WORKING PAPER

Institute for the Study of Cognitive Systems

PRODUCTION AND CONTROL OF VISUAL PATTERN VARIABILITY BY COMPUTER

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Computer generation of patterns for pattern perception research offers several advantages over other methods. A large number of patterns can be produced easily and quickly, and they appear in a standard format, but most importantly, the set of patterns generated by a computer following certain rules will constitute a random sample from a well-defined population.

This paper is concerned with one class of generators for one type of pattern, and in particular with the Institute's progress in the area. As such, it is more a progress report than a general review, yet the overall approach should be applicable to other classes of patterns.

Much of the Institute's research makes use of 48 X 48 matrices with black and white cells producing a visual pattern. Let us consider all possible ways such a pattern may be altered. Note that various combinations of the methods discussed may be used either to make a pattern less recognizable or to transform it into an entirely different pattern. Thus pattern alteration can be a subset of pattern generation. Furthermore, alteration which utilizes a random number generator will produce a random sample of deviations about a prototype. The production and control of these alterations, or variability, can thus be important for both generation of specific patterns and for the generation of classes of patterns with similar characteristics.

Variability can disrupt effective pattern transmission in several ways. It may be entirely random, or white noise. It may affect only edges, as in blurring. It may be a change in orientation, position, size, or compression-expansion along various dimensions. Or it may involve complex twists and projective transformations. All these types of variability can be present in a black and white pattern on flat paper and all can be produced by programs existing, or under development at the Institute.

(1) The most general type of noise is that which is independent of the pattern, or random noise. It occurs in our

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standard matrix when there is a fixed probability, less than one, that any particular cell will be transmitted correctly. This type of alteration can be produced with VARGUS 6D on the IBM 1620 or with VARGUS 6E on the IBM 1800.

(2) Related closely to random noise is blur or edge interference. It is produced in the computer, at least indirectly, by the random walk method. VARGUS 8 (obsolete - no longer operational), for the IBM 1620, in fact, uses this method. Every black cell is given a number of one cell steps, in random directions, so that white areas far from the pattern and black areas, interior to the pattern, are unchanged, but edges suffer degradation. BLUR, for the IBM 1800, achieves a similar effect by loading a matrix, successively centered on black cells of the pattern, into corresponding cells of a matrix congruent to the pattern matrix. The moving sub-matrix carries numbers representing blur for a specific number of random steps.

(3) Rotation of a pattern may occur about any axis, and through any angle. The current program, ROTAT, for the IBM 1800, however, only rotates the matrix in which the pattern appears about the center of the matrix and only in multiples of ninety degrees. Note that rotations of less than ninety degrees are not only difficult to program but (because of the coarse grain of the matrix) produce changes in shape, which rotation, alone, does not imply.

(4) Position change can have a large effect on pattern recognition in natural situations. It is produced in the computer by moving every cell of a pattern in the same direction relative to a straight line. For example, the cell with coordinates (I, J) would be moved to position (I + M, J + N), where M and N are intergers, constant across cells of the pattern. This type of alteration, as yet not programmed, can easily be added to existing programs or, if necessary, be coded as a separate program.

(5) Alterations (5) through (8) include more complex changes in patterns, and may be grouped as mirror distortions, since, in natural situations, convex and concave mirrors and lenses will produce the same effects. Although different in appearance or natural origin, they may all be produced in the computer by the same method, which is similar to the procedure for position change with one important distinction. Instead of moving cells a constant distance, all cells are moved a distance proportional to their present distance from the straight line, or axis, which determines direction.

For example, the first mirror distortion, change in size without change in shape, is produced by moving every cell in a pattern successively towards (or away from) a pair of straight lines which cross at right angles in the center of the pattern. The other mirror distortions are similarly produced, always moving a distance proportional to the initial distance. Both (4) and (5) are included here more for the sake of completeness than because of their value in research. Changes in size and position have little effect on recognition, for this type of pattern, though they may later find some importance in the joining of subschemata by computer.

(6) Changes in shape can take many forms. The grouping here (6,7, and 8) is somewhat arbitrary, since all the distortions discussed will be produced by a similar method. However, they may have different appearance and natural origin.

The first is compression or expansion in any direction. Equal compression (expansion) in directions at right angles is a special case discussed above as change in size. In general, this distortion is produced by moving cells of the pattern towards (or away from) a line which passes through the pattern.

(7) Twists and turns of a pattern can be produced by passing short line segments through a pattern and compressing (or expanding) all points to (or from) the line.

(8) Projective transformation is a particularly interesting class of distortions, although somewhat limited in two-dimensional patterns. One type is that produced by looking at a pattern on paper from a vertical angle other than ninety degrees. Disregarding our subjective compensation, we see a simple case of compression-expansion in the direction of viewing, which can be produced in the computer by the method discussed in (6). If we continue adjusting our angle of view, or turning the paper, we eventually see a single line. Further turning results finally in a mirror image of the pattern, or that seen by flipping a pattern completely over and holding it up to the light. This is produced in the computer by continuing the mathematical equivalent of compression, beyond compression to a line.

In summary, we now have separate programs for introducing random noise, blur, and rotation. Work is beginning on a program, DSTRT, which will produce the distortion types of variability, changes in size, compression-expansion, twists and turns, and projective transformations. One program can serve for these varied ends because all the effects can be produced by various combinations of one process.

First, one or more axes is introduced in the matrix. The input includes the starting point coordinates, the length, and the orientation of each line. At present only straight lines with horizontal, vertical, or diagonal orientations will be used.

The next input is a parameter specifying the amount of compression-expansion, say "M". Note that both inputs may be varied randomly, within certain constraints. For example, to produce a size change without a change in shape M may take on any value greater than zero or less than minus one, but there must be a pair of axes which cross at right angles in the center of the pattern.

