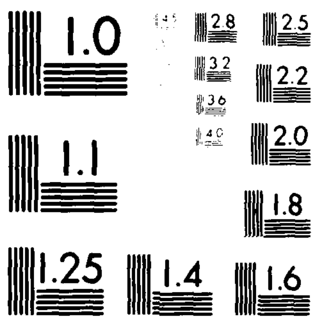

MICROCOPY RESOLUTION TEST CHART

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Defense Mapping Agency produces and maintains cartographic digital data bases in support of military flight simulation and aeronautical operations. These data bases include terrain elevations over various geographic areas, stored in grids of varying intervals. In order to have effective management of these digital data bases, it is necessary to display them quickly, in a format which permits human comprehension of the information. An Image Manipulation Station (IMS) has been developed for this purpose. It is a color display processor interfaced to a minicomputer, magnetic tape drive

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and disk storage device. The IMS reads digital terrain elevations from magnetic tape, manipulates the data with software and displays various images of the information. The programs generate an image with the general appearance of topographic relief. Shaded relief and anaglyph stereo views can be added to further enhance the image. Color views are also generated for analysis purposes. Because the data base and the displayed image are congruent, an analyst can point to a position in the image and display the corresponding terrain elevation values on a CRT terminal. The IMS satisfies quality control requirements in a timely and inexpensive way. It allows the analyst to view the digital data quickly and positively to ensure that a data tape generated for distribution to field users is complete, free of discontinuities and covers the required geographic area.

INTERACTIVE DIGITAL TERRAIN DATA DISPLAYS

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Defense Mapping Agency Aerospace Center

(@@Figure 1) The Defense Mapping Agency produces and maintains cartographic digital data bases in support of military flight simulation and aeronautical operations. (@@Figure 2) The data bases include terrain elevations over various geographical areas, stored in matrix formats of varying intervals. (@@Figure 3) In DMA Standard Format, the elevation data bases are arranged into one degree by one degree geographic areas. The horizontal spacing of points in an elevation array is three arcseconds in both directions. This is about one hundred meters on the ground. Thus, a data base comprises a matrix of 1201 x 1201 points. The elevation values themselves are 16-bit signed binary numbers, with a resolution of one meter.

(@@Figure 4) In order to examine these data bases quickly and carefully the Image Manipulation Station, or IMS, has been developed. It is a color display system interfaced to a minicomputer, magnetic tape drive and disk storage device. The minicomputer has sixteen thousand 16-bit words of memory; the magnetic tape unit reads and writes dual density tapes at 45 inches per second; and the disk has a ten million byte capacity. The color display system contains its own processor, four thousand words of program memory and additional memory sufficient to store and display two 512 x 512 pixel x 8-bit images. Composite ~~RGB~~ Red-Green-Blue video signals generated in the display system feed a standard color monitor.

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(@@Figure 5) Prior to displaying terrain images, the digital data on tape must be read in and transformed to appropriate display formats. These transformations take place in two steps. In the first step the data tape is read record by record, each signed binary elevation value is converted to a two's-complement number, and various statistical properties of the data are computed. This data is written to the disk as an elevation data file for subsequent access. The minimum and maximum elevations over the entire one-degree square are also determined.

(@@Figure 6) During the second step the actual image data is produced and stored on disk. For every elevation point in the elevation data file, a 16-bit pixel is generated which contains all the information needed to display the terrain image in grey-coded, color-coded, shaded relief, tinted shaded relief or stereo anaglyph form. When one of these images is to be displayed, only the appropriate eight bits are extracted from each 16-bit display-file pixel and transmitted to the display system.

(@@Figure 7) An examination of one of the 16-bit display-file pixels shows that the lowest-order eight bits provide the grey-coded or color-coded terrain image. These eight bits represent a value of 0 to 255 proportional to the real-world elevation as scaled between the minimum and maximum elevations values. (@@Figure 8) The next four bits represent a value of 0 to 15 proportional to the slope of the terrain. The slope is found by convolving the elevation data with a 2 x 2 weighted mask which determines elevation differences in the northwest-southeast direction. Displaying this 4-bit image produces a shaded relief image which is brightened where the terrain slopes toward the northwest and darkened for terrain sloping away from the northwest. (@@Figure 9) The high-order four bits also represent a 16-grey-level shaded relief image. These bits, however, are generated from the normal shaded relief image (strictly speaking the orthographic shaded relief image) by displacing each pixel in the normal image a varying amount depending on the elevation of that pixel. The result is a stereo mate image in which each pixel has a parallax appropriate to its elevation.

(@@Figure 10) The algorithms which operate on the disk-stored elevation data file are invoked during the second step to generate the 16-bit display-file pixels, also stored on disk. For a full one-degree square, these computations take about 2 1/2 minutes. Subsequent display commands read the disk image file in real time as the images are being displayed. The following examples demonstrate the variety of ways which a single image data base can be displayed.

(@@Figure 11) The specific geographic area covered by the example data is shown here copied from a 1:500,000-scale Tactical Pilotage Chart. This one-degree square area is located along the coastline of California northwest of Los Angeles. North is at the top, and the various colorings on this printed chart show elevation relief, which range between sea-level and 1400 meters.

