108 chips and occupies a volume approximately 4 inches by 4 inches by 6 inches. There is no room inside the camera for additional memory.

A memory cartridge with a one-picture capacity is unsatisfactory. A crew member inside the Space Station would find it irritating to change memory cartridges after every camera shot. For an extravehicular activity, crew members would find this problem extremely troublesome. A solution to the memory capacity problem is to use a compression algorithm in order to store multiple images on the memory cartridge.

Compression is the process of representing an image file in fewer bits[2]. The original image file is compressed into a smaller file. (See figure 2.) Reconstructing the image from the compressed file yields a viewable picture. Important properties of compression algorithms are fidelity, compression ratio and speed. Fidelity is the degree to which the reconstructed image matches the original image. The compression ratio is a ratio of original file size to compressed file size. Speed is either expressed as a proportion relative to a function of the image resolution or in the number of seconds required to compress a file of specified dimension[3,4].

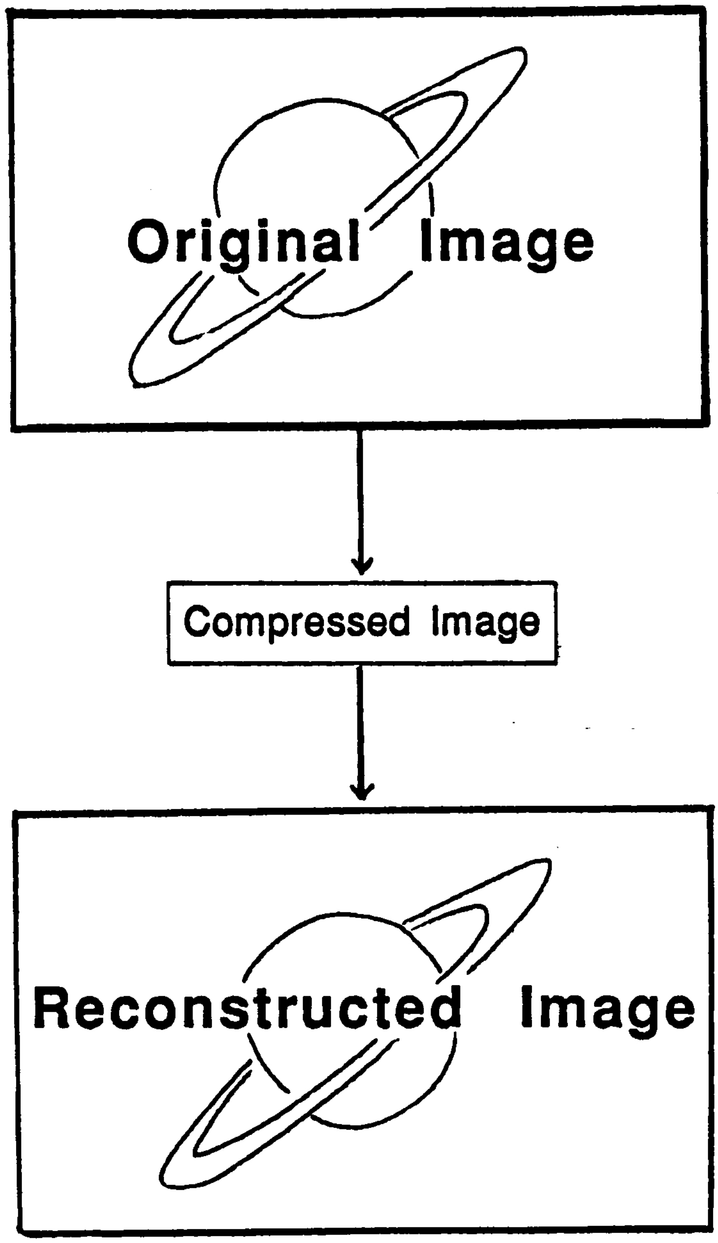

Figure 2.- The Compression Process

Goals

The compression algorithm for the Electronic Still Camera must have high fidelity, a constant compression ratio and high speed. The images from the Space Station must be good enough to be used for public affairs. A constant compression ratio is necessary because the crew member must know in advance how many shots can be stored on a single memory cartridge. The speed is important because the logic in the camera must compress over four million pixels between shots. Waiting more than five seconds between shots would be annoying. For this application, fidelity and speed are more important than a high compression ratio. The compression algorithm will most likely be implemented as a specialized processor in the camera.

Method

I am using all three properties to evaluate the merit of compression algorithms. Objective and subjective measure are necessary to evaluate fidelity. Such objective criteria as root-mean-squared error and signal-to-noise ratio are helpful, but they do not adequately measure fidelity because two pictures with the same rms error may appear to have drastically different visual qualities[5]. A useful subjective method is the pair-comparison method, where observers are shown two images at a time and are asked to give a preference. For measuring speed, I chose to record the number of arithmetic operations per pixel, and the number of separate passes through the image file. The first gives a machine-independent measure that is more precise than O-notation and the second gives a good indication of the amount of parallelism in the algorithm.

