ELECTRONIC MULTI-IMAGE ANALOG-DIGITAL PROCESSOR AND COLOR DISPLAY

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Extraction of information from images may be facilitated by automatically processing to bring out features of most interest. Color displays improve the interpreter's ability to make full use of his visual perception ability. The system described here is a flexible research tool for testing image processing techniques and for aiding interpretation.

Analog processing of video signals at TV scan rates permits nearly instantaneous enhancement and feature selection, but processing in a digital computer permits more flexibility in experimentation and use of more complex pattern recognition algorithms. The IDECS (Image Discrimination, Enhancement, and Combination System) is a hybrid combining the advantages of high-speed analog processing with the flexibility of digital processing and digital control of the analog processor. A human operator may interact with the machine either through a control panel (machine operates like an analog processor) or through typed computer-language commands. Algorithms developed by processing test data digitally may be automatically set up on the IDECS, and actions of the human operator may be monitored for analysis and for future use.

The IDECS has continually evolved since 1964. Initially it was completely analog in operation, so use of algorithms developed in a general purpose computer required manually setting the controls and repetition of operator-developed settings required manual logging. A 24-channel 2.4 M bit disc memory was added about three years ago. Recent changes have provided overall digital control and monitor capability using a PDP-15/20 DEC computer and a central processor unit for the IDECS itself. With addition of the computer the IDECS displays can also be used for graphic output of non-image data such as plots and histograms.

The original purpose of the IDECS was processing of multispectral radar and photographic images. Applications on enhancement of single images have included X-ray and gamma-ray medical scans, artistic composition, and various sensor images. Examples described below are creation of specialized maps from multiple factor transparencies and enhancement under computer control of a radar image for category selection.

THE IDECS CONCEPT

The driving force behind IDECS development was the obvious difficulty photo interpreters have in transferring information perceived from the images of a multispectral or multitime set. A logical first step in improving perception of such sets of two or three images is straightforward color combination using weights designed for best recognition of desired features. If an operator presents a selected intensity range from one or more images in different colors, he may improve interpretability.

Automatic point-by-point feature extraction for multi-image sets can be achieved by selecting only those points for which the combinations of intensities for the N images of a set lie within certain boundaries in a N-dimensional space. The IDECS does this in a unit called a "signature selector." Establishing the boundaries of this region in N-space is a major task in pattern recognition, and often is performed on a general-purpose digital computer. Once the boundaries have been set, the IDECS can select out any region bounded by a 4-dimensional parallelepiped, and curved boundaries can be approximated by successive operations with the signature selector. The same technique can be used to provide color intensity slicing for single images. An example of single-image computer controlled intensity slicing is shown in Figures 1 and 2.

Figure 1. HV polarized radar image, Garden City, Kansas.

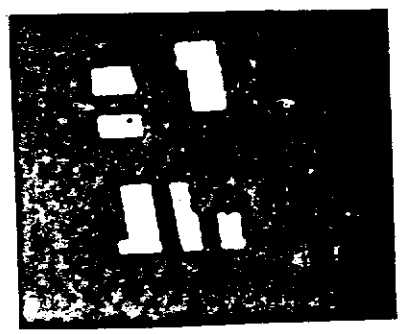

Figure 2. Enhancement of fields with bright return from above photograph.

Examples of Application

The HV radar image of an agricultural scene at Garden City, Kansas, is shown with sugar beets enhanced and presented exclusively. IDECS was directed by the PDP, after a pointer was placed over one of the beet fields by the operator, to sample intensity values for a training set; the PDP then directed the IDECS to scan the whole image, picking out for display only those intensities established through a decision rule based on the sample. By repeating the procedure and utilizing multi-image sets of the scene, the IDECS could produce other categories for display, each in a different color. Figures 3 and 4 show another example of processing, generation of factor maps from factor transparencies.

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A map of soil strength, clear acetate where the strength is a given value and opaque elsewhere, was stored in the disc memory along with several other maps including soil thickness. The result of Boolean ANDing soil strength with surface thickness is shown in Figure 4. The IDECS by commands entered at the PDP teletype directed the Boolean operation; other operations on any two factors or combination of factors can be made and displayed or stored. Figure 4 in effect shows the area where soil strength and soil thickness are each within given limits. By providing a group of factor maps for a given area, color coded maps with given characteristics can be generated.