(@@Figure 12) When the digital terrain elevation data for this one-degree square is processed with the IMS, the low-order 8-bits can be displayed as a grey-coded image. As in the chart, north is at the top. Low elevations are shown as light areas and high elevations are shown as dark areas. In order to display the entire one-degree square area, which contains over 1.4 million pixels, on a display monitor containing only

65000 picture elements, every fifth pixel in every fifth column of pixels has been extracted for display. Although only 4% of the available displayable data is utilized to produce this "low resolution" image, that is sufficient to identify the geographic area and to assess qualitatively the salient characteristics of the terrain elevation matrix. To extract 4% of the data and display the image in totality takes about 9 seconds.

The display system provides a mechanism, through lookup tables, of generating colors in the display independently of the image data itself. Having loaded the displayable image, it is possible to modify the color presentation of it in an interactive way. A variety of color mappings (i.e. lookup tables) are implemented to provide for flexibility in interpreting the information in the image data base. Color mapping algorithms are relatively easy to implement.

(@@Figure 13) For example, instead of examining a 16-grey-level grey-coded image, an analyst can mix [illegible] 16 levels of green to provide 32 levels of discrimination in elevations. In this grey-green image the contouring effects in the terrain begin to be apparent.

(@@Figure 14) As another example, it is possible to display the image with colors similar to the Tactical Pilotage Chart (Figure 11). In this case all sea-level elevations are blue, while higher elevations are given various shades of green, yellow, orange, brown and white. These colors can be used in an absolute way so that the <u>same</u> elevations from square to square have the same colors, or (@@Figure 15) they can be used in a relative way to provide increased discrimination of elevations within a single one-degree square.

(@@Figure 16) The image can also be displayed with completely arbitrary colors. While the image does not necessarily look like the terrain data it was generated from, there are 256 different colors here which provide the greatest discrimination of elevations.

These previous images show some of the ways the terrain data can be examined when the lowest-order 8-bits, representing scaled elevations, are extracted for display. (@@Figure 17) The shaded relief image is produced by extracting the middle eight bits from the 16-bit display-file pixel and using an appropriate lookup table to decode only the upper four bits. Here areas which are neutral grey are horizontal, flat areas in the real world. Terrain which slopes toward the northwest is brightened, and it is darkened where it slopes away. The illumination is in the upper left corner.

The black-and-white shaded relief image decodes only part of the eight bits sent to the display system. The low four bits are part of the scaled elevations which originally produced the grey-or color-coded image. (@@Figure 18) When the full eight bits comprising information about elevations and slope are appropriately decoded, a tinted shaded relief image is produced. The shading in the image is created by changing the intensity of the color used to indicate the elevations. (@@Figure 19) When the highest-order eight bits are extracted from the 16-bit display-file pixel, the normal shaded relief image can be decoded through a 16-red-level lookup table while the stereo mate shaded relief image is decoded through a 16-blue-level lookup table. When the red and blue images are displayed simultaneously, someone using red and blue glasses will perceive a true stereo image of the terrain in shades of grey. Broken line contours appear in the image because integer arithmetic is used in computing the parallactic displacement. (@@Figure 20) Examining the lookup table itself shows how it is possible to display a red and blue image simultaneously. The red image, represented by the low four bits, is decoded by the red rows in the table. Each row contains the same 16 red levels as the first row. The blue image, represented by the high four bits, is decoded by the blue columns in the lookup table. Each column contains the same 16 blue levels as the lefthand column. A stereo image, which comprises eight bits, is then decoded by the appropriate shade of red and blue simultaneously. (@@Figure 21) For computational efficiency, the data are used in the order in which they are stored. Thus, the parallax is calculated in the north-south direction. To see proper stereo in the image, north must be displayed to the right on the monitor. In fact, in the usual operation of the IMS, north is always displayed on the right.

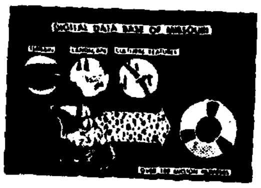
(@@Figure 22) Finally, for reviewing terrain data more carefully and quantitatively, additional interactive capabilities are provided. The capabilities permit examination of the display-file pixels at 100% resolution and the retrieval of numerical elevation values corresponding to selected positions in the image.

(@@Figure 23) A computer-driven cursor can be moved over the entire low-resolution display image to point to an area of interest. The data around that cursor's position can then be displayed at maximum detail. All of the image color mappings previously described are available, including the stereo anaglyph (seen here with north to the right), (@@Figure 24) the grey-coded image, (@@Figure 25) the grey-green image, (@@Figure 26) the map colored image (@@Figure 28) the shaded relief image, and (@@Figure 29) the tinted shaded relief image. (@@Figure 30) The entire operation of the IMS is controlled by a user-friendly menu which allows an analyst examining a terrain elevation data base to ensure that the data is complete, conforms to product specifications and covers the required geographic area.

LIST OF FIGURES

FIGURES FOR BERG: INTERACTIVE DIGITAL TERRAIN DATA DISPLAYS (ACSM/ASP)

Fig 1



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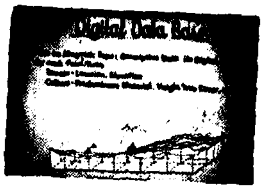

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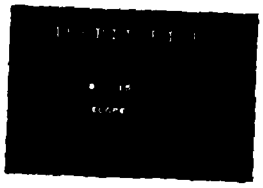

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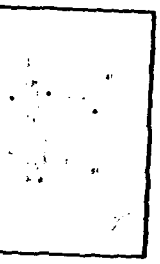

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