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A PROBLEM IN FORM PERCEPTION:
ODD SHAPE DETECTION

By

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Abstract

A procedure to determine an odd shape or form in a given set of shapes, each set consisting of more than two shapes, is described. The "oddness" of a shape in a set of shapes on the basis of a specified feature is defined and then the "most odd" shape on the basis of many detected features is defined. To make the system response like an average human response, modification of an assumed weight vector by means of an "attention mechanism" is considered.

Some of the results attained for various criteria by the system simulation are as follows: (1) A comparison of Linear Separation and Euclidean Distance Separation methods indicates that the Linear Separation model adequately models psychological form perception. (2) The attention mechanism described in this paper gives better system responses than those given without it. (3) The gestalt measure (emphasized in the psychology literature) which is defined as the function of the perimeter and area of a given shape becomes less important. (4) The shape representation used in this paper, called the pattern sequence, $S_r(x_0)$, has many advantages in the analysis of geometric shapes.

Index terms---shape, form, oddness, feature, pattern sequence, linear separation, Euclidean distance separation, attention mechanism, system response, human response.

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1. INTRODUCTION

Stimulated by the publication of Wertheimer's "Principles of Perceptual Organization" in 1923 many psychologists have studied intensively human perception of shape and form. A good survey paper of these studies is found in Hake (1957) and a recent book, Visual Perception of Form by Zusne (1970), is an excellent summary and contains an extensive bibliography. A 1966 collection of papers edited by Leonard Uhr deals with various problems of pattern recognition by computers. However, many of the more crucial problems such as how humans encode shape information, detect near similarity or dissimilarity of shapes, focus attention upon particular aspects of shapes, and achieve perceptual invariance are not yet adequately understood.

A basic weakness of shape/form recognition by present computer systems may stem from the observation that shape/form recognition by humans has not yet been solved on the psychological level. Zusne (1970) says:

In the history of modeling pattern perception on the computer, the task is really one of modeling discrimination rather than recognition. Recognition in a computer is recognition only in a trivial sense. Recognition by organisms implies previous experience, and with experience there accrue meanings to patterns that are uncorrelated in any important way with the physical dimensions of patterns. Whether a machine will ever be able to cope with this problem is uncertain. (page 84)

The objectives of this report are to construct a computer system in which the system response is demonstrably similar to an average human response on a specified task¹ and to provide clues for exploring

1. task: detection, discrimination, recognition, identification, judgment (Hake 1957).

some unsolved problems of shape perception in psychology.

Let us first investigate the problems involved with defining shape and form. Webster's Third New International Dictionary (1961) defines shape as "the visual make-up characteristic of a particular item or kind of item: characteristic appearance or visual form, or spatial form or contour that is used". The term "form" is somewhat more nebulous-- it is used by different people to mean different things and by the same person to mean different things on different occasions. Shape, figure, structure, pattern, order, arrangement, configuration, plan, outline, and contour are similar terms without distinct meanings. This indefinite terminology is a source of confusion and a more rigorous terminology may be very much needed. The Webster's Dictionary defines form as "the shape and structure of something as distinguished from the material of which it is composed", and it defines gestalt as "a structure or configuration of physical, biological, or psychological phenomena".

A number of explicit definitions of visual forms have been given by Gibson (1951); they were proposed out of a conviction that "psychologists should come down to earth to say exactly what they mean when they talk about form". According to his proposed definitions solid² forms and surface³ forms are realities. However, there is no such thing as form-in-general with the universal characteristics ascribed to it by gestalt theorists. The only kinds of visual form we shall undertake to deal with hereafter are those associated with or derived from physical objects.

2 Solid form: the closed physical surface enveloping a substance of some kind. The surface may be curved or it may be composed of adjoining flat surfaces with edges.

3 Surface form: a flat physical surface with its edges.

Let us describe briefly what kind of experimental studies have been made on human shape perception by psychologists. They have first tried to define what is the quality of "goodness" in a shape or form. If a line forms a closed or almost closed figure we may no longer see merely a line on a homogeneous background, but a surface figure bounded by the line. It seems that a straight line is a more stable structure than a broken one and that therefore organization will occur in such a way that a straight line will be perceptually continued as a straight line (this idea was implemented by Guzman (1968) in his "Decomposition of Scenes Into Bodies"). Koffka (1935) generalizes this as:

"Any curve will proceed in its own natural way; a circle as a circle, an ellipse as an ellipse, and so forth". Attneave (1954) says that many of the gestalt principles of perceptual organization pertain essentially to information distribution⁴ and the good gestalt is a figure with some high degree of internal redundancy. It may be that an important criteria for "goodness" of form, however, is the relative importance of simplicity and complexity--a "good" configuration being simple. The theory is that our perceptual and memorial processes tend toward simplification of forms.

To get a "good" figure from a given figure, Mowatt (1940) obtained the statistical result that the large majority, about 94%, of all changes to a given figure consist in the addition of lines or dots to the figure. He also shows that open figures are changed much more frequently than closed figures, and he concludes that closure and symmetry are considered "good" properties of a figure. Another way to determine goodness

4. It was demonstrated by Attneave (1954) that information is concentrated at points where there is a change in an otherwise continuous gradient; at the contours of a form which mark the change from ground to figure; and at any inflection along the contour where the direction of the contour changes most rapidly.

of shapes is to determine some kind of threshold function (Bobbitt 1942). For example, the threshold may be stated in terms of the percentage of the total perimeter of the figure present at the point in the series representing the transition between the forms having the quality of twoness and those having the quality of oneness.

In 1955 Deutsch observed that "the perceived form or shape of patterns must be invariant with changes in location and orientation of the patterns, and even minor changes in shape itself". However, recognition of forms and comparative judgment of forms deteriorates when forms are rotated with respect to the observer. In fact, there is considerable evidence to indicate that orientation plays a part in the definition of what we mean by the form of an object (Dodwell 1961). Thus it may be so that the form of an object may not be invariant with rotation of the object and is partly defined in terms of orientation characteristics (see Zusne).

Some of the stimuli, or target shapes, which have been used by psychologists to study the problem of human form perception are: Dot Patterns (French 1954), Metric Figures (Fitts and Leonard 1957), Random Polygons (Attneave and Arnoult 1956) and Computer-Generated Luminous Polygons (Polidora and Thompson 1964). Because of the simplicity of generation by computers, polygons are used quite frequently in psychological experiments. While it is true that a curved shape may be approximated with straight-line segments without appreciable loss of information, some information is irretrievably lost, depending on how crude or fine the approximation is. How such approximation affects perceived complexity is not known.

The methods of polygonal shape representation which have been studied are mostly independent of shape orientation (see Deutsch, 1962, Attneave and Arnoult, 1956). However, it may be that the perceptual

independence of shape orientation may not play as significant a role for form perception in psychology. For the analysis of shapes and forms, a large number of physical characteristics and form invariances have been suggested and studied. Some of these are: the ratio between area and perimeter, maximum dimensions of geometric forms, number of angles and line segments, number of elements in dot patterns, texture, regular-irregular, simple-complex, and first, second, third and fourth moments of area.

There have also been many other studies: theories of visual form perception, perceptual tasks, memory for form, form perception by animals, application, etc., have been done and being continued by thousands of psychologists (see Zusne 1970). However, as we stated earlier in this chapter, knowledge of how humans perceive shape and form on a psychological level is still exceedingly primitive.

