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IBM 7350 IMAGE PROCESSING SYSTEM: A TOOL FOR EARTH RESOURCES DATA PROCESSING

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I. ABSTRACT

The IBM 7350 is a new product capable of displaying and processing color image and graphic data. It contains up to 8 megabytes of image storage, special image processing capabilities, and supports a 1024 x 1024 color display. This paper summarizes the IBM 7350 architecture and presents IPS/7350 (Image Processing System/7350), an application level software system using the 7350.

II. 7350 HARDWARE OVERVIEW

A simple schematic of the 7350 is given in Figure 1. The 7350 may include from three to six band buffers, each 1024 by 1024 by 8 bits. To each band buffer may be associated a band buffer look up table (BLUT) which has 256 entries, 16 bits wide. The BLUTs can be used to transform the buffer data as it passes to the Arithmetic Logical Unit (ALU), which can perform arithmetic operations (e.g. adding, ratioing, etc.). The Classification Look up Table (CLUT) is 8K bytes and can be configured either as 4K halfword entries or 8K one byte entries.

The Interpolator can apply an impulse function to the data (e.g. cubic convolution), and the Histogrammer may be enabled to histogram the data in a number of ways.

Data from band buffers may pass through BLUTs, the ALU, interpolator and histogrammer and be put back in another band buffer or be sent directly to the refresh buffer. The refresh buffer is 1024 by 1024 by 12 bits. Another one bit plane (the overlay) plane is associated with the refresh buffer and is used for vector and alphanumeric overlay over the image data.

The mask buffer may be loaded with a mask and enabled to limit operations on an image to a specific area. For example, histograms may be computed only over a polygonal region. The random address processor (RAP) permits various addressing modes of the refresh buffer, permitting two dimensional histograms and arbitrary image rotations to be performed by the hardware.

The Pseudo Color Look up Table (PCLUT) has the same resolution as the CLUT and is used to transform the color assignments before display. Three five-bit digital-to-analog converters are used to drive the high resolution (1024 x 1024) color display monitor, connected to the 7350 controller by coax cable. Hardware zoom keys can be used to expand the displayed image by pixel replication using factors of 1, 2, 4, and 8. An attached joystick may be used to control the position of the cursor or to scroll a displayed image (moving a window over the image).

The conversational monitor is an IBM 3278 model 3 (32 lines of 80 characters) Display Station with keyboard and audible alarm. It has 24 function keys which may be used by application programs to select processing functions. In addition, many hardware functions, such as enable and disable DACS (digital to analog converters), are available as special local function keys.

