Processing of Two-Dimensional Patterns by Scanning Techniques

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IN THE STUDY of visual perception and of the processes involved in the recognition and recollections of patterns, it is desirable to have mechanisms available to manipulate two-dimensional patterns. Although such operations might be accomplished, to some extent, by manual means or by special techniques using photographic processes, it appeared that there would be considerable advantages in the great rapidity of action and flexibility that may be obtained by the use of electro-optical scanning techniques.

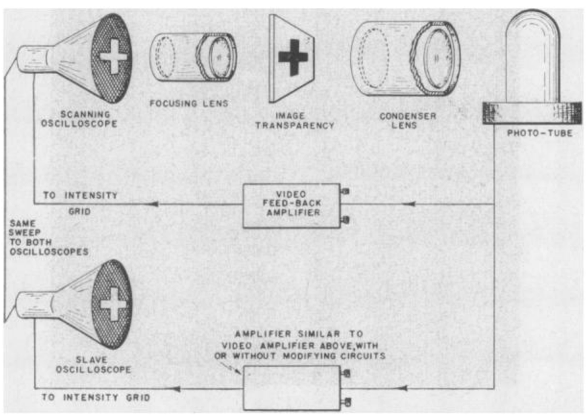

FIG. 1. Image feedback system. Block diagram of apparatus. The scanning spot is focused on the transparency. The transmitted light is converted to electrical signal by the phototube and fed back to the intensity grid of the scanner, thus producing a negative picture on the face of the scanner. The same video signal is modified and displayed on a second slave oscilloscope.

Those considerations led the senior author to suggest that manipulations of a pattern could very conveniently be studied by the system described herein. As a result of this suggestion the equipment described below has been built for the purpose of studying the potentialities of manipulating two-dimensional patterns. The apparatus consists essentially of a flying-spot scanner and a monitor or "slave" oscilloscope to view the results of the scan, connected as indicated in the block diagram, Fig. 1. The scanner employs negative feedback to obtain a more faithful response in the video signal.[2] The modification of the picture is accomplished by inserting a suitable electrical circuit modifier between the output of the phototube and the intensity grid of the slave cathode-ray tube.

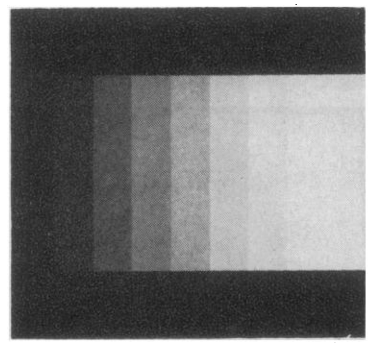

FIG. 2. Step wedge of density. Note the brightness contrast effect at the boundaries of the steps. Each step looks as if its shading varies across the step, although the shading is uniform. (This may be checked by covering the adjacent steps.)

The operations that may be pertinent to the problem of recognition and recollection, to some degree, appear to be independent of the orientation of the pattern. Isotropic Operations (that have no preferred direc-

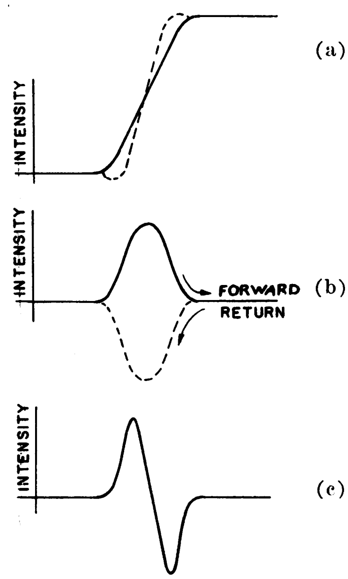

FIG. 3. (a) Signal obtained from scan of a step at transition (slightly defocused). (b) Differentiated signal of (a). (c) Second derivative of (a). *Note.* The sign is independent of the direction of scan.

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[2] A description of negative feedback applied to a flying-spot scanner has appeared in an article by R. Theile and H. McGhee, "The Application of Negative Feedback to Flying Spot Scanners," in *J. Brit. Inst. Radio Engrs.* June, 1952.

tion) can be accomplished without resorting to special memory devices by using a scan that is isotropic in its properties.