The plan of this report is as follows: In Chapter 2, we define shape and form. These concepts are then refined to provide a mechanism to identify the oddness of a shape in a given small collection of shapes on the basis of one or more features. In Chapter 3, we introduce a shape representation called a "pattern sequence", and a process to detect features appropriate for shape representation. In Chapter 4, a system to detect an odd shape or form from a given set of shapes is described, and the comparison between an average humans response and the system response is discussed in Chapter 5. In Appendix A, we show stimuli which are used for the experiment and their features are listed in Appendix B. In Appendix C, an example of the system response on the decision of oddness is given; and other aspects of system response under various criterion are tabulated in Appendix D.

2. DEFINITION

Let us first define shape

Shape: a closed physical contour (or a closed physical surface where the texture is assumed not to influence our system perception of shape.)

Since texture can be considered as one of many features, we can simply modify the feature vector, which will be discussed in the following chapter, to compensate for the texture influences in shape perception. However, in this report, we assume that the texture is identical for shapes presented simultaneously and, thus, we simply omit it.

We assume a system for shape perception which is somewhat similar to the one given by Attneave & Arnoult (1956). That is, we assume that the first stage of shape or form perception is "contour abstraction", the second is "feature detection" and the third stage is "analysis and decision". Our working hypothesis is that neither shape nor form is affected by rotation, translation, or the relative position to other objects.

In this chapter we describe briefly our model system to detect an odd shape in a given set of shapes. The details of the system will be elaborated in the following two chapters. We define an odd shape/form in a given set of shapes as the one different from the others on the basis of some features.

Let us first define discrimination within a given set of shapes on the basis of one single specified feature. (We assume that the given set of shapes to be presented to the subject (man/machine) consists of more than two shapes.) We assume that the given set of shapes consists of n shapes, $\Omega_1, \Omega_2, \dots, \Omega_j, \dots, \Omega_n$.

Assume that a specified feature, $n \geq 3$, takes test results $x_1, x_2, \dots, x_n$ for the n shapes respectively.

Definition 1 Odd Shape/Form on C

We define the D-interval, d_j , for each Ω_j as:

$$d_j = \max_{\substack{k=1 \\ \neq j}}^n \{x_k\} - \min_{\substack{k=1 \\ \neq j}}^n \{x_k\}.$$

Then we define Ω_j as an odd shape/form in the given set of n shapes on the basis of C if $d_j = \min_{k=1}^n \{d_k\}$

To see how the above definition of oddness reflects human response on the basis of a specified feature, let us consider the examples illustrated in Figure 1. We assume, for simplicity, that the specified features are the number of vertices and convexity. Table I shows the extracted feature values for the specified two features, and Table II shows the D-intervals, where we assume that the convex shape is denoted with value 1 and the concave one with 0. For the set A, Ω_4 is said to be an odd shape on the basis of the number of vertices, while Ω_3 would be chosen as an odd shape on the basis of convexity since $d_3 = 0$ is the minimum. For set B, the number of vertices is not significant for the decision of oddness, since d_j , $j = 1, 2, 3, 4$, assume identical values. Similarly, for set B, the feature of convexity does not play any significant role for the decision of oddness since Ω_1 and Ω_2 are concave and Ω_3 and Ω_4 are convex.

The following is an alternative definition of oddness based on a single specified feature:

-
2. It is easy to see that d_j is minimum only if x_j is an extremal.

(a) Set A of Four Shapes

(b) Set B of Four Shapes

Figure 1 Trial Sets of Shapes

Table I Feature Values of Shapes in Figure 1

		Ω_1	Ω_2	Ω_3	Ω_4
Set A	Number of Vertices	5	6	6	3
	Convexity	1	1	0	1
Set B	Number of Vertices	5	4	5	4
	Convexity	0	0	1	1

Table II D-Interval by Definition 1

		Ω_1	Ω_2	Ω_3	Ω_4
Set A	Number of Vertices	3	3	3	1*
	Convexity	1	1	0*	1
Set B	Number of Vertices	1	1	1	1
	Convexity	1	1	1	1

Table III Dispersion by Definition 2

		Ω_1	Ω_2	Ω_3	Ω_4
Set A	Number of Vertices	4	10/3	10/3	4/3*
	Convexity	4/3	4/3	0*	4/3
Set B	Number of Vertices	4/3	4/3	4/3	4/3
	Convexity	4/3	4/3	4/3	4/3

Definition 2 Odd Shape/Form on C

We define dispersion, d_j , for each Ω_j as:

$$d_j = \sum_{k=1, k \neq j}^n |x_k - \bar{x}_j| \text{ where } \bar{x}_j = (\sum_{k=1, k \neq j}^n x_k) / (n-1)$$

Again we define Ω_j as an odd shape/form in the given set of shapes on the basis of feature C if $d_j = \min_{k=1}^n \{d_k\}$.

Table III shows the dispersion for shapes which are illustrated in Figure 1. Comparing Table II and Table III, we see there is no significant difference between the odd shapes detected by Definition 1 and those detected by Definition 2. The only difference that appears in these two tables is in the very first rows for the set A. If we consider detection of two shapes from each set of shapes; one for the most odd shape and the other for the second most odd shape, then the Dispersion approach gives the second most odd shape as either Ω_2 or Ω_3 for the set A on the basis of the number of vertices. However, the D-interval approach gives the second most odd shape as either Ω_1 , Ω_2 or Ω_3 . At this stage, we have no criteria for which definition of oddness is preferable, especially when the number, n , of shapes is small (about 4 to 6). However, as n becomes large then Definition 2 is preferable to Definition 1. These two definitions become identical when n is 3.

Thus far we have discussed oddness of shape on the basis of a single feature, C. We will now expand the above definitions to enable choice of oddness on the basis of m features, $C_1, C_2, \dots, C_i, \dots, C_m$.

Definition 3 Odd Shape/Form on $C_1, \dots, C_i, \dots, C_m$

Let us assume that d_{ij} denotes the D-interval or dispersion of the j -th shape, Ω_j , on the basis of feature C_i , and let

$$H_j = \sqrt[K]{\sum_{i=1}^m (W_i d_{ij})^K} \quad \text{for } j=1,2,\dots,n$$

Then the shape Ω_j is said to be the most odd shape in the given set of n shapes

if

$$H_j = \min_{k=1}^n \{H_k\}$$

Here $W = (W_1, W_2, \dots, W_i, \dots, W_m)$ is called the modified weight vector, which can be adaptively varied, and will be discussed in Chapter 4.

In the above definition, if $K=1$ then the method is called the Linear Separation (LS); if $K = 2$ then this is called the Euclidean Distance³ Separation (EDS); and if $K>3$ it is called the K -th degree Separation.

-
3. Attneave (1950) asserts that psychological distances could not be fitted in Euclidean space since the psychological difference between any two stimuli is approximately equal to the sum of their differences with respect to the physical variables, not to the square root of the sum of the squared differences as demanded by an Euclidean space. A comparison between a Multiple Regression and Multiple Discriminant models can be found in Jones (1971).

3. CONTOUR ABSTRACTION AND FEATURE DETECTION

In this chapter we describe the representation of shape by a pattern sequence, the features which have been chosen to characterize a shape, and the process by which we extract features for each given shape. A simple model for contour abstraction and feature detection is illustrated in Fig. 2 and it will be discussed later.

3.1 Contour Abstraction

Let us first describe a class of target stimuli and then we will introduce the representation of this class. As many experimental psychologists have used polygons for the study of form perception, we will restrict our class of stimuli to a class of polygons. A polygon Ω with basic points p_i , $i = 1, 2, \dots, v$, is said to be angularly simple if there exist a point x_0 and the line $\overline{x_0 p_i}$ does not intersect any edge of Ω for all i . In other words, Ω is angularly simple if and only if there exists x_0 in Ω such that at x_0 the contour of Ω is totally visible.