The algorithm will be used to compress pictures similar in composition to those taken on the Space Shuttle. I chose nine NASA photographs as being "typical" and used a Howtek scanner to convert them into computer files. The pictures include shots of payloads, the orbiter, people, equipment and experiments. In addition, I scanned a piece of photoblack paper and a piece of white paper to serve as baseline images. The eleven files serve as test data for the algorithms.

Results

Compression algorithms are called either "lossless" (information-preserving) or "lossy" (entropy-reducing)[6]. Lossless algorithms allow exact duplication of the original image from the compressed form. Lossy algorithms lose some information and an exact duplicate cannot be reconstructed.

I chose to concentrate on the lossless algorithms for the initial study because fidelity is important and because lossless algorithms are generally faster than lossy algorithms. However, the results were disappointing. Figure three is a graph giving the maximum ratios for compression pixel values in the images. For lossless algorithms, there is an upper limit on the compression ratio based on entropy[7]. For a second attack, I compressed the relative differences between adjacent pixels instead of the pixel values. The results were better, but not significantly better. (See figure 4.)

It was troublesome that the image of uniform photoblack did not compress very well. When the image's pixels were magnified on a monitor, I found a lot of noise. For lossless algorithms, high compression ratios occur when long strings of pixels have the same value. Noise corrupts any long string into many shorter strings of slightly differing values. The Howtek scanner used to convert the photographs into computer files uses a charge-coupled device to convert the light into a voltage. The camera will use the same technology, so noise is a problem that must be addressed.

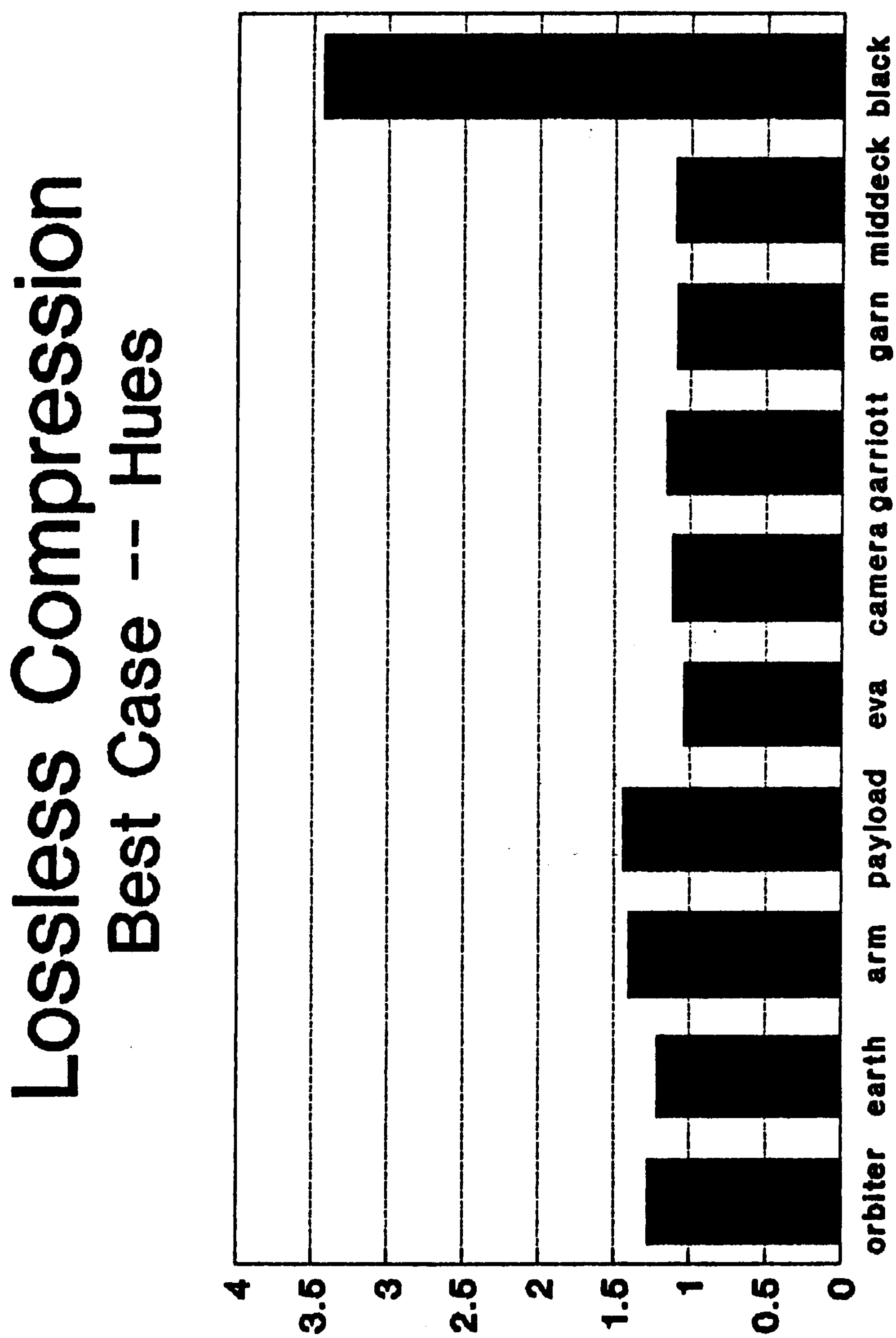

Figure 3.- Compression Ratios for Hues, Best Case
X-axis: picture
Y-axis: compression ratio

