NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Technical Report No. 32-877

Digital Video-Data Handling

Robert Nathan

Karl W Linnes

K. W. Linnes, Manager
Space Instrument Systems Section

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

January 5, 1966

FIGURES (Cont'd)

ABSTRACT

A technique has been developed which makes it possible to perform accurate, detailed operations and analyses upon digitized pictorial data. Television pictures transmitted from the *Ranger* and *Mariner* spacecraft have been significantly improved in clarity by correcting those system distortions which affect photometric, geometric, and frequency fidelity. Various classes of structured noise have also been detected and removed digitally by means of newly devised two-dimensional filters. Although mathematically the filters are easier to describe in the frequency domain, they are more effectively applied as a convolution operation on the original digitized photographs. The cleaned-up, enhanced pictures are then used by the computer for further interpretive and statistical analyses.

I. OBJECTIVES

It is the function of the video-data-handling system to reproduce the original scene of transmitted television pictures as faithfully as possible in terms of resolution, geometry, photometry, and perhaps color. The difficulty lies in overcoming limitations imposed by the noise, distortions, and information bandwidth of the system. These corrections are performed by computer after the pictures have been digitized. The pictures in cleaned-up form can be enhanced in contrast and used for detailed visual photo-interpretation.

Once the pictures have been corrected, information can be extracted from them. Since the pictures are now in digital form, some of the analyses can be performed by the computer. In the case of the Moon (where surface photometric properties can be considered reasonably homogeneous), the slope and relative elevation can be calculated from the relation of the surface to the brightness as a function of Sun, observation point, and surface location.

II. PROBLEMS

There are several significant differences between taking a picture with a film camera and a television vidicon camera. Assuming that the lenses are not the limiting factor, the differences appear in the manner in which the image projected onto the receiving surface is sensed. Spectral and dynamic sensitivity and linearity differ. Grain size limits film resolution, and scanning-beam spot size limits vidicon resolution. Geometric fidelity is worse in the vidicon scanning camera than in film. Noise in transmission is unique to electrically encoded pictures.

There are several other problems unique to film, but emphasis here is upon those weaknesses of television systems which add to the photo-interpretive and map-making difficulties.

Several years ago, when the *Ranger* effort was first proposed, no known methods existed of performing by analog means alone all the desired operations of clean-up, calibration correction, and information extraction on video data. The most practicable approach to the solution of these problems available at that time was to digitize the data and perform these operations on a computer. The next problem was the conversion of analog video data to and from digital form. A determined effort was undertaken by the video-processing group to digitize the data directly from photographs produced from an analog signal. Although it was possible to recover everything that was on the film, there was already too great a system loss from the film recording itself. However, if the signals were recorded on magnetic tape at the time of transmission, the analog video could be digitized directly from the tape, and ground recovery losses became minimal.

After the analog tapes were converted to digital tapes, the remaining major problem was reduced to creating the computer programs which would perform the corrections, enhancements, and analyses.

The last step in the sequence was the conversion of the digital tapes to an accurate visual presentation (Ref. 1).

III. COMPUTER MANIPULATIONS

A. Corrections

The first of the computer operations is the reconstitution of the picture array from the digitized data. This process amounts to an interleaving or a sorting by computer. The picture is then packed, six digital samples of six bits each (64 gray levels), into one 36-bit word of the IBM 7094 computer. During any computer operation, the picture is brought into core memory a few video scan lines at a time from tape (or disk) and unpacked to one video brightness point per computer word. The picture is now an array in computer memory and is available for correction.

The following series of corrections evolved as a result of working with the pictures themselves. (Other photo or video systems may or may not require these operations.)

1. Geometric correction – physical straightening of photo image.

2. Photometric correction — correction of nonuniform brightness response of vidicon.

3. Random-noise removal — superposition and comparison (anticipated but not necessary for *Ranger*).

4. System-noise (periodic) removal — elimination of spurious visible frequencies superimposed on image.

5. Scan-line-noise removal — correction of nonuniform response of camera with respect to successive scan lines.

6. Sine-wave correction — compensation for attenuation of high-frequency components.

1. Geometric

The first calibration to be applied must be geometric in order to ensure the proper registration of other calibrations. This correction is determined from preflight grid measurements as well as postflight reseau measurements.