Definition 4

A Pattern Sequence, $S_r(x_0)$, is defined as follows:

$$S_r(x_0) = s_r, s_{r+1}, \dots, s_{r+i}, \dots, s_{r+N-1}$$

If $r+i < 0$ then $r+i$ is interpreted as $r+i+N$ and then for all i , $r+i \pmod{N}$.

In the above definition, r denotes the rotation index such that $r > 0$ means clockwise rotation of $S_0(x_0)$ by angle $r(2\pi/N)$, and $r < 0$ means counter clockwise rotation by angle $r(2\pi/N)$. x_0 is a point called the encoding point and N is the number of elementary radii called the circularity of the pattern sequence.

We will consider this pattern sequence representation of a class of polygons, especially angularly simple (AS) polygons. As one

Figure 2 Contour Abstraction and Feature Extraction

can see that this representation for a shape simplifies rotation and translation operations. The detailed discussion of the correspondence between polygons and pattern sequences can be found in Maruyama (1971 a, 1971 b).

Stage A Input N number of polygons, $\Omega_1, \dots, \Omega_j, \dots, \Omega_n$

We assume that each polygonal shape, Ω_j , is given as a sequence of point coordinates, $p_1, p_2, \dots, p_v$, where each adjacent pair of coordinates corresponds to an edge of the polygon. Moreover, this sequence is considered closed, i.e. the pair p_v and p_1 are adjacent. An example of a polygon with a sequence of point coordinates, $p_1, \dots, p_{15}$, is illustrated in Figure 3.

Stage B Find the encoding point, x_0 , for each Ω_j

To generate a pattern sequence, $S_0(x_0)$, from a given polygon, we must find the encoding point, x_0 , for each polygon Ω_j . To have a unique pattern sequence for Ω_j we must uniquely determine x_0 . (x_0 should not be affected either by the rotation or translation of Ω_j .) The center of gravity of the polygon can be considered as the encoding point because of the uniqueness of the center of gravity. If we restrict our class of polygons to a class of AS-polygons, we can use a quite different approach of finding the encoding point. Since each angularly simple polygon defines a convex set, which consists of all angularly simple points inside the polygon, we select a point inside the convex set which maximizes, or minimizes, a given objective function¹ (Maruyama 1971 b).

-
1. An example is to maximize $\sum_{i=0}^{n-1} s_i$, or to minimize $\sum_{i=0}^{n-1} (s_i - \bar{s})$,
 $\bar{s} = (\sum_{i=0}^{n-1} s_i)/N$, where the s_i 's are obtained from the contour of the convex set instead of the given polygon.

A polygon illustrated in Figure 3 is an AS-polygon since at any point in the convex polygonal region which is denoted by dotted contour, the entire boundary of the given polygon is visible. An example of a non-AS polygon is illustrated in Figure 4 where x_0 denotes the center of gravity.

Stage C Generation of Pattern Sequences

i) Class of AS-polygons as Stimuli

The encoded configuration of the AS-polygon of Figure 3 is illustrated in Figure 5. The vector which corresponds to the X-coordinate denotes the very first elementary pattern, s_0 , of the pattern sequence, $S_0(x_0)$; the rotation index, r , is assumed to be 0 at this stage, and each elementary pattern, s_i , follows in the counter clockwise direction. In this example, the circularity, N , of the pattern sequence is 48. Figure 6 shows error dependence on the circularity N for the polygon of Figure 3, where the values obtained at $N = 180$ are assumed to be true values. For small circularity, errors are heavily dependent upon the orientation of the given shape. However, for sufficiently large circularity, orientation errors become essentially negligible.

To generate each elementary pattern, s_i , detect the innermost intersection between the line segment at angle $i2\pi/N$ and an edge of the polygon. The pattern sequence generated in this manner is called the interior (or primal) pattern generation.

ii) General Polygons as Stimuli

Let us consider the polygon which is illustrated in Figure 4, where x_0 , the center of gravity, is used as the encoding point to generate a pattern sequence.

Figure 3 Input Representation of a Shape

Figure 4 An Example of A Non-Angularly Simple Polygon (x_0 Denotes the Center of Gravity)

Figure 5 Example of An Encoded Representation
By Pattern Sequence, $S_0(x_0)$

Figure 6 Error ϵ vs. Circularity N for the Polygon in Figure 3

Alternatively, to generate each elementary pattern, s_i , instead of measuring distance from x_0 to the innermost radial intersection, the following method (which is not implemented in the model discussed), called exterior (or dual) pattern generation, is used.

We first choose a circle of radius R which is large enough to contain the polygon, where the center of the circle is the center of gravity of the figure. Then we measure the distance, $\bar{s}_i$, to the outermost radial intersection and the boundary of the encompassing circle of radius R . Finally the desired pattern sequence, $S_0(x_0)$ is derived by $s_i = (R - \bar{s}_i)$ for $i = 0, \dots, N-1$. The above process of generating the pattern sequence, $S_0(x_0)$, of the polygon in Figure 4 is illustrated in Figure 7, where the dotted arrows show the $\bar{s}_i$'s and the solid arrows emanating at x_0 show the s_i 's. The contour obtained by dual pattern generation is also illustrated in Figure 7. As we can see from the contour of the pattern sequence, we lost some information about the polygon of Figure 4. This loss of information can be compensated by the introduction of many pattern sequences (Maruyama 1971b²). However, we feel that the polygon denoted by a single pattern sequence is accurate enough for the study of geometrical shapes.

From a study of the above two methods of generating pattern sequences, we see that sharp corners of polygons do not show up in the abstracted contour. One way to avoid such information loss is to increase the circularity N . However, the problem here is the estimated error of encoding a given shape by a pattern sequence of circularity N . In Figure 8, we show abstracted contours obtained by the primal encoding method applied to the polygon of

2. An exact representation of the contour of a shape (i.e. a pattern sequence which is generated by following the contour of a shape) is described in Maruyama (1971b).

Figure 3 with different values of circularity N . If the circularity is larger than 12, then the abstracted contour holds the outline of the original polygon in Figure 3, even though some minor abrupt changes of the original polygon have disappeared from the abstracted contours. However, when the circularity becomes small, like 6, then the outline of the polygon given by a pattern sequence is completely different from the contour of the original polygon. The detailed discussion of the optimal choice of circularity for our experiments appears in Section 3. (See also Maruyama 1971b).

Stage D Normalization & Orientation

Each elementary pattern, s_i , in the pattern sequence $S_0(x_0)$ of an object Ω_j , is normalized by the maximum-valued elementary pattern s_r , namely

$$s_r = \max_{i=0}^{N-1} \{s_i\}$$

Thus, each value of the elementary pattern of $S_0(x_0)$ ranges from 0 to 1. This normalization process eliminates differences in size of shapes for form perception. (s_r will, however, be stored for consideration of the actual size of the shape.) To assign an orientation for each pattern sequence, $S_0(x_0)$, r is considered to be the orientation of the pattern sequence and the sequence becomes $S_r(x_0)$. This orientation r of $S_r(x_0)$ may be changed if the shape Ω_j to be nearly symmetric. Another way to assign an optimal orientation for a given shape, using an idea of vari-valued logic, has been given by Tareski & Michalski.³

Stage E (Feature Extraction)

This stage will be discussed in the following section.

