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Synthetic Stereo and LANDSAT Pictures

By introducing parallax into one of two identical images, the two images may be viewed stereoscopically.

Abstract: *Digital image processing techniques can be used to introduce stereoscopic parallax into a composite data set consisting of digital terrain elevation data and corresponding digital television images. The technique was developed with part of a LANDSAT scene and digital elevation data provided by the Defense Mapping Agency. The geometry of the LANDSAT image was digitally modified to coincide with that of the elevation data set. Parallax was introduced as a simple linear function of terrain height at each picture element, to produce a stereoscopic mate to an image which has essentially no parallax.*

Introduction

A wide variety of digital enhancements has been applied to LANDSAT images to increase their interpretability. These include manipulation of color bands by contrast stretching and ratioing, and cosmetic improvements such as haze and noise removal (Rowan and others, 1974; Chavez, 1975; Albert and Chavez, 1975). Stereoscopy is also a powerful photointerpretation tool, but has had only limited use with LANDSAT pictures because their base-height ratios result in a weak stereoscopic effect and over only limited areas.

A strong stereoscopic effect can be introduced into LANDSAT pictures by displacing image details by varying amounts as a function of their known relative elevations. This effect can be introduced in identical amounts into each band, so that stereoscopic color composites can be made. Although the effect is useful in interpreting any color scene, its utility in color-ratioed images is particularly important, because the ratioing technique removes shading due to relief. It is only by utilizing stereopsis that the three-dimensional context of the color ratios can be examined.

The Technique

The introduction of stereoscopic parallax into a monoscopic image requires

(1) A digital array of brightness values (the image), and
(2) A digital array of terrain elevations.

Data sets utilized to date are LANDSAT images with 128 brightness levels in each of four spectral bands of picture elements (the elements measure 59 by 79 metres on the ground) and terrain data sets produced by the Defense Mapping Agency with elevation values in one-foot increments and 200-foot spacing, on the Universal Transverse Mercator projection. The image data sets are contained in LANDSAT scenes; the terrain data in one-by-two-degree quadrangles.

Correlation of one data set with another requires the identification of corresponding points on each set. The method used for identification required construction of an

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image of the terrain data set so that features could be identified visually. The principle involved in making such images may have been conceived originally by Wiechel (1878). It was developed by Yoeli (1967) and Brassel (1974). Efficient and inexpensive techniques for making shaded relief images from digital terrain elevation data were developed by the authors (1975) and used in the present effort. Figure 1 is a reproduction of a part of LANDSAT 1 image 1407-17190, covering part of the Montrose quadrangle, Colorado (1:250,000 scale topographic series). Figure 2 is a computer-generated shaded relief image of the same area, made with digital topographic elevation data from the Montrose quadrangle. Both images have every 50th line of data and every 50th sample within each line replaced with black or white picture elements. Control points were identified on each image and their locations in terms of lines and samples measured from the resulting grids. A transformation was then performed by standard image processing techniques on the images so that they would coincide geometrically with each other.

Simple manipulation of the digitized altitude data makes it possible to form stereoscopic images. This requires only the equation

$$\Delta p = \Delta h \, (K)$$

where Δp is the parallactic displacement of an object on an image whose height above a base level is Δh. K is a constant that will determine the strength of the stereoscopic illusion. The selection of the constant is arbitrary. Large values of K will result in exaggerated stereoscopic effect, whereas small ones will produce a weak effect. Plate 1 is a stereogram of the image of Figure 1. A value of K was selected for Figure 3 such that no value of Δp was greater than 2 mm.

An acceptable stereoscopic pair can be made by using an original, undistorted image and a second image into which parallax has been introduced.