Equipment Description of the IDECS

The IDECS is illustrated in the functional block diagram of Figure 5. Here input and output units presently available are shown, along with both the enhancement/signature selection systems and the configuration matrix, storage, and control units. Signal flow lines in the diagram are greatly simplified for ease of presentation.

Inputs are from film transparencies through three feedback-compensated flying spot scanners whose resolution is compatible with the TV displays. A single vidicon camera input is provided for an additional transparency or for an opaque input, such as a map; of course the uniformity of the vidicon scan is not as good because feedback control is not possible. The scanners operate with a standard TV scan, in a dot matrix scan, and in a computer controlled incremental scan. Signals recorded on digital tape may also be fed into the system via the PDP-15/20 digital computer.

Figure 3. Display of factor transparency of soil strength.

Figure 4. A factor map of soil strength and soil thickness.

Outputs may be displayed on a color TV, a monochrome TV, or an X-Y oscilloscope. System bandwidth is 10 MHz, so the TV displays are of high quality. The X-Y oscilloscope is used for diagnostic purposes and to provide outputs equivalent to a scanning densitometer.

The heart of the processing system is the 20 x 20 matrix that permits a multiplicity of configurations to be set up. Scanner and vidicon inputs always channel through the matrix as do all outputs. The matrix may be set by pushbuttons or by computer control. The linear combiner permits the various inputs to be combined with any linear weight (positive or negative) before they are fed either to an output or to the other processing elements.

The level slicer/signature selector contains four intensity slicing units with adjustable upper and lower thresholds. Logical ANDing of their outpus selects a region in 4-space corresponding to the desired feature. The automatic discriminator performs a similar function, but its upper and lower slicing thresholds are set by the maximum and minimum intensities in a "training region" selected from within the image set by the framer. Areas associated with individual selected features may be measured.

The 24-channel disc may be used to store the outputs of the signature selector or automatic discriminator, with each output stored on a different channel. The disc has many other applications; for example, change detection is achieved by storing two images on the disc and displaying only their difference. The disc may be used for storing color images and reconstituting the full range of colors using the D/A output, or it may be used for storing binary outputs such as from the signature selector. The latter may be displayed in 10 colors and 10 cross hatch forms.

The entire machine is controlled and monitored by the IDECS CPU, which contains some 800 IC's in 300 logic cards. The CPU may be controlled by pushbuttons from the front panel, but much of the time it is controlled by the PDP-15/20, with control signals generated either through the teletype input to the computer or through operating programs.

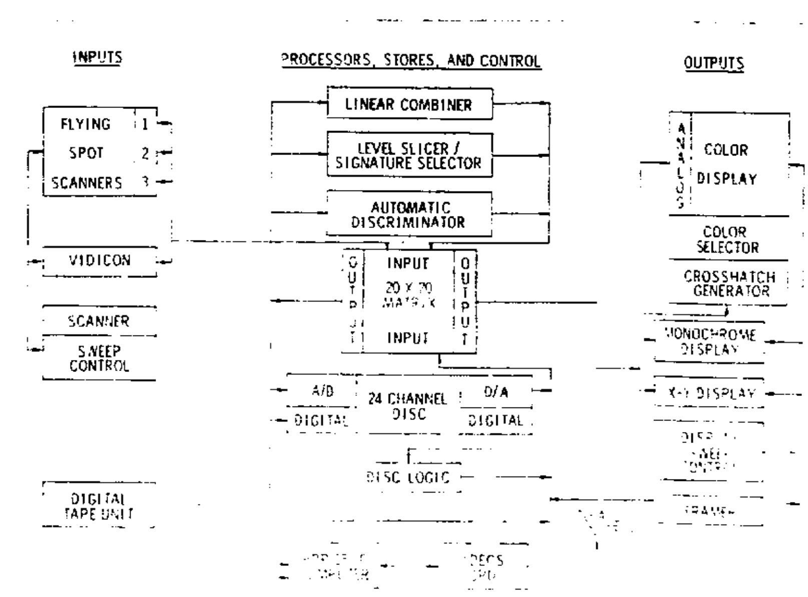

FIGURE 5. IDECS FUNCTIONAL BLOCK DIAGRAM