The scan employed has the same velocity in two orthogonal directions, e.g., in both horizontal and vertical directions. Some operations upon the beam intensity in the time dimension have the effect of modifying the pattern in space. In this manner fairly simple electrical operations in time made upon the intensity signal are transformed into corresponding operations in two-dimensional space. For example, forming the second derivative of the light intensity in time, d^2I/dt^2 results in a pattern on the screen representing $\nabla^2 I$, the Laplacian of I.

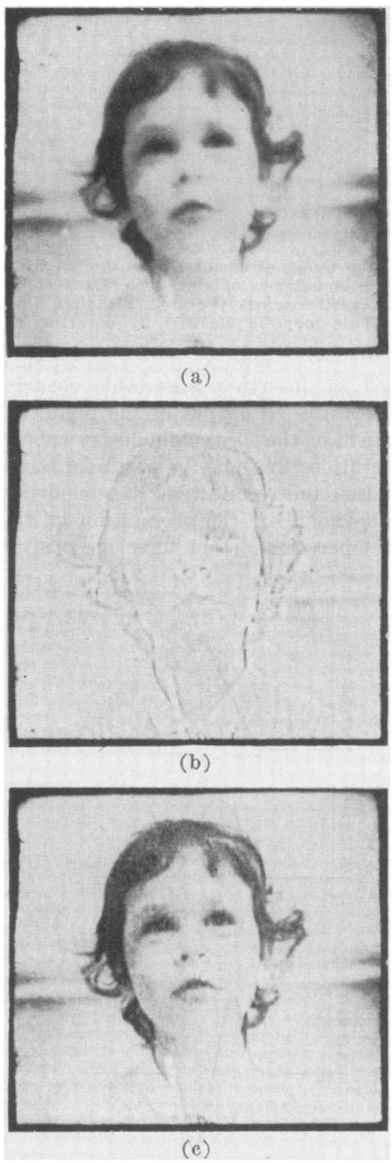

FIG. 4. (a) Picture produced by video signal. (b) Picture produced by negative of the second derivative of the video signal. (c) Picture produced by electrical additional of above signals.

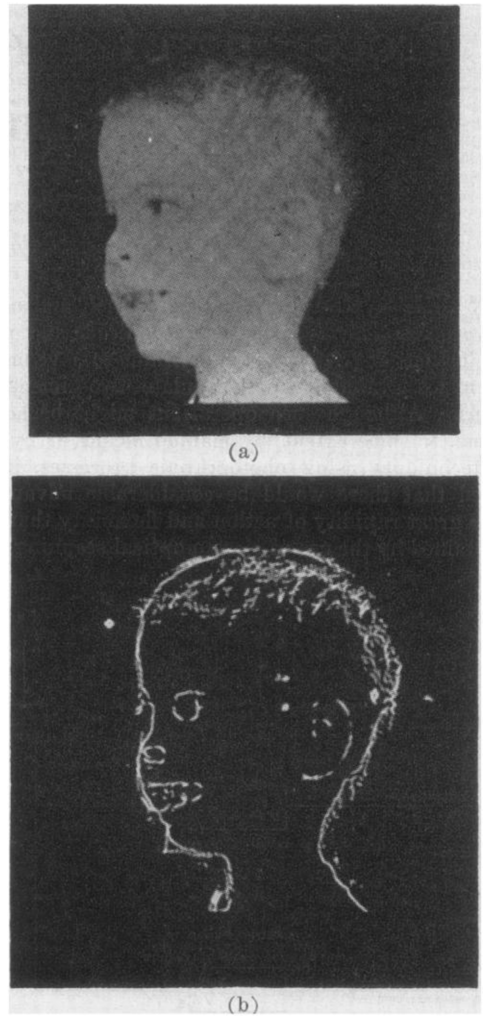

FIG. 5. (a) Direct reproduction. (b) Contour outline of direct reproduction in (a).

The scan, itself, was obtained by applying a train of triangular waves to the horizontal deflection plates and a slightly different frequency triangular wave train to the vertical direction. Since the phase difference between the vertical and horizontal waves changes at a constant rate, the resulting rectangular Lissajous figure changes shape and covers the picture area in the period of the difference frequency. The scanning spot moves in each of the orthogonal directions of the rectangle at a constant velocity and thus the scan is isotropic.