3. Tareski, V.G. and Michalski, R.S., "Interval Covers Synthesis: Computer Implementation of and Experiments with Algorithm A^q", Department of Computer Science, University of Illinois, Urbana, Illinois, 1971. (in progress)

Figure 7 Dual Encoded Pattern Sequence of the Polygon in Figure 4

(a) $N = 24$

(b) $N = 12$

(c) $N = 6$

Figure 8 Contours Abstracted by Primal Encoding of the Polygon of Figure 3, Illustrating Dependence on Circularity N

3.2 Feature Extraction

The performance of a pattern recognition system depends crucially on the design of the feature extractor. Methods by which features are selected, however, are often intuitive and empirical, and depend upon the designer's experience with the problem. Both feature selection (Jones, 1971, Brown and Owen, 1967, etc.) and dimension reduction (Shepard, 1962, etc.) are important aspects of the design of a shape recognition system. The main guides to feature selection are: (1) Features should be invariant to irrelevant variations, such as limited translation, rotation, changes of scale, etc.; and (2) Differences that are important for distinguishing between patterns of different types need to be emphasized.

Five major features⁴ and physical form measures most highly correlated with these requirements are tabulated by Zusne⁵ (1970, p. 223). They are "Compactness", "Jaggedness", "Skewness" of contours relative to the Y-axis, "Skewness" of contours relative to the X-axis and "Dominant Axis". However, these features are not completely independent of the orientation of the shape.

3.2.1 Description of Selected Features

In Table IV, we list 22 features which are independent of the orientation of a shape. Furthermore, these features are valid not only for a class of polygonal shapes but also for the closely allied class of polynomial

4. Jones (1971) classified measures into 13 major features.

5. The parameters of dispersion, symmetry and elongation are considered to be analogs of the second, third and fourth moments of distribution of the area of a shape (page 215).

Table IV 22 Selected Features

NO.	NAME	DESCRIPTION
F1	MAXAMP	$(s_{\max} - s_{\min})$, where $s_{\max} = \max_i \{s_i\}$ and $s_{\min} = \min_i \{s_i\}$
F2	MEANVDN	$\bar{s} = \sum_{i=0}^{N-1} s_i / N$
F3	DIVE#	$\sum_{i=0}^{N-1} s_i - \bar{s} / N$
F4	DSQUARE	$\sum_{i=0}^{N-1} (s_i - \bar{s})^2 / N$
F5	AVDIVE#	$\sum_{i=0}^{N-1} s_i - \bar{s} / \sum_{i=0}^{N-1} s_i$
F6	ALT#	The number of alternations in $S_r(x_0)$ wrt $\bar{s}$.
F7	MAXIMAL#	The number of maximal points in $S_r(x_0)$.
F8	VERTEX	The number of vertices.
F9	CONVEXV#	The number of convex vertices.
F10	CONCAVEV#	The number of concave vertices.
F11	D-EDGES	Divergence of edge length.
F12	PERIMETER	Perimeter P derived from $S_r(x_0)$.
F13	AREA#	Actual area A derived from $S_r(x_0)$.
F14	P OVER A	P/A
F15	P**2/A	P^2/A
F16	P-SRA	$P/\sqrt{A}$
F17	P-A-S	$(1 - 2\sqrt{\pi A} / P)$
F18	CONVEXITY	Near convexity or concavity.
F19	SYMMETRY	Near symmetry or asymmetry.
F20	IDS	Interval difference sum.
F21	EXTONE	Existence of only one shape which is neither convex nor symmetric.
F22	N-SIMILARITY	Near similarity of dissimilarity.

curved shapes. Features F1 through F19 can be extracted for each shape; the rest, however, are dependent upon the given set of shapes - because of the nature of the feature to be extracted. Some of these features are self evident and for those which are not, brief explanations are given below:

Feature F6: the number of times the sequence $S_r(x_0)$ crosses the circle of radius $\bar{s}$. For the polygon which is illustrated in Figure 9(a), the number of alternations is 8.

Feature F7: the number of local maxima in the sequence $S_r(x_0)$. (This is identical to the number of local minima in the sequence.) In the example of Figure 9, elementary patterns s_0, s_4, s_8 , and s_{12} , correspond to local maxima, and s_2, s_6, s_{10} , and s_{14} , correspond to local minima.

Features F8, F9, and F10: the number of vertices (or the number of convex or concave vertices) is clear for polygonal shapes. For example, the polygon of Figure 9(a) has 12 vertices; 8 convex vertices and 4 concave vertices. However, it is not self evident for the polynomial shape of Figure 9(b), which is represented by the same pattern sequence of the polygon. For polynomial curved shapes, the number of convex vertices is defined to be the number of maximal points in $S_0(x_0)$; similarly the number of concave vertices is defined as the number of minimal points in $S_0(x_0)$. Thus the number of vertices is the sum of the number of local maxima and minima. In the example of Figure 9(c) there are 4 convex vertices and 4 concave vertices.

(a) A Polygon and a Circle of Radius $\bar{s}$

(b) A Polynomial Curved Shape

(c) The Sequence, $S_0(x_0)$, of the Above Polygon

Figure 9 Examples of Shapes and Their Pattern Sequences, $S_0(x_0)$

Feature F11: for a polygonal shape, Feature F11 is defined as

$$\sum_j |e_j - \bar{e}| / (\text{actual perimeter})$$

where e_j is the j -th edge length and $\bar{e}$ is the mean edge length. This feature value for the polygon of Figure 9(a) is zero since all edge lengths are identical. For a polynomial curved shape, distances between adjacent pairs of extrema (maximal and minimal points) are considered to be the e_j 's. For example, in Figure 9(c), $\overline{s_0 s_2}$ is an edge and $\overline{s_0 s_1} + \overline{s_1 s_2}$ is a curve length for the shape of Figure 9(b). In other words, the distance between two adjacent extrema or the arc length between two adjacent extrema is interpreted as e_j .

Feature 18: a shape Ω_j is said to be nearly convex if for each pair of adjacent maximal elementary patterns the minimal elementary pattern between the pair is greater than the minimal pattern obtained by assuming that the pair form a straight edge of the given shape. In Figure 9(c), for example, s_0 and s_4 are a pair of adjacent maxima and s_2 is the minimal elementary pattern. Since the minimal pattern length which is derived by assuming that the pair s_0 and s_4 is connected with a straight edge is greater than the length of s_2 , we conclude that the shape which is denoted by the pattern sequence of Figure 9(c) is near concave.

Feature F19: a shape Ω_j is said to be nearly symmetric⁶ for orientation r if the following property holds for $S_r(x_0)$:

$$|s_{r+i} - s_{r-i}| < 0.14 \cdot \max(s_{r+1}, s_{r-1})$$

for $i = 1, 2, \dots, N/2 - 1$, where if $r-i < 0$ then $r-i$ is interpreted to be $N+r-i$ and $r+i \pmod{N}$ for all i .

Feature F20: let s_i^k denote the i -th elementary pattern of the k -th shape. Then the 20th feature value of the j -th shape Ω_j, x_{20j} , is defined as:

$$x_{20j} = \frac{\sum_{i=0}^{N-1} (\max_{\substack{k=1 \\ \neq j}}^n \{s_i^k\} - \min_{\substack{k=1 \\ \neq j}}^n \{s_i^k\})}{N}.$$

Feature 22: the near similarity of shapes is defined as follows.

Let us define a mask bit M_i for each feature C_i , $i = 1, 2, \dots, 21$, where M_i assumes either 0 or 1 depending upon which features, C_1 through C_{21} , should be satisfied by "near" similar shapes, e.g. $M_i = 1$ for all i . Then we define shape Ω_j to be the odd shape in the set of n shapes only if the shape Ω_j is detected as an odd shape for those features whose mask bit is one.

6. The parameter of symmetry is considered to be the analog of the third moment of distribution of area [Brown and Owen (1967)].