The geometric correction is measured from the distorted image of the calibration grid, which has about ten to fifteen rows per picture height and width. The corresponding video elements between these intersections are shifted by a linear interpolation to the corresponding original position. If it appears by visual inspection that the change between grid points warrants more than a single interpolation because of severe nonlinearity, then more correction points may be chosen between rows. While these shifts could be determined prior to flight, in practice, the measurements are made after success is assured. In fact, calibration and reseau-shift information are combined into one geometric correction (Fig. 1). This program is also used to reproject the picture to the normal direction (Fig. 2).

2. Photometric

If the camera characteristics as measured on the ground could withstand launch and the interplanetary voyage, their measurements could be applied to the data later. However, such an assumption cannot realistically be made. The only trustworthy method of calibration is that performed against a standard immediately before, during, and after the experimental measurements have been made. For *Ranger*, the "after" was too late; and there was no inflight calibration incorporated into the mission design for "during." (Inflight calibration was also not performed for *Mariner*.) Therefore, the preflight measurements alone had to be depended upon.

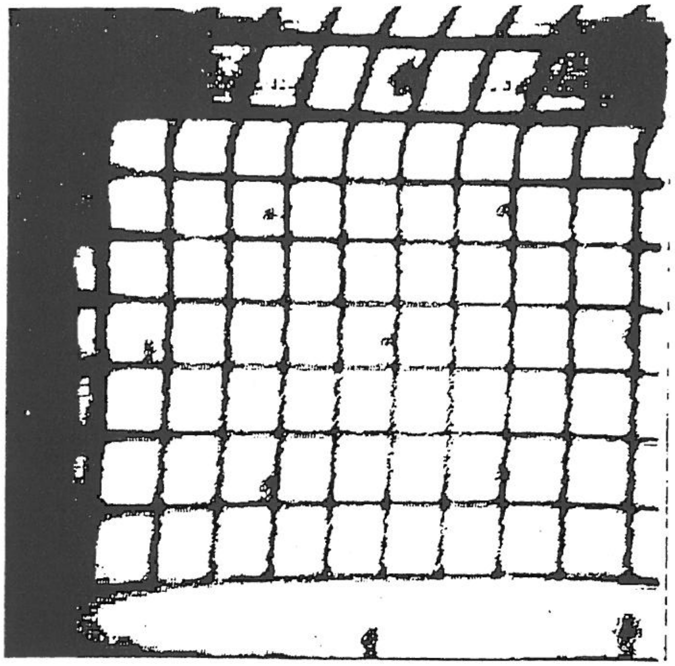

Fig. 1a. Image of a uniform grid as seen by an early *Ranger* camera

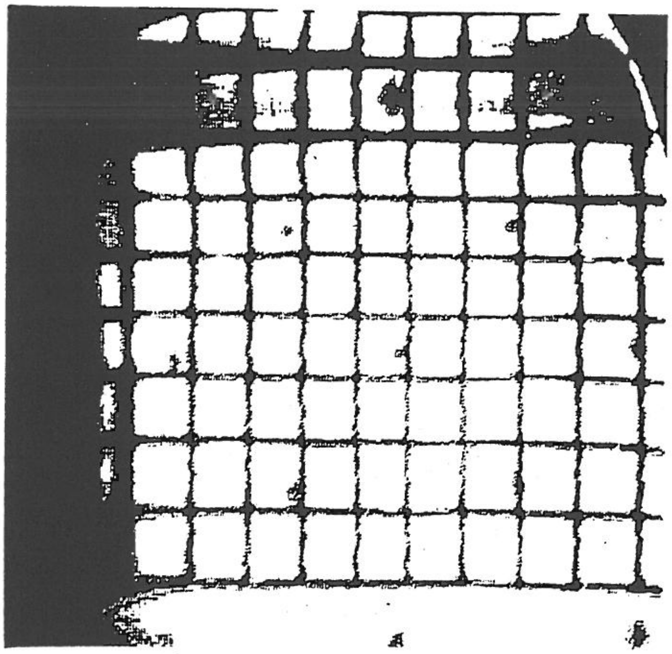

Fig. 1b. Corrected grid after moving intersections back to a square array (Note that some distortion remains in the third row as a result of extreme nonlinear distortion. Reference points could have been selected in a finer mesh to create better results.)

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