The first process simulated with the equipment was that of the brightness contrast effect noted in the human eye. It can be observed by the reader in the step wedge (Fig. 2). Each step looks as if its shading varies across the step, although the shading was reproduced uniformly.[3] This effect is the enhancement of changes at boundaries or contours.

The contour enhancement was produced in the

[3] A similar accentuation occurs in photographic processes as the Eberhard effect.

monitor oscilloscope by forming the Laplacian of the density pattern and subtracting it from the directly reproduced pattern. The enhancement obtained is indicated for a one-dimensional pattern in the diagram of Fig. 3. The solid line in Fig. 3a shows the light amplitude, I, that would be obtained by scanning the area across the boundary between two of the steps in Fig. 2, both in the forward and the reverse directions. The solid line in Fig. 3b shows the first derivative obtained when scanning forward and the dotted line the opposite sign of differentiated light signal obtained when scanning in the reverse direction. Figure 3c shows the second derivative, whose sign is independent of the direction of scan. The dotted line in Fig. 3a shows the increased sharpness of transition obtained by subtracting a portion of the second derivative.

The effect of performing the same operation in two dimensions upon a photographic transparency is shown in the pictures of Fig. 4. Figure 4a is the direct reproduction of the picture as it appeared on a cathode-ray tube screen. Figure 4b is the negative of the second derivative as it appears on the same screen. Figure 4c shows the result of electrically adding the two signals. The definition of Fig. 4a was limited largely by the minimum scanning spot size available. The improvement in overall sharpness of the picture in Fig. 4c is readily apparent in the original photographs.

Other pictures have been degraded by increasing the scanning spot size or by reproducing the transparency in an enlarger by slightly defocusing the image. A similar improvement in sharpness was obtained in each of those cases. A mathematical analysis shows that this represents a first order restoration of a degraded function in cases when the original has been degraded by the processes mentioned above as well as by limited video pass band or by diffusion. This is a two-dimensional analogue of high-frequency compensation of an amplifier whose amplitude-frequency response decreases at higher frequencies.

This process has been repeated, or recycled, by scanning the reproduced pictures in the same manner as the originals. As expected, the direct reproduction is better when the improved picture (Fig. 4c) is used as the original. This tends to show that the two-dimensional analogue of preemphasis of the higher frequencies may be utilized to improve the reproduction of a picture by compensating for the properties of an imperfect system.

In addition to producing contour enhancement, the same equipment was used to produce a contour outlining effect, a method by which, it is believed, the visual memory extracts essential information from a pattern. By rectifying the signals shown in Fig. 3b and limiting them to a constant level, it is possible to outline the boundaries of the picture (resembling cartoon drawings) on the cathode-ray tube screen. A picture outlined in two dimensions is shown in Fig. 5. The picture shows an outline in white lines against a black background. However, it is easily possible to produce a white line picture by reversing the polarity of the rectifier.

The exploration of the properties of this system will proceed with attempts to determine the effects of other processes such as integration, modifications in the feedback circuit itself, and other matters. In addition to the potential practical values of the processes so far studied, the method of modifying two-dimensional patterns may be useful as an analogue computer for two-dimensional partial differential equations, and for studying the problem of the recognition and recollection of visual patterns.

Instrument Society of America Annual Conference and Exhibit

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THE Instrument Society of America held its Eighth National Instrument Conference and Exhibit in Chicago during the week of September 21–25. More than 11,000 persons registered to attend the large exhibit held in the Hotel Sherman or to attend the sessions of the technical program held in the Hotel Morrison. As many as six sessions were held concurrently, with 37 sessions in all, and a total of nearly 100 papers presented. In addition to sessions arranged by technical committees of the Instrument Society of America, there were also sessions arranged by cooperating societies, including the American Society of Mechanical Engineers, the Institute of Radio Engineers, and the American Institute of Electrical Engineers. As in previous years, an interesting feature of the technical program was an "Instrument Maintenance Clinic" arranged for the instruction of plant and laboratory personnel in the operation and maintenance of various basic types of instruments. Manufacturers provided instructors and demonstrated equipment for this clinic, which lasted

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