3.2.2 Feature Dependence on Circularity

In the first section of this chapter, we briefly discussed feature value dependence upon the circularity N . Here, we will continue this discussion as well as illustrate how circularity affects the detection of the odd shape using the four shapes: Ω_1 , Ω_2 , Ω_3 , and Ω_4 (illustrated in Figure 10). Tables V and VI show MEANVDN(F2) values and DSQUARE(F4) values of these four shapes with respect to different choices of circularity N , respectively. In these two tables, those feature values extracted at circularity $N=96$, whose values are identical to those extracted at $N=180$, are considered to be true feature values of the given shapes. To illustrate feature dependence on circularity, errors of MEANVDN and DSQUARE for shapes Ω_1 , Ω_2 , Ω_3 , and Ω_4 , with respect to different circularities, N , are illustrated in Figures 11, 12, 13, and 14, respectively. Roughly speaking, errors decrease as the circularity N increases for $N \geq 48$.

To understand how these errors affect the detection of odd shapes with respect to differences in circularity, we show, in Table VII, odd shapes detected at different circularities on 16 features, again using the four shapes of Figure 10. As we can see from the table, for $N \geq 48$, the odd shape detected for each feature is stable. However, for smaller N , detected shapes vary. It is interesting to note that the variation of circularity does not influence significantly the detection of an odd shape on the basis of a single specified feature, especially for $N \geq 24$. Those features which are influenced by the reduction of circularity and which also affect seriously the detection of the odd shape are DIVE#(F3) and MAXIMAL#(F7). From the above argument, we conclude that circularity $N=48$ is sufficient for the design of our model. As examples of computer extracted features, feature values for the shapes of Figure 10 are tabulated in Table VIII.

Ω_1

Ω_2

Ω_3

Ω_4

Figure 10 An Example of a Set of Four Shapes
for the Detection of the Odd Shape

Table V MEANVDN (F2) With Respect To
Different Circularity N.

$N \backslash \Omega$	Ω_1	Ω_2	Ω_3	Ω_4
6	0.700	0.489	0.992	0.368
12	0.597	0.467	0.970	0.415
18	0.614	0.433	0.950	0.328
24	0.601	0.439	0.916	0.350
36	0.615	0.433	0.949	0.335
48	0.607	0.4305	0.911	0.329
72	0.608	0.429	0.910	0.324
96	0.608	0.428	0.910	0.323

Table VI DSQUARE (F4) With Respect To
Different Circularity N

$N \backslash \Omega$	Ω_1	Ω_2	Ω_3	Ω_4
6	0.0900	0.0538	0.0001	0.0800
12	0.0794	0.0576	0.0001	0.1126
18	0.0799	0.0327	0.0009	0.0406
24	0.0661	0.0359	0.0017	0.0651
36	0.0806	0.0303	0.0009	0.0501
48	0.0731	0.0282	0.0012	0.0436
72	0.0751	0.0265	0.0011	0.0384
96	0.0761	0.0259	0.0010	0.0365

Figure 11 Errors of Shape Ω_1 of Figure 11 With Respect to Different Circularities, N

Figure 12 Errors of Shape Ω_2 of Figure 11 With Respect to Different Circularities, N

Figure 13 Errors of Shape Ω_3 of Figure 11 With Respect to Different Circularities, N

Figure 14 Errors of Shape Ω_4 of Figure 11 With Respect to Different Circularities, N

Table VII Odd Shapes Detected At Different Circularities, N,
On Different Features Using the Shapes of Figure 9
(Those rows marked with * indicate features which
are influenced by the variation of circularity and
which are also affected for the detection of the
odd shape.)

[illegible]

Table VIII Computer Extracted Features
for Shapes Ω_1 , Ω_2 , Ω_3 , and Ω_4
of Figure XI

OBJECT NO =	1	2	3	4
MAXAMP =	0.7196	0.6865	0.1191	0.8380
MEANVDN =	0.6072	0.4305	0.9111	0.3289
DIVE# =	0.2482	0.1253	0.0273	0.1504
DSQUARE =	0.0731	0.0282	0.0012	0.0436
AVDIVE# =	0.4087	0.2911	0.0299	0.4573
ALT# =	8	4	16	6
MAXIMAL# =	4	4	8	3
VERTEX# =	12	4	8	6
CCNVEXV# =	8	4	8	3
CCNCAVEV# =	4	0	0	3
D_EDGES =	0.3045	0.0047	0.0024	0.0075
PERIMETER =	7.4614	4.1925	5.9203	5.5440
AREA# =	548.5852	384.5632	2081.8154	226.7480
P OVER A =	5.5349	6.4110	2.2750	12.9339
P**2 / A =	41.2979	26.8779	13.4688	71.7050
P_SRA =	6.4263	5.1844	3.6700	8.4679
P_A_S =	0.4484	0.3162	0.0341	0.5814
	SYMMETRIC	SYMMETRIC	SYMMETRIC	SYMMETRIC
	CCNCAVE	CONVEX	CONVEX	CONCAVE
ICS =	30.5607	30.4554	18.1797	24.1289

4. A SYSTEM TO DETECT AN ODD FORM

We described the outline of our model for the detection of an odd shape/form among a given set of shapes in Chapter 2. This chapter develops the model rigorously. The block diagram of our model is illustrated in Figure 15 and we shall discuss here the role of each block.

Let us assume that for shapes Ω_j , $j = 1, \dots, n$, that $\vec{X}_j$, $j = 1, \dots, n$, are feature vectors of dimension m , respectively, where:

$$\begin{aligned} \vec{X}_1 &= (x_{11}, x_{21}, \dots, x_{i1}, \dots, x_{m1})^T \\ &\vdots \\ \vec{X}_j &= (x_{1j}, x_{2j}, \dots, x_{ij}, \dots, x_{mj})^T \\ &\vdots \\ \vec{X}_n &= (x_{1n}, x_{2n}, \dots, x_{in}, \dots, x_{mn})^T \\ X &= (\vec{X}_1, \vec{X}_2, \dots, \vec{X}_j, \dots, \vec{X}_n)^T \\ &= [x_{ij}]_{m \times n}, x_{ij} \in R \end{aligned}$$

m : the number of features considered,
 n : the number of shapes presented,
 x_{ij} : the feature value of the j -th shape Ω_j on the basis of the i -th feature.

4.1 Analysis

A D-Table is defined as:

$$D = [d_{ij}]_{m \times n}$$

where, Case 1 (Using Definition 1 of D-interval)

$$d_{ij} = \hat{d}_{ij} - \check{d}_{ij} \text{ where } \hat{d}_{ij} = \max_{k \neq j} \{x_{ik}\} \\ \check{d}_{ij} = \min_{k \neq j} \{x_{ik}\}.$$

Figure 15 A System to Detect An Odd Shape/Form Among A Given Set of N Shapes

Case 2 (Using Definition 2 of Dispersion)

$$d_{ij} = \sum_{\substack{k=1 \\ k \neq j}}^n |x_{ik} - \bar{x}_{ij}|$$

where $\bar{x}_{ij} = (\sum_{\substack{k=1 \\ k \neq j}}^n x_{ik}) / (n-1)$

Thus, d_{ij} denotes the original D-interval or dispersion for the shape Ω_j on the basis of the i -th feature, C_i . Since we are dealing with m different features, we will normalize the D Table, i.e., $d_{ij} = d_{ij} / \hat{d}_i$ where $\hat{d}_i = \max_j \{d_{ij}\}$. This is quite important because each individual feature value is evaluated by quite different scales.

The T Table, which is derived from the D Table, may be used to save storage for our model:

$$T = [t_{ij}]_{m \times n}$$

$$\text{where } t_{ij} = \begin{cases} 1 & \text{if } d_{ij} = \min_k \{d_{ik}\} \\ 0 & \text{otherwise} \end{cases}$$

Thus t_{ij} is 1 if and only if shape Ω_j is defined as an odd shape, by either Definition 1 or 2, on the basis of the i -th feature C_i .

