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IMAGE DATA ORGANIZATION

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ABSTRACT

A magnetic tape conversion program is being developed to facilitate picture processing by medium sized digital computers. The approach is to obtain a revised image format that allows sophisticated algorithms to process small contiguous areas. A tree structure is presented based on regular decomposition of two-dimensional arrays. Magnetic tape capacity parameters are reviewed and applied to develop the best tape organization for this data structure. Alternate neighbor region and partitioning regimes are described and a sample calculation discussed.

1. INTRODUCTION

Digitized picture consists of large sequential files generated by scanning devices. Magnetic tape is the most common storage medium for such files since it is portable and possesses sufficient storage capacity to contain an entire visual image. One common resolution for digitized images (1024 x 1024) results in over a million data points: light samples found in scanning over the 1024 lines (raster scan) can have grey levels ranging from 0 to 255. Each value corresponds to a spacial picture element or pixel. Tape storage for pixels quantized to 256 levels uses three characters, one for each numeric in the values 000 to 255. Pixels are represented then by triples of characters where each character is a byte of 6 or 8 bits (depending on tape device). When pixels are stored using triples of characters, files of over 3 mega-bytes are formed for a single image. Since 25 mega-bytes fit on a single magnetic tape, the raster scans of several pictures can be contained and accessed sequentially. In this paper we address the problem of using this large storage capacity to organize the visual information in a single image for future processing.

The goal of this research is converting raster scan tape records of images to a series of smaller sets of pixels restricted to subregions of the original. This extends /1/ and creates hierarchial organizations /2/ of visual data. The subregions may be arranged in a tree and obtained by regular decomposition of the original image /3/. The form of the tree (some regions may be deleted as valueless) could yield object-location and symmetry detection information /3,4/.

This paper describes the current status of an effort to develop a computer program system to convert raster scan records to hierarchical form involving many smaller images. The planned organization of the resultant tape image is described with detailed analysis of tape capacity and pointer definition requirements. A summary of considerations regarding choice of image decomposition mode is presented. Finally, a display program to generate the picture-tree on an interactive graphics console is discussed and a sample tree shown.

2. TAPE ORGANIZATION OF IMAGES

The 'raster scan' organization obscures actual physical proximity of picture elements. However, the limits on fast memory storage require processing small areas of an image. For example, see /5/; there locating the boundary of single chromosomes involved extensive computing on successive image lines: only when that task was done could any information be obtained. This section discusses how regional proximity of pixels can be obtained by decomposing a digitized image to raster-scan sub-pictures. The key to the technique is maintaining an accurate file directory to facilitate efficient retrieval of picture regions.

Picture files are usually segmented into blocks: each block's byte store light intensity values in pixels corresponding to one line of the image. Large blocks generally reduce I/O time, but several lines may not fit in fast memory simultaneously. A medium size computer with 48K bytes of core storage can hold only 16 lines (1.5%) of a 1 mega-byte digitized image, even if all available fast memory is used (and this leaves no room for programs). To examine even a small image region, this could cause extensive I/O costs. Reducing storage requirements for picture data is necessary for image processing on medium size machines. Before describing how we plan to do

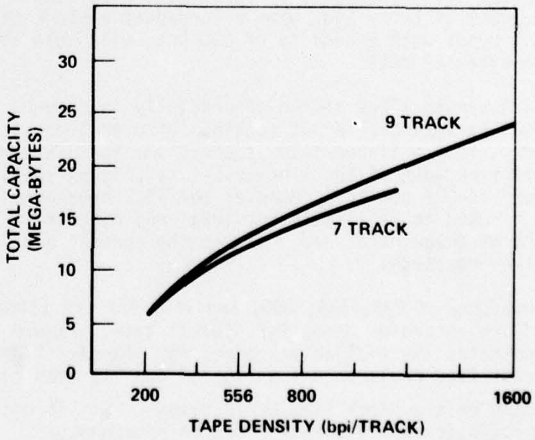

Figure 1. Magnetic tape storage capacity.