Now, one coordinate of every cell of the matrix is operated upon by the following formula:

$$I = I + \left(\frac{I-K}{M}\right)$$

where I is a coordinate of the cell in question,

K is the corresponding coordinate of the axis, and M is the amount of compression-expansion.

Suppose that the pattern is being compressed towards a horizontal axis. Then I will be the row number of each cell, K will be the axis row, and M will be negative. Thus only the row coordinates will be changed, and in this case, changed so that the absolute value of (I-K) diminishes.

If, however, the pattern were being compressed towards a vertical axis, I would be the column number for each cell and K would be the axis column, so that only the column coordinates would change. When the axis is diagonal, the formula is applied to both the row and the column coordinates. Thus, in every case, the same formula is applied, whether the row values, or the column values or both are to be changed.

For expansion, M should be positive. When M is less than zero but greater than minus one, a mirror image is produced.

The relationships among I, K, and M are summarized in Figure 1.

The type of input necessary for specific types of distortion are summarized in Table 1.

Table 1

Types of Alterations Which Can Be Produced By Program DSTRT and the Corresponding Types of Data Input

Type of Alteration	Input to DSTRT Program
Size Change	two lines which cross at right angles in the center of the pattern; $M > 0$, or $M \leq -1$
Compression	one line which extends across the pattern; $M \leq -1$
Expansion	one line which extends across the pattern; $M > 0$
Mirror Image	one line which extends across the pattern; $-1 \leq M < 0$

Table 1 (con't)

Type of Alteration	Input to DSTRP Program
Twists or turns	short line segments which pass through or near the edge of the pattern; $M \neq 0$
Projective Transformations	one line which does not cross the pattern; $M \leq -1$

Reviewer: S. H. Evans

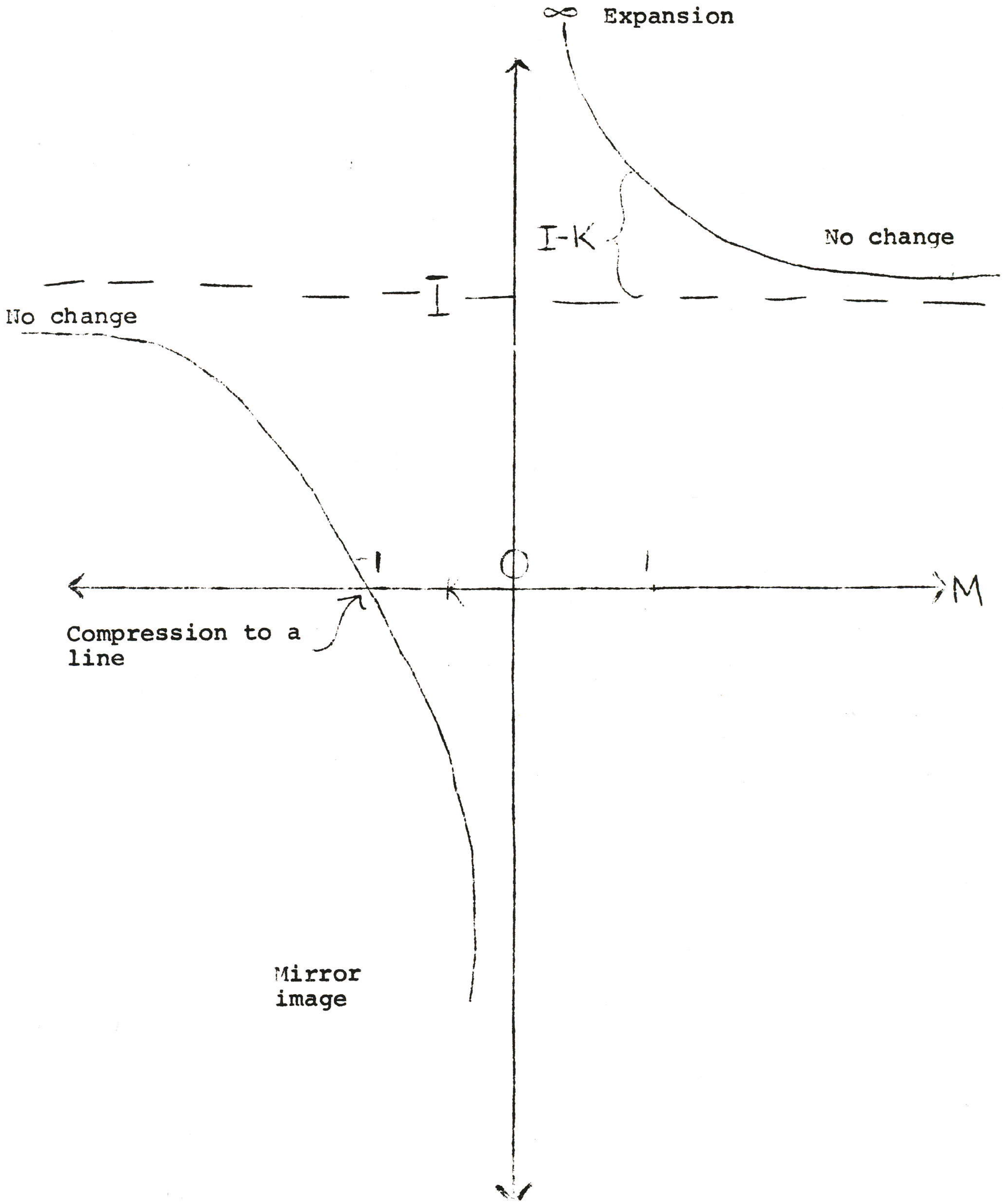

Fig. 1. Relationships of axis coordinate K, cell coordinate I, and compression-expansion parameter M.