4.2 Attention and Weight Modification

Since humans pay attention to some features more than others (these attention centering features varying with the object) we will introduce a mechanism, called the attention mechanism, into our model. We call ϕ the attention function and we assume ϕ is a mapping from the D table into a vector $\vec{A}$ of dimension m, called the attention vector.

Thus

$$\phi : D \rightarrow \vec{A}$$

$$\text{where } \vec{A} = (A_1, A_2, \dots, A_i, \dots, A_m)$$

$A_i \in \mathbb{R}$ called the attention factor for the i-th feature detection.

Note that $\phi(D)$ assumes different values for different sets of shapes.

Without loss of generality, we write

$$A_i = \phi_i (d_{i1}, d_{i2}, \dots, d_{ij}, \dots, d_{in})$$

for $i = 1, 2, \dots, m$. To simplify our model we assume that $\phi = \phi_i$ for all i. Then the modified weight vector $\vec{W}$

$$\vec{W} = (W_1, W_2, \dots, W_i, \dots, W_m)$$

is defined as $W_i = \omega_i A_i$ for all i where

$$\vec{\omega} = (\omega_1, \omega_2, \dots, \omega_i, \dots, \omega_m)$$

is the originally given (or assumed) weight vector (e.g., $\vec{\omega} = (1, 1, \dots, 1)$ implies that all features are considered to be equally significant).

Let us give a simple example of such an attention function ϕ ;

$$\phi : (\alpha_i, \beta_i) \rightarrow A_i \text{ for all } i \text{ where } \alpha_i = \min_k \{d_{ik}\},$$

$$\beta_i = \min_k \{d_{ik} | d_{ik} \neq \alpha_i\}.$$

More explicitly

$$A_i = \phi (\beta_i - \alpha_i)$$

Figure 16 An Example of Attention Function
 $\phi: (\beta_i - \alpha_i) \rightarrow A_i$ Where $A_i \in [0,1]$

and ϕ has a property such that whenever $\beta_i - \alpha_i > \beta'_i - \alpha'_i$ then

$$\phi(\beta_i - \alpha_i) \geq \phi(\beta'_i - \alpha'_i) \text{ holds.}$$

A simple example of such a function ϕ is illustrated in Fig. 16, where

$A_i = \phi(\beta_i - \alpha_i) = \beta_i - \alpha_i$ for all i . Many other attention functions based on the value $(\beta_i - \alpha_i)$ are discussed in the following chapter.

4.3 Decision and Selection

The role of this block is to form a vector $\vec{H}$ of n dimensions and then select an odd shape according to Definition 3.

$$\vec{H} = (H_1, H_2, \dots, H_j, \dots, H_n)$$

where: Case 1 (D Table is used)

$$H_j = \sqrt[K]{\sum_{i=1}^m (w_i d_{ij})^K}, \quad K \geq 1$$

Case 2 (T Table is used)

$$H_j = \sqrt[K]{\sum_{i=1}^m (w_i t_{ij})^K}, \quad K \geq 1.$$

The selection of the most odd shape or form is accomplished in the following manner:

Case 1

Ω_j is the first choice odd shape if $H_j = \min_{k=1}^n \{H_k\}$

Ω_ℓ is the second choice odd shape if $H_\ell = \min_{k=1}^n \{H_k | \neq H_j\}$

Case 2

Ω_j is the first choice odd shape if $H_j = \max_{k=1}^n \{H_k\}$.

Ω_l is the second choice odd shape if $H_l = \min_{k=1}^n \{H_k | \neq H_j\}$.

To get some idea of how our model behaves, let us consider an example of detecting an odd shape or form from a set of four shapes; Ω_1 , Ω_2 , Ω_3 and Ω_4 , which are illustrated in Fig. 10. The computer extracted feature vectors $\vec{X}_1$, $\vec{X}_2$, $\vec{X}_3$ and $\vec{X}_4$ for shapes Ω_1 , Ω_2 , Ω_3 and Ω_4 respectively, are tabulated in Table IX. In this example, for the sake of simplicity, we consider 8 features labelled as $C_1, C_2, \dots, C_8$. In Fig. 17, we plot these feature values, which are normalized, for each shape to understand the variation of feature values for the considered 8 features. At this stage, it is not clear which shape our model will select as an odd shape. The D-table, given by Definition 1 (D-interval) in Chapter 2, which is derived from feature vectors of Table IX is tabulated in Table X. The value $(\beta_i - \alpha_i)$ for each feature C_i is also shown in the very last column. In Fig. 18, we plot D-intervals for each feature of Table IX and the value $(\beta_i - \alpha_i)$ for feature C_i is indicated with a solid line segment for all i . From this, it is now clear to see which shape will be selected as an odd shape or form on the basis of a single feature C_i for $i = 1, \dots, 8$. This is also confirmed from T-table which is tabulated in Table XI. The selected most odd shape or form for each feature is shown in the very last column of T-table.

Figure 17 Plotted Feature Values of Table IV (Normalized)
 (The Symbol, $\cdot$, Denotes Ω_1 , x Denotes Ω_2 ,
 Δ Denotes Ω_3 and $\circ$ Denotes Ω_4 .)

Table IX The Feature Vectors $X_1, X_2, X_3,$ and X_4 of the Shapes $\Omega_1, \Omega_2, \Omega_3,$ and Ω_4 Respectively, where the Sigmas are those illustrated in Figure 10.

Feature \ Shape	Ω_1	Ω_2	Ω_3	Ω_4
C_1 DSQUARE	0.0731	0.0282	0.0012	0.0436
C_2 DIVE#	0.2482	0.1253	0.0273	0.1504
C_3 MEANVDN	0.6072	0.4305	0.9111	0.3289
C_4 ALT#	8	4	16	6
C_5 MAXIMAL#	4	4	8	3
C_6 P-SRA	6.4263	5.1844	3.6700	8.4679
C_7 VERTEX#	12	4	8	6
C_8 AREA#	549	385	2082	227

Table X D-table Derived From the Feature Vectors in Table IX

Feature \ Shape	Ω_1	Ω_2	Ω_3	Ω_4	$\beta_i - \alpha_i$
C_1	0.59	1.00	0.62	1.00	0.02
C_2	0.56	1.00	0.56	1.00	0.00
C_3	1.00	1.00	0.48	0.83	0.35
C_4	1.00	0.83	0.33	1.00	0.50
C_5	1.00	1.00	0.20	0.80	0.60
C_6	1.00	1.00	0.68	0.57	0.11
C_7	0.50	0.75	1.00	1.00	0.25
C_8	1.00	1.00	0.17	0.91	0.74

Figure 18 Plotted D-Intervals of Table V -
 (Solid Intervals Show Values $(\beta_1 - \alpha_1)$;
 • Denotes Ω_1 ; x Denotes Ω_2 ; Δ Denotes
 Ω_3 ; and x Denotes Ω_4 .)