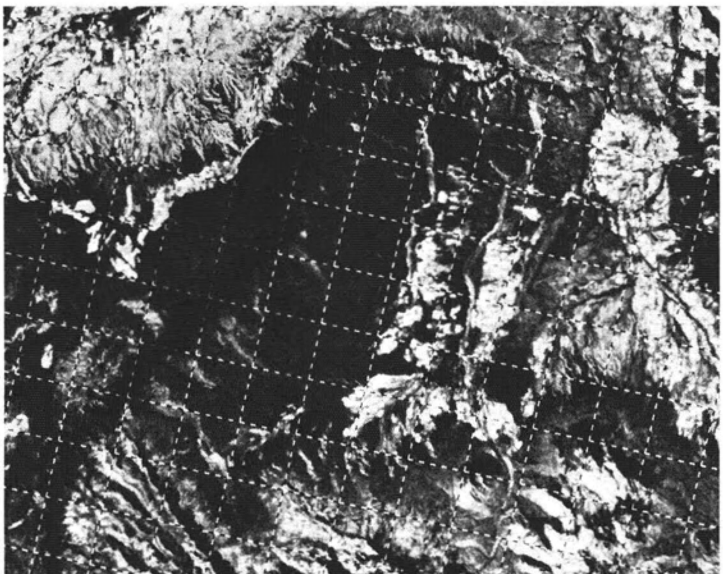

FIG. 1. Part of LANDSAT 1 image 1407-17190, covering part of the Montrose quadrangle, Colorado (1:250,000 scale topographic series). A grid has been introduced by replacing every 50th line and every 50th sample with a black or white picture element to facilitate control point coordinate measurement.

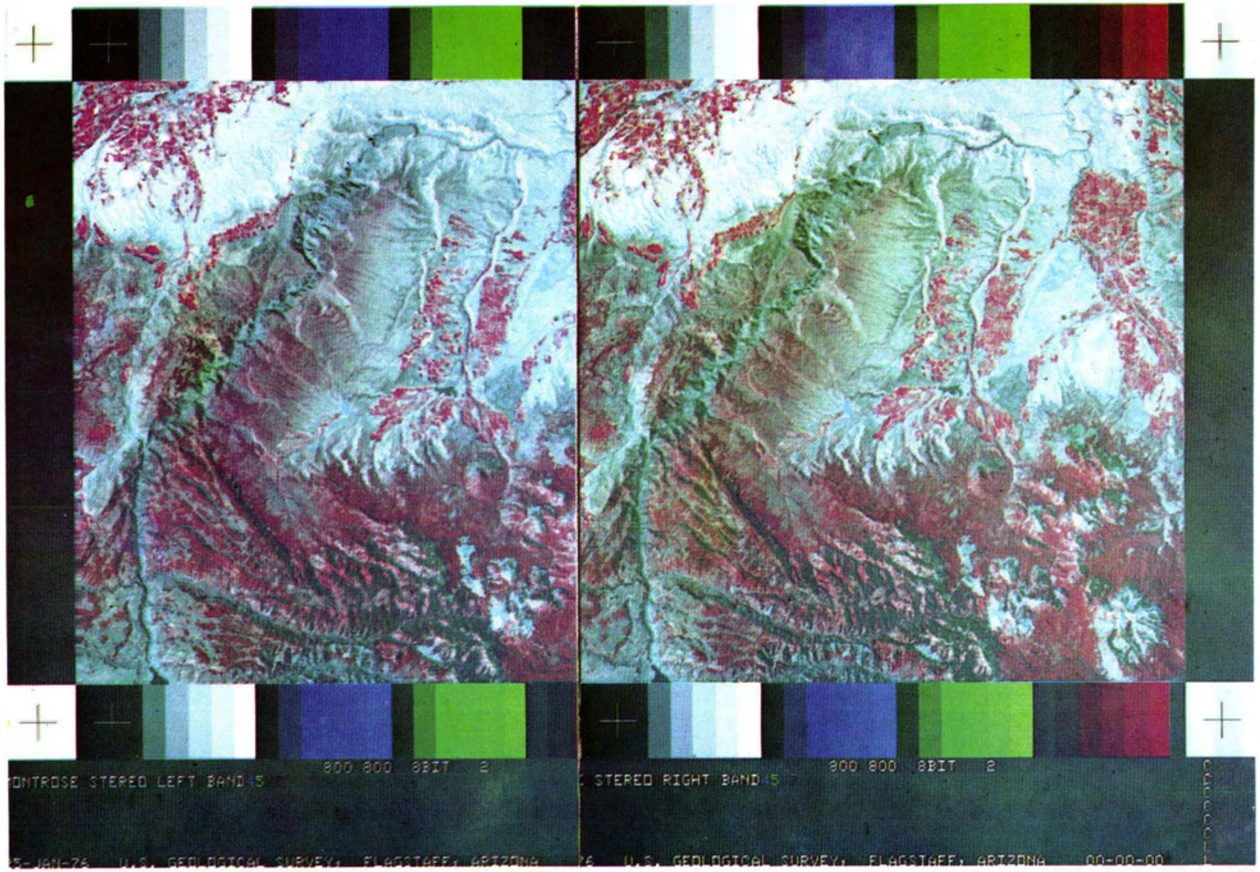

PLATE 1. False-color stereogram made from a single LANDSAT image and a digital terrain data set provided by the Defense Mapping Agency.