III. IPS/7350 APPLICATION SOFTWARE

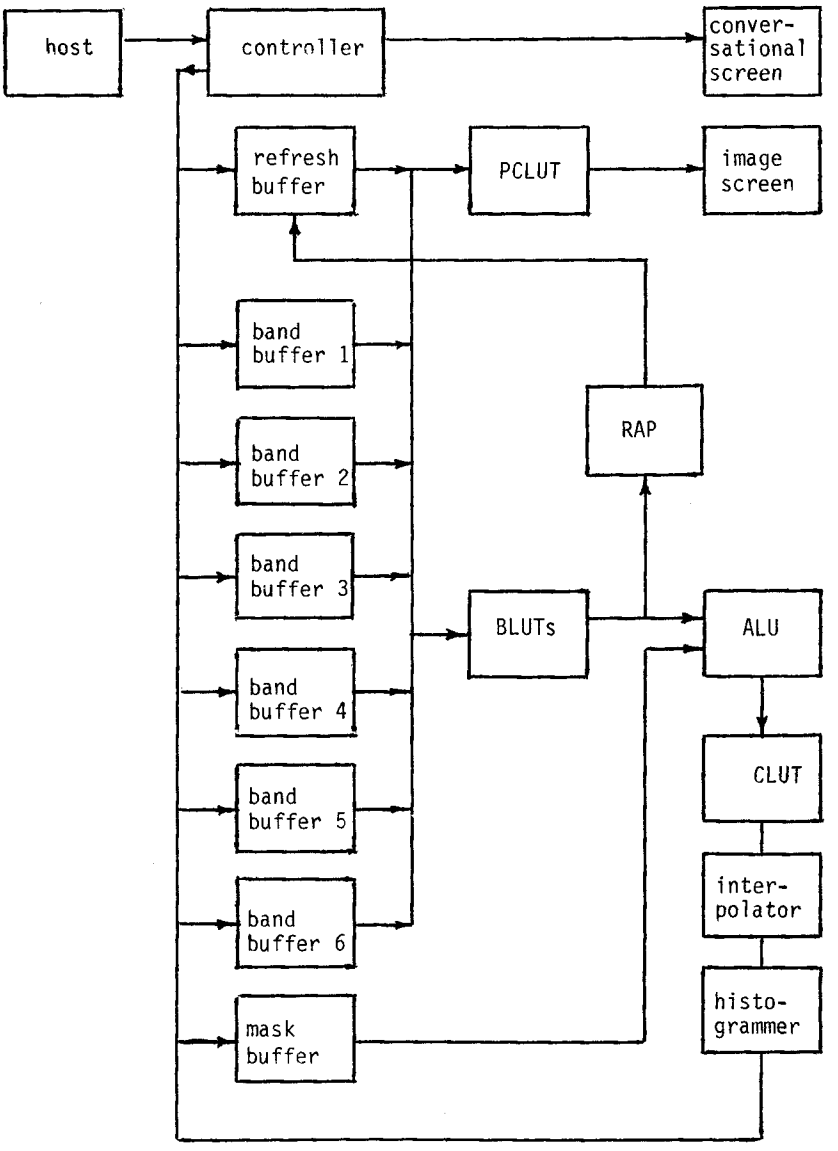

Figure 1. 7350 architecture

Several application level software systems have been written for the 7350. Applications addressed have included remote sensing, siesmic data processing, mathematical modelling, astronomy, and slide and foil production. The largest and most general application software is IPS/7350, the Image Processing System/7350. Selected functions of IPS/7350 are described in the remaining sections of this paper.

A. DISPLAY IMAGES

IPS/7350 provides several display techniques. Single band images may be displayed in color (density slicing) or in shade of grey, and multiband images may be displayed in standard red-green-blue, or as intensity, hue, and saturation. In the latter case, one band represent the intensity or brightness at each point, another the shade or hue, and the third the saturation or purity of the color. This display method has the advantage that the three components are nearly orthogonal as perceived by the human eye so that changes to one band of a multiband image are more easily identified in the displayed composite. IPS/7350 takes advantage of this property by providing options which let the user easily modify the three components, the most useful being the ability to rotate the "color wheel" (technically the "hue wheel").

IPS/7350 can also display images in shade of grey. The main use of this mode is for images in which the user wants an intuitive representation of increasing pixel value in the display.

For all display techniques, many "translate table" options are available such as "isopopulation" or "histogram equalization". Other methods include histogram equalization over a specified area, using a named, saved table, adjusting the gain and bias of the display (digitally), or using an identity table.

B. INTERACTIVE CLASSIFICATION

The translate table methods mentioned above allow a user to display and/or change the colors in an image by an adjustment based on the pixel values in a single band. Two other methods are available in IPS/7350 which allow the user to change the colors based on multiband critera. These methods are particularly useful because they provide interactive approximations to more sophisticated algorithms for multispectral classification.

The first method is the interactive parallelipiped classifier. In a displayed image, the user can identify a class and request that it be painted a certain color. He has several choices for identifying a class, such as pointing to a single pixel or drawing a polygon. He designates a color for the class, and the image is dynamically changed so that all pixels in the class are painted the chosen color. Each time the user identifies a new class, those pixels are painted on the screen. Machine response time is about 7 seconds for each new class.

The second method allows a user to identify clusters in a two dimensional histogram, and request that the corresponding data be painted a selected color in a display of the image. The important point here is that a human being can intuitively recognize clusters in a two dimensional histogram that are difficult to detect automatically.