Table XI T-table Derived From the D-table of Table X

Shape Feature	Ω_1	Ω_2	Ω_3	Ω_4	The Most Odd Shape
C_1	1	0	0	0	Ω_1
C_2	1	0	1	0	Ω_1 or Ω_3
C_3	0	0	1	0	Ω_3
C_4	0	0	1	0	Ω_3
C_5	0	0	1	0	Ω_3
C_6	0	0	0	1	Ω_4
C_7	1	0	0	0	Ω_1
C_8	0	0	1	0	Ω_3

Table XII The $\vec{H}$ Vector is Evaluated
The Most Odd Shape is Marked With *

Shape	Ω_1	Ω_2	Ω_3	Ω_4
$\sum_i w_{ij} d_{ij}$	6.65	7.58	4.04*	7.11
$\sum_i w_{ij} t_{ij}$	3	0	5*	1
$\sum_i W_{ij} d_{ij}$	2.51	2.43	0.91*	2.27
$\sum_i W_{ij} t_{ij}$	9.27	0.00	2.19*	0.11

For the decision of the most odd shape or form on the basis of 8 features, in the given example, let us assume that all features are considered to be equally significant, i.e., the originally given weight vector $\vec{w}$ is:

$$\vec{w} = (1, 1, 1, 1, 1, 1, 1, 1).$$

We also assume that our attention function is simply

$$A_i = \emptyset (\beta_i - \alpha_i) = \beta_i - \alpha_i \text{ for all } i,$$

which is illustrated in Fig. 10. Thus our modified weight vector $\vec{W}$ becomes:

$$\vec{W} = (0.02, 0, 0.35, 0.5, 0.67, 0.11, 0.25, 0.74),$$

which is shown in the very last column of Table X. Finally, vectors $\vec{H}$ are evaluated for various parameters; with or without our attention mechanism and D or T tables, are tabulated in Table XII. For example, the row of $\sum_i w_i t_{ij}$ indicates the values which are evaluated by using T-table without attention mechanism (i.e., the given weight vector is not modified), and the row of $\sum_i W_i d_{ij}$ indicates the values which are evaluated by using D-table with attention mechanism (i.e., the given weight vector is modified).

For each evaluation, the most odd shape or form selected by the model is marked with *, and as the result, the third shape Ω_3 is selected.

5. HUMAN RESPONSE AND SYSTEM RESPONSE

In this chapter we compare human response and our system response to the task of detecting an odd shape from a given set of four shapes. The data stimuli, 20 sets of four shapes each, are illustrated in Appendix A, and their computer extracted feature values are listed in Appendix B.

5.1 Human Response

To get an average human response to the 20 sets of shapes, we obtained exactly 100 student samples on campus at the University of Illinois. We asked each student to pick an odd shape from each set of shapes and we counted the frequency of response for each shape. Table XIII shows the human response for each set. For the first set of shapes, for example, 57 students chose the second shape, Ω_2 , as an odd shape, 22 students chose Ω_3 as an odd shape, and 17 students chose Ω_1 as an odd shape. Thus the human response for the first set of shapes is Ω_2 as the most odd shape and Ω_1 or Ω_3 as the second most odd shape. This response is denoted as $\Omega_2/\Omega_1, \Omega_3$ (for the sake of simplicity we write 2/1,3). Considering the 7-th set of shapes in Appendix A, Ω_1 , Ω_3 , and Ω_4 are identical except for their rotation. Therefore, shape Ω_2 should be chosen most frequently as the odd shape. According to Table VIII, 98 students chose Ω_2 and two students chose Ω_4 as the odd shape. The average human response is Ω_2 and is denoted by 2/ .

5.2 Attention Function

As an example of the system response, a complete computer printout for the 9-th set of shapes is found in Appendix C.

Before we compare our system response to the human response we shall introduce the attention function, ϕ . ϕ is of the form $A_i = \phi(\gamma)$, where $\gamma = \beta_i - \alpha_i$ (see Chapter 4). We focus our discussion on the following two

Table XIII HUMAN RESPONSE: The numbers represent the number of times each shape was chosen as ~~off~~ by students. The average human response is $i/j (\Omega_i/\Omega_j)$.

	Ω_1	Ω_2	Ω_3	Ω_4	Average H.R.
1	17	57	22	4	2/1,3
2	46	5	48	1	1,3/
3	44	12	35	9	1,3/
4	1	0	97	2	3/
5	1	8	86	5	3/
6	9	65	4	22	2/4
7	0	98	0	2	2/
8	35	20	20	25	1,2 3,4
9	22	6	67	5	3/1
10	2	11	31	56	4/3
11	88	0	11	1	1/3
12	4	0	42	54	3,4/
13	44	42	1	13	1,2/4
14	26	29	22	23	1,2 3,4
15	23	16	42	19	3/1,2,4
16	31	35	4	30	1,2,3
17	44	13	1	42	1,4/2
18	7	14	68	11	3/2,4
19	50	28	15	7	1/2,3
20	81	4	5	10	1/4

types of attention functions:

$$(1) \quad \phi(\gamma) = \gamma^k, \quad k > 0$$

$$(2) \quad \phi(\gamma) = [C_1 \sin(\pi + C_2 \gamma) + 1]_0^1$$

where $[X]_0^1$ means if $X > 1$ then $\phi(\gamma) = 1$ and if $X < 0$ then

$\phi(\gamma) = 0$, otherwise $\phi(\gamma) = X$.

The first type of attention functions, γ^k , $1/2 \leq k \leq 4$, are illustrated in Figure 19. The second type of attention functions, with $C_1 = 0.4$ and $5.23 \geq C_2 \geq 3.93$, are illustrated in Figure 20. Figure 21 shows attention functions of the second type with $C_1 = 0.2$ and $5.23 \geq C_2 \geq 3.93$. We will see later, after running our model for various attention functions, that the second type of attention functions, which consist of trigonometric functions and linear functions with $C_1 = 0.2$, are at least as good as those functions discussed above. For a comparison with other attention factors see [Maruyama 1971 b].

The following is notation and abbreviation used for the system response.

(i) D-interval: oddness given by Definition 1

Dispersion: oddness given by Definition 2

LS: Linear Separation

EDS: Euclidean Distance Separation

D: D-table (See Chapter 4)

T: T-table (See Chapter 4)

(ii) HR: Average Human Response (See Table XIII)

CR: The percentage of Correct System Responses with respect to the average Human Response.

5.3 Weight Vectors

Various weight vectors for two classes of features are tabulated in Table XIV. The first class of features consists of 16 features and the

Figure 19 Attention Function of the Form
 $\phi(\gamma) = \gamma^k, 1/2 \leq k \leq 4$

Figure 20 Attention Function of the Form
 $\phi(\gamma) = [0.4 \sin(\pi + c_2 \gamma) + \gamma]_0^1$,
 $3.93 \leq c_2 \leq 5.23$

Figure 21 Attention Function of the Form
 $\phi(\gamma) = [0.2 \sin(\pi \cdot C_2 \gamma) + \gamma]_0^1$,
 $3.93 \leq C_2 \leq 5.23$

Figure XIV Weight Vectors

No.	Weight Vector $\vec{w}$					
	No.1	No.2	No.3	No.4	No.5	No.6
F1						
F2	1	3	1	1	1	4
F3	1	6	6			
F4	1	6	2	1	8	8
F5	1	5	2			
F6	1	4	1	1	1	7
F7	1	8	3	1	30	23
F8	1	8	10			
F9	1	2	13			
F10	1	2	4			
F11						
F12						
F13	1	4	1	1	1	11
F14						
F15						
F16	1	8	2			
F17				1	2	2
F18	1	5	3			
F19	1	5	3			
F20	1	10	12	1	12	2
F21	1	4	1			
F22	1	20	20	1	20	20

As we can see that the above system is infeasible, we eliminate the 20th row of C, and we try to find a feasible solution, $\vec{w}$, which satisfies the remaining 19 inequalities. We can also see from C that we cannot evaluate the weights, w_{19} , w_{21} and w_{22} , these weights are assumed and assigned as $w_{18} = w_{19}$, where w_{21} is small and w_{22} is quite large (actually the weight of w_{22} does not effect the system response). Thus we obtain a feasible solution for Weight Vector Number 3.

Weight Vector Number 5 is derived from Weight Vector Number 3 by taking into consideration the dependency between features.