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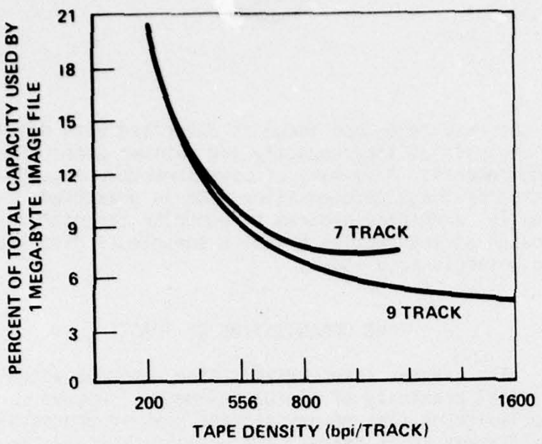

Figure 2. Percent of tape capacity used by one mega-byte file.

this, we need to examine tape storage capacity in detail.

2a. Tape Capacity

If C is tape capacity (maximum number of bytes of data that can be written on tape);

L is the tape length in inches;

B is the block size in bytes;

D is the density in bits per track[1];

I is the interblock tape gap length in inches[2];

then the storage capacity of magnetic tape is:

$$C = (L * B)/ ((B/D) + I)$$

Standard 10.5" 9-track tape reels hold 2400 feet (23,800") of tape, and, when recorded at a block size of 3K bytes with a density of 800 bpi, will hold 19.2 mega-bytes of data.

A single image stored sequentially in conventional raster-scan format consists of over 3 mega-bytes. Such a linear file is efficient for picture display because of the line-at-a-time (flying spot) nature of CRT devices. However the 19.2 mega-bytes can be used to facilitate retrieval and matching parts of image data, and that is the central aim of this research.

Density of 200, 556, 800, and 1600 bpi are standard hardware recording modes for digital tape. Figure 1 illustrates the available storage for standard 7 and 9 track tape reels as a function of density when recording with a block size of 1K bytes[3]. At 556 bpi 10 mega-bytes of information can be recorded on either tape: room enough for 10 one mega-byte image files. This is further illustrated by Figure 2 which shows the percentage of available storage used by a one mega-byte file on both 7 and 9 track tapes. In the following sections we show this extensive tape storage capacity is soon exhausted if storage maintenance is not enforced when reorganizing picture data.

2b. Data Reorganization and Pointer Definitions

Image data tape files generally have blocks correspond to one scan line and triples of characters indicating pixel light intensity (both occur in /6, 7/). Since typically 15% of available tape storage is needed for a picture, refinement by regular decomposition /1, 2, 3/ can be implemented by duplicating pixel intensities on tape in shorter raster-scan lines than in the original image. The resulting series of sub-pictures is stored after the whole image's last row last pixel. If sub-pictures at the same level do not overlap, a single decomposition results in creation of a reorganized "duplicate" set of data, essentially the same length as the original digitized image (see 3.a for "level").

Picture refinement creates new sub-pictures stored on tape and additional leaves in the tree structure representing the image. Each node on the growing structure will contain its identifier, feature measurements over the area (i.e., average pixel intensity, measure of gradient change, etc.) and pointers to contiguous data on tape as a well-defined sub-picture. Dedicated tape storage is inherent to the creation of sub-pictures and their relative positions are approximated by the tree-structure (each sub-picture corresponds to a node in the tree).

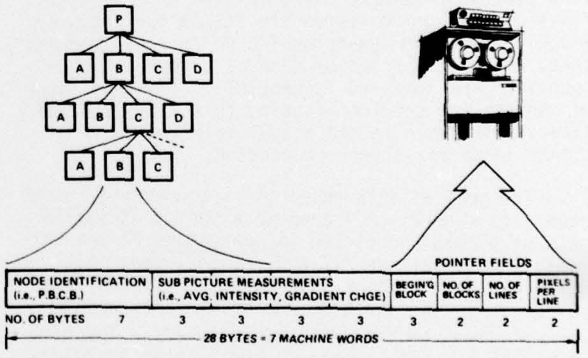

Figure 3. Information stored in data structure nodes.

Figure 3 shows information fields in each structure node. The node identification fields contain information to identify ancestors and level of decomposition. Each structure node contains four measurement fields for sub-picture feature data and four pointer fields used to locate the stored sub-picture on tape.