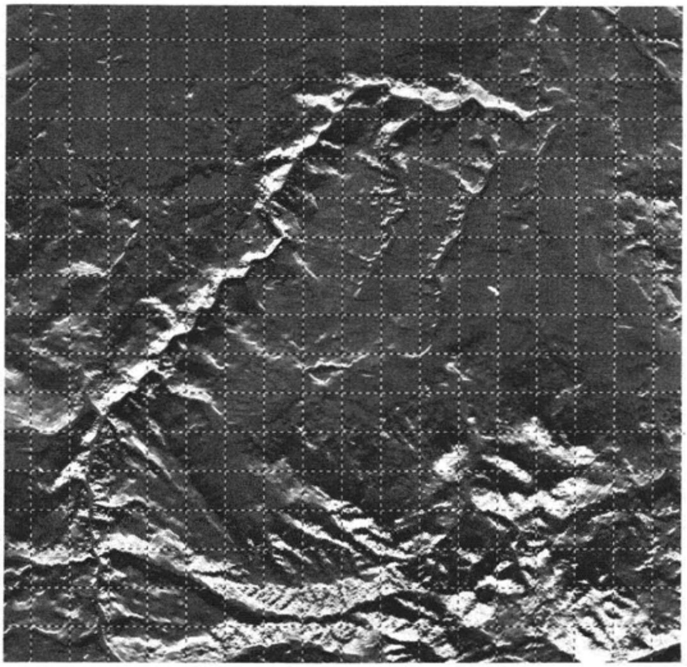

FIG. 2. Computer-generated shaded-relief image of part of the Montrose quadrangle, Colorado (1:250,000 scale topographic series). A counting grid similar to that in Figure 1 has been introduced.

REMAINING PROBLEMS AND CONSIDERATION

Various problems remain to be solved in order to simplify the method and make it acceptable for routine production of stereoscopic LANDSAT images. One problem lies in the interpolations required in reformatting digitized contour lines into raster-type arrays showing topographic heights in terms of lines and samples (i.e., rows and columns). The simplest routines make linear interpolations between contour lines along parallel profiles, whereas the correct (but extremely slow and complex) method would interpolate values in the direction of maximum slope. As a result of the simplified interpolation method, peculiar step-like artifacts appear in the shaded relief image. In general, the complexity of detail in a LANDSAT image tends to overwhelm these artifacts and make them difficult to detect.

Until the latitude and longitude of each picture element can be defined precisely by automatic methods, the use of human interpreters in the selection of control points is unavoidable. Unless this selection is done carefully and accurately, disconcerting effects, such as streams climbing out of their banks and crossing ridges, will compromise the usefulness of LANDSAT stereograms.

The problems are not so large as to preclude the generation of synthetic stereograms for photointerpretation with LANDSAT images. If demand for images of this type continues to increase, more sophisticated and efficient methods can be developed that will increase the utility and decrease the cost of the stereograms.

ACKNOWLEDGMENTS

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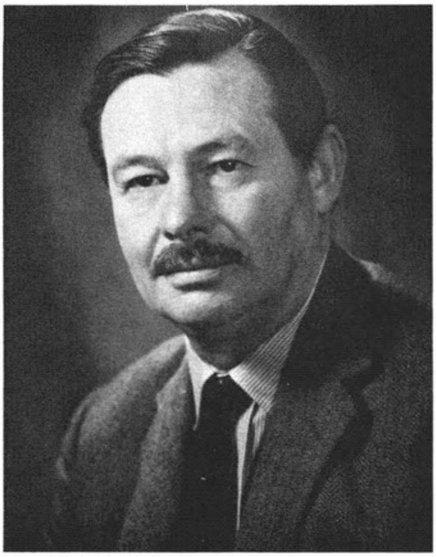
Two Giants of Photogrammetry

The June 1976 issue of *Photogrammetric Engineering and Remote Sensing* contained obituaries of two renowned photogrammetrists who died within a fortnight of each other. Photographs of Professor E. H. Thompson, who was striken with a fatal heart attack on April 9, and Russell K. Bean, who was similarly striken on April 20, were not available in time for the June issue. We publish these photographs now to do honor to the memory of two internationally eminent members of our calling, one in the United Kingdom and one in the United States, whose contributions to the art and science of photogrammetry were indeed extraordinary. These were giants of our profession—Edgar Hynes Thompson and Russell Kerr Bean.

—*Morris M. Thompson*



Prof. E. H. Thompson 1910-1976

Russell K. Bean 1900-1976