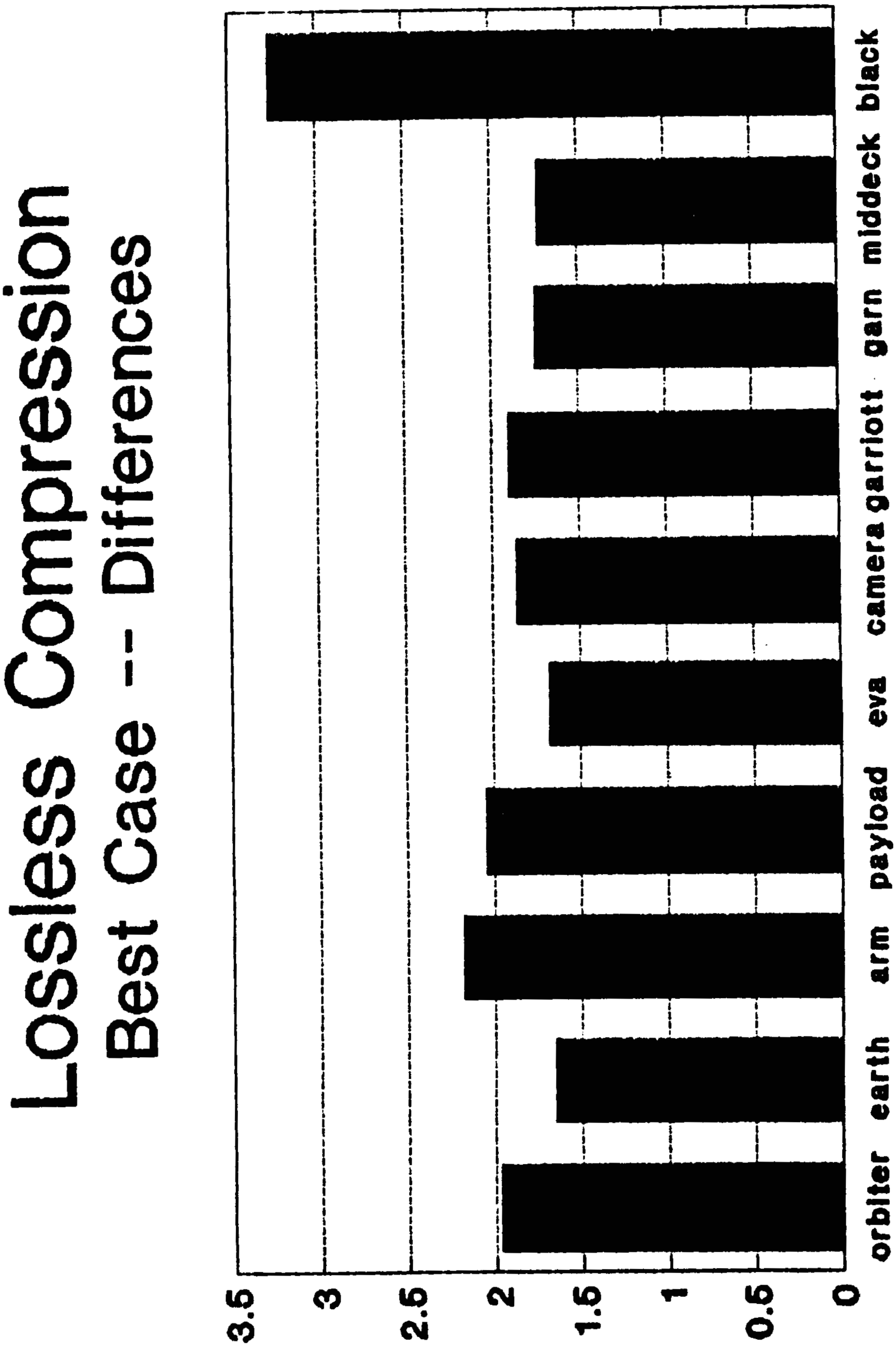

Figure 4.- Compression Ratios for Differences, Best Case
X-axis: pictures
Y-axis: compression ratio

Future Work

One approach to increasing the compression ratio is to "clean up" the image before compressing it. One way to clean up the image is to try calibrating the camera's charge-coupled devices. Another method is to use statistical techniques to compare a pixel with its neighbors and adjust its value if it meets certain requirements.

The act of cleaning up an image loses information. Therefore, I want to explore some lossy algorithms, especially the transform methods, because they reduce noise and compress the image as one process.

References

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