Regular decomposition of picture data into sub-quadrants has been extended by /8/ to include neighbor quadrants that may possibly contain extensions of an object in the quadrant which is to be isolated

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1. Usually 200, 556, 800 or 1600 per track.
2. This is 0.6" for 9-track tapes and 0.75" for 7-track tapes.
3. Larger blocksizes will increase capacity by reducing the occurrence of interblock gaps.

for finer picture decomposition. Data reorganization on tape could also include border information at each refinement. Overlap of data may reduce tape "thrashing" if border information is found to be essential for object recognition. In Figure 4 storage requirements for successive refinements of image data by quadrants and ninths is shown to increase exponentially when border data is included in the replication of the file. Including border data expands the boundary of each sub-picture to the midpoints of each neighboring partition; border inclusive partitions for quarters result in a file 2.25 times larger than the original sub-picture, 3.5 times larger when partitioning in ninths (see Figure 4). If only 10% of the tape is used to store the original image (N in Figure 4 equals 0.1 of available storage) three full refinements by quadrants will fill the tape when border data is included and only two full refinements will fill the tape when refined by ninths.

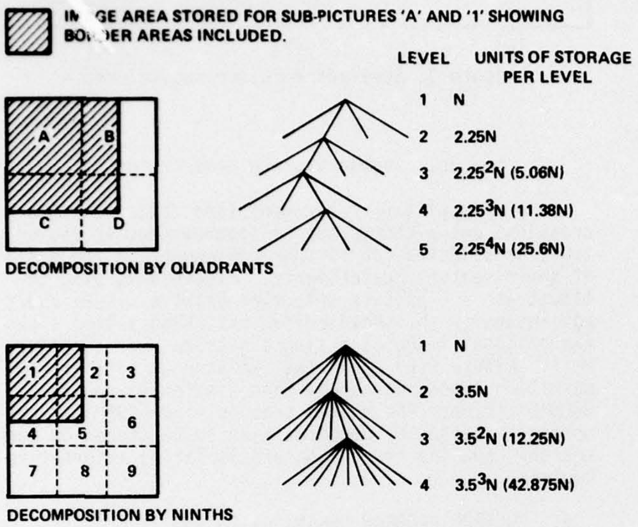

Figure 4. Number of Pixels to store.

Additional refinement is possible by increasing tape storage capacity, compressing the representation of the image (reducing N), or by selecting only "promising" sub-pictures for storage during refinement.

The first alternative is hardware dependent making it the least expedient accommodation for most computer installations. Our computer system uses 7-track tape drives of 556 bpi density making the storage capacity for standard reels 11.378 mega-bytes. This hardware restriction directs our attention to the latter two alternatives for increasing image refinement capability.

We plan to compress image data by a linear mapping of the triples of characters, which represent pixel grey codes (0-255), to single byte encoding. Each 6-bit encoding forms a one-byte 0-63 grey scale representation for pixels that previously used 3 bytes of tape storage. This reduces N, the amount of storage needed on tape for each image. Despite our low density tape facility (i.e., 7-track, 556 bpi), N is kept to 9.21% of available storage. We sacrifice the reduced grey-level discrimination in order to increase tape storage capacity. Selecting "promising" sub-pictures is discussed in sections 3b and 4.

3. DECOMPOSITION OF IMAGES

The following presents in a condensed format concepts relating to regular partitioning (regular decomposition, tree data structure, pyramid data structure /9/). An example is given after the basic terms developed in /1, 2, 3, 8/ are introduced.

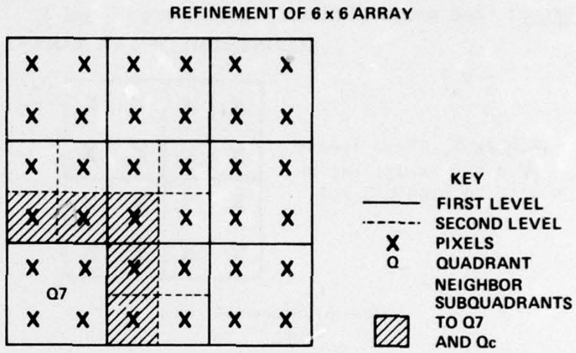

Figure 5. Ninth partition and quarters of result.