C. LOCAL IMAGE MANIPULATIONS

The 7350 architecture naturally lends itself to operations on one or more bands of image data. IPS/7350 uses these hardware capabilities by providing options to:

1. Add or subtract several bands. The actual operation performed is a general linear combination of bands of the form:

   $$out=W0 + W1xI1 + W2xI2 +...+ W4xI4$$

   where the user can specify W0, W1, W2,..., and I1, I2, ... represent the input bands selected.

2. Ratio two bands. The ratio is computed as:

   $$out = W \times (I1+1)/(I2+1)$$

   where the user can specify W.

3. Expand an image. The 7350 hardware interpolator allows images to be scaled. The IPS/7350 user can request an expansion using cubic convolution, bilinear interpolation, or nearest neighbor at a scale of a/b where $1 \le a \le 32$ and $1 \le b \le 8$. Thus the interpolator can be used to provide non-integer expansions such

as 8.2 or 3.33, and can be used to reduce an image such as by a factor of 0.8. Expanding to a 1024 x 1024 image requires about 7 seconds using cubic convolution.

4. Compute Principal Components. Principal components of an image may be computed. Typically in IPS/7350, the first two principal components are computed for an original 1024 x 1024 four band image, and the computation requires about 54 seconds.

5. Filter an image. Low pass and high pass filters can be applied to images. Several standard filters are predefined, such as a five point Laplacian and 3 x 3 averaging. Other filters may be defined using IPS/7350 menus, with kernels up to size 8 x 8.

6. Image Rotation. An image can be rotated by an arbitrary angle.

D. DEFINE AND USE FIELDS

IPS/7350 allows a user to define and use fields. A field is an arbitrary polygon of up to 30 vertices (the vertices must be unique and the sides may not cross). The fields may be defined by pointing to their vertices with the cursor, or by explicitly typing in the coordinates. Once defined, they may be saved, modified, overlaid on a displayed image, or used in other IPS/7350 functions. For example, they may be used as training areas for a Bayesian classifier, to define the area of a histogram, or to define the area to enhance in a display of the image.

E. PLOTS AND DATA DISPLAY

IPS/7350 provides functions to let a user plot one dimensional histograms, two dimensional histograms, and to request pixel value displays of a small region of an image. One dimensional histograms are dynamically scaled, and several may be overlaid in color for comparison. Two dimensional histograms are generated by the hardware and are presented in color on the image screen. Depending on the scaling options, from 4 to 16 seconds are required to generate a two dimensional histogram of one megabyte.

F. MULTISPECTRAL CLASSIFICATION

IPS/7350 provides a Bayesian maximum likelihood classification function, based largely on the ERMAN-II program. Several enhancements were added, such as the ability to easily change and resubmit runs, improved reporting of results, thresholding of the resulting values based on the likelihood values, and color displays of the results in which the color intensity is derived from the likelihood.

G. PARTITION SCREEN SUPPORT

IPS/7350 supports a partitioned refresh buffer screen. The user can define up to 20 "logical screens" and IPS/7350 treats each as an independent display screen. The only requirement is that each is a rectangle. These can be of arbitrary size (up to 1024 x 1024) and overlapping, and each can be used for any IPS/7350 function.

The user defines the partitions he wants by entering their origin, height, and width in a IPS/7350 menu. Thereafter, in any IPS/7350 function, he moves from one to another by pressing a PF key. The cursor moves to the center of the active screen, and all IPS/7350 processing is then relative to that particular partition.

IV. CONCLUSIONS

The IBM 7350 provides image processing hardware ideally suited to multispectral remote sensing applications, including both computations and display functions, and IPS/7350, an application software system, provides a friendly user interface to the 7350 capabilities over a very wide range of functions.

AUTHOR BIOGRAPHICAL DATA

Wayne Niblack received a B.S. degree in Physics from Georgia Tech (1970) and a M.A. degree in Mathematics from Texas (1976). He joined IBM in 1973 where his work has included development and implementation of image processing algorithms and systems. He was the analyst on the NASA contract for the development of the CPLBS, the system used to find control points in Landsat MSS and RBV data. In 1979 he joined the IBM Science Center in Paris where he has worked on the application software for the IBM 7350 Image Processing System.