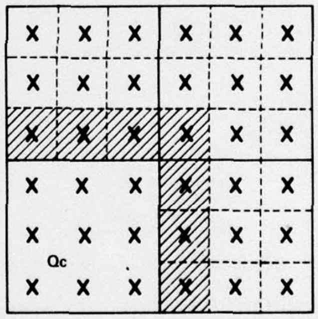

Figure 6. Quarter partition and ninth of result.

3a. Sub-Picture Concepts and Terms

Definition 1: A sub-area one-quarter or one-ninth of a digitized picture or any previous quarter or ninth of it, is called a quadrant.

Lemma 1: The smallest pixel array that is refinable by either quarters or ninths is of size 6 x 6, and there are neighboring pixels on every two-quadrant boundary that can be organized into single-pixel neighbor-subquadrants.

Proof: Refinement into quarters requires bisection of the pixel-array sides, and into ninths, trisection. The smallest integer divisible by both two and three is six. The neighboring pixels adjoining a ninth-partition quadrant are obtained as quarter-partitions of the adjacent (ninth) quadrant (see Figure 5). Those adjoining a quarter-partition quadrant are obtained as ninth-partitions of the adjacent (quarter) quadrant (see Figure 6).

Definition 2: In a pixel array of any size (including an entire digitized picture), the root of a tree corresponds to the entire array, and successor tree nodes to its regular partitions. The root is called level one and quadrants resulting from further subdivision are at one more level than the array they divide.

Definition 3: Quadrants with one higher level value and adjacent to a quadrant are called neighbor subquadrants.

Lemma 2: The size 6 x 6 pixel array is the smallest that can be regularly partitioned twice to yield neighbor subquadrants for both quarter and ninth first level refinements.

Proof: See proof of Lemma 1 and Figures 5 and 6.

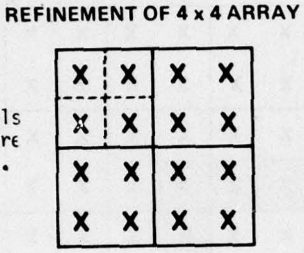

Figure 7. Three levels of a 4x4 array: Entire area to single pixel.

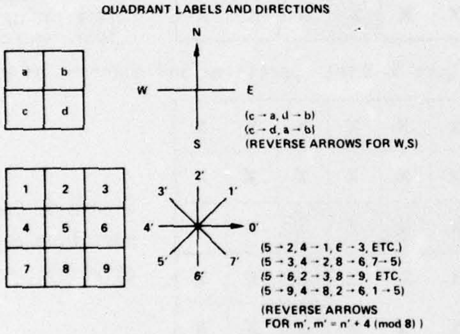

Figure 8. Convention for quadrant labels, directions.

Definition 4: Direction information refers to spatial relationships that can be extracted from a tree representing an image. (Referring to Figure 8, presence of quadrants A and D in a tree and absence of B and C, implies downward-diagnol orientation of an object in the image.)

Lemma 3: Both 6 x 6 and 4 x 4 pixel sets can support three-level picture-area comparison algorithms. The tree of quadrants retained can provide some eight-direction information on object location and orientation in either case.

Proof: By examination of Figures 5 through 8. Note that 6 x 6 arrays are shown with alternate ninth and quarter partitioning (following /1/) while the 4 x 4 array in Figure 7 shows only quarter partitions.

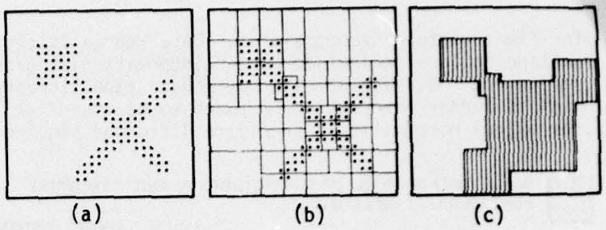

Figure 9. Stylized airplane subpictures.

3b. Sample Storage Computation

During picture refinement (and data structure creation) sub-pictures can be ignored (not stored on tape) or selected for further refinement on the basis of their feature measurements. Figure 9 is used to illustrate sub-picture selection using a simple average intensity threshold criterion. Figure 9(a) shows the original image as a single picture before refinement. Figure 9(b) shows the skeleton of successive partition lines imposed by hand simulating regular decomposition. The shaded area in Figure 9(c) is the portion selected by decomposition to be stored on tape thereby reducing image data and isolating informative regions.

4. CONTROL PROGRAM ORGANIZATION AND PICTURE TREE DISPLAY

Image reorganization requires accurate bookkeeping operations. The data utility and control programs execute this and are designed to enable flexible interaction with the new form of image data. The programs are like an operating system since a variety of computer facilities are integrated in our installation (including SDS 920,930 and IMLAC computers). Human interaction is allowed any time between tasks; either automatic or human control of image refinement and feature extraction is possible; display of image areas on peripheral devices is provided. Our goal is a tool for operator use to: (1) obtain informative picture-regions, (2) examine the syntactic relationships described by the tree structure and, (3) provide indexing for image data retrieval. The creation and maintenance of the tree structure is essential to our system.

Figure 3 illustrates information fields in a typical structure node. Each node uses 7 SDS 24-bit words. In addition to an abstract image representation the structure acts as a directory for accessing previously refined regions or finding quadrants that can be refined to yield sought sub-pictures. During program operation 1K of core is allocated to the data structure leaving room for 146 7-word nodes. In effect this enables 3 full refinements of a picture by quadrants (i.e., 4 + 16 + 64 = 84 nodes after 3 refinements). During picture refinement feature measurements (i.e., average intensity, gradient measures, etc.) can be gathered simultaneously as tape data is reformated to picture partitions. Picture refinement programs are I/O bound, the time used in transmitting data to and from tape is often the slowest portion of any tape accessing program. As data is transmitted from one part of the computer processing can continue in another. This means no significant timing costs are introduced when features are extracted if they are processed during refinement and syncronized carefully with tape access instructions. Information gathered during refinement may guide the program or operator to focus further refinement on those areas with conspicuous feature measurements.

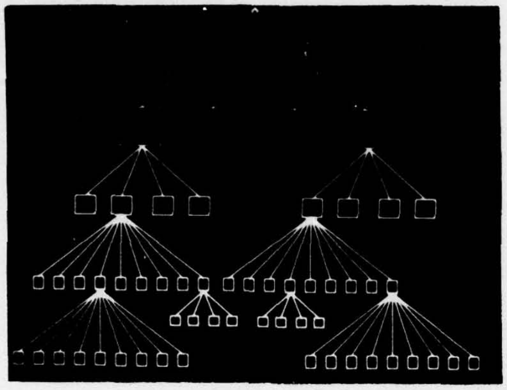

Figure 10. CRT display of data structure.

The data structure formed from an image refined three or four levels can show symmetric features present in the image [4]. When the data structure itself is displayed additional clues may be given an operator for object location. In Figure 10 we show a sample data structure display which illustrates both quadrant and ninth partitions of sub-pictures. This display is a preliminary version of an option to be available to the program operator. The display uses an IMLAC PDS-1 mini-computer connected with our SDS 920-930 computer system.

Sub-pictures corresponding to nodes in the image data structure will also be displayed on the IMLAC CRT. Preliminary work /10/ has been done but further work is needed to integrate the display terminal with tape data indexed by the data structure.

5. CONCLUSIONS

We have summarized progress toward a tape-to-tape conversion program. The purpose: to obtain a revised image format that allows sophisticated algorithms to process small contiguous areas, was explained. We developed an approach based on subpictures and evaluated the storage cost and feasibility of that technique. We discussed tree data structure indexing scheme and regular decomposition nodes for two-dimensional arrays. A review of magnetic tape capacity parameters established that about 15% of a tape is needed to store a raster-scan picture digitization, and that many tree-levels' sub-pictures could be kept in the remaining tape. We reviewed the neighbor region concept and alternate partitioning nodes, and discussed a sample calculation involving a stylized airplane image.

In future work we will experiment on /6,7/ to evaluate partitioning schemes (/1, 2, 3, 8/) and neighbor zone retention rules (/8/, above illustrations).

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