5.4 System Responses

Some examples of our system response are tabulated in Table XV, where the LS method and the D-interval are assumed. Those attention functions are illustrated in Figures 19, 20, and 21. The first column indicates the set number of shapes which are illustrated in Appendix A. Columns indicated by D or T show the system response with various assumptions. The next column, denoted by H.R., shows the Average Human Response for those 20 sets of shapes. To compare the behavior of the system with the average human response, the last row, denoted by C.R., shows how many times the system response matches the average human response for the first choice of the odd shape. For example, if the given weight vector is Number 1 and a D-table with no attention mechanism is assumed, then the system response matches the average human response exactly 14 sets out of 20 (a 70% correct response). If the weight vector is Number 3, which is given by the solution of the Linear Programming Problem, and a T-table with an attention mechanism of $C_1 = 0.2$ and $C_2 = 4.49$ are assumed, then the system response matches the human response up to 18 sets out of 20 (a 90% correct response).

Table XV Some System Responses: LS, D-Interval

SET No.	WEIGHT VECTOR No.1				WEIGHT VECTOR No.2				WEIGHT VECTOR No.3				H.R.
	NO AM		$\gamma^{1/2}$		γ		γ^3		$C_1=0.4$ $C_2=5.23$		$C_1=0.2$ $C_2=4.49$		
	D	T	D	T	D	T	D	T	D	T	D	T	
1	3/1	3/1	3/2	3/2	2/3	3/2	2/3	2/3	2/3	2/3	2/3	2/3	2/1,3
2	3/1	3/2	3/1	3/1	3/1	3/1	1/3	1/3	3/1	3/1	3/1	3/1	1,3/
3	3/4	3/4	4/3	3/4	4/3	3/4	4/3	4/3	3/4	3/4	3/4	3/4	1,3/
4	1/3	1/3	3/4	3/1	3/1	3/1	3/4	3/4	3/4	3/4	3/4	3/1	3/
5	3/4	4/3	4/3	4/3	4/3	4/3	4/2	4/3	4/3	4/3	3/4	3/4	3/
6	4/2	4/2	4/2	4/2	4/2	4/2	2/4	2/4	2/4	2/4	2/4	2/4	2/4
7	2/	2/	2/	2/	2/	2/	2/	2/	2/	2/	2/	2/	2/
8	1/3	1/2	3/1	3/1	3/1	3/1	3/1	3/1	3/1	3/1	3/1	3/1	1,2,3,4
9	3/1	3/1	3/4	3/1	3/1	3/1	3/4	3/1	3/4	3/1	3/1	3/1	3/1
10	4/3	4/3	4/3	4/3	4/3	4/3	4/3	4/3	4/3	4/3	4/3	4/3	4/3
11	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3
12	1/4	1/4	1/4	1/4	4/1	1/4	4/1	4/1	4/1	4/1	4/1	4/1	3,4/
13	4/1	4/1	4/1	4/1	4/1	4/1	4/1	4/1	4/2	4/1	4/2	4/1	1,2/4
14	3/1	3/1	1/3	1/3	3/1	3/1	1/2	1/2	1/3	1/3	1/3	1/3	1,2,3,4
15	4/2	4/2	4/2	4/2	4/2	4/2	2/4	2/4	4/2	4/1	4/2	4/2	3/1,2,4
16	2/1	2/1	2/1	2/1	2/4	2/1	2/4	2/4	1/2	1/2	1/2	1/2	1,2,3
17	4/2	4/2	4/1	4/2	4/1	4/1	4/1	4/1	4/1	4/3	4/1	4/3	1,4/2
18	3/4	3/4	3/	3/	3/	3/	3/	3/	3/2	3/2	3/2	3/4	3/2,4
19	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/2,3
20	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/4	1/4	1/4	1/4	1/4
C.R.	70	65	65	70	75	70	80	80	85	85	90	90	

Table XVI lists the features which command the most attention in each of the 20 sets of shapes and also lists the three most heavily weighted features (based on the example using weight vector number 3 of Table XV). We can see from the table that some of the features do not significantly contribute to the detection of the odd shape. Most attention is paid to features F8 (VERTEX#), F9 (CONVEXV#) and F10 (CONCAVEV#).

Other examples of our system response with LS and Divergence are tabulated in Table XVII. Only half the features are considered. If weight vector number 4 with a D-table and no attention mechanism are assumed, then we get about 55 to 60% correct response. However, if weight vector number 6 with a D-table and an attention mechanism of $C_1 = 0.2$ and $C_2 = 4.49$ are assumed, then we get about 70 to 75% correct response. Some other examples of our system response can be found in Appendix D.

5.5 Experimental Results

From our experiments we conclude that we can achieve a wide variety of system responses using different assumptions: different separation methods, definitions of oddness, weight vectors and attention mechanisms. We summarize our overall experimental results as follows:

5.5.1 Definition of Odd Form in Terms of D-interval or Dispersion

The number of shapes, n , in the set decides which definition of oddness is to be used. From our experimental results, if $n \leq 6$ either odd form definition gives almost the same system response. However, when n gets large the oddness definition in terms of Dispersion is preferable.

5.5.2 LS & EDS

For the analysis of the system, the LS model is preferable to the

Figure XVI Features Which Command the Most Attention
and the Three Most Heavily Weighted
Features; Based on Example, Weight Vector
No. 3 of Table XV

Set No.	Features With Large Attention Factors	3 most Havily Weighted Features
1	F8,F18,F10	F8, F10, F18
2	F18,F7,F13	F18,F 8, F 9
3	F18,F10,F 9	F10,F18, F20
4	F 6,F 7,F 8,F 9	F 9,F 8, F 7
5	F16,F13,F 3	F 3,F16, F13
6	F 8,F 9,F 2	F 9,F 8, F 7
7	F3,F2,F16,F5,F13,F20,F22,	F22,F20, F 3
8	F18,F10,F20	F20,F10, F18
9	F13,F 6,F 5	F20,F13, F 8
10	F 7,F 8,F18,F 9,F10	F 9,F 8, F10
11	F 6,F 7,F 8,F18,F 9,F10	F 9,F 8, F10
12	F 7,F 8,F18,F10	F 8,F10, F18
13	F 7,F 8,	F 9,F 7, F 8
14	F 6,F18,F10	F10,F 8, F 3
15	F 6,F 7	F20,F 9, F10
16	F 6,F18,F10	F 9,F10, F18
17	F 7,F16,	F 8,F 9, F20
18	F18,F10,F 8	F 8,F 9, F10
19	F16,F10,F 6	F20,F 8, F10
20	F 6,F18,F 9,F10	F 9,F 8, F10

Table XVII Some System Responses: LS, Divergence

SET No.	WEIGHT VECTOR No.4		WEIGHT VECTOR No.5		WEIGHT VECTOR No.6		H.R.
	NO AM	$\gamma^{1/2}$	γ	γ^3	$C_1=0.4$ $C_2=5.23$	$C_1=0.2$ $C_2=4.49$	
	D T	D T	D T	D T	D T	D T	
1	1/3 3/1	1/3 3/1	1/3 1/3	1/3 1/3	1/2 1/2	1/3 1/3	2/1,3
2	3/2 1/3	3/4 3/1	3/4 4/3	3/4 3/4	3/4 3/1	3/4 3/1	1,3/
3	3/4 4/3	3/1 3/4	3/1 3/1	3/1 3/1	3/1 3/1	3/1 3/1	1,3/
4	1/4 1/2	4/1 1/4	1/4 1/4	4/1 1/4	4/1 4/1	4/1 4/1	3/
5	4/3 4/1	4/3 4/3	3/4 3/4	4/3 4/3	3/4 4/3	3/4 3/4	3/
6	4/1 4/	4/1 4/	4/1 4/	4/1 4/	4/ 4/	4/ 4/	2/4
7	2/ 2/	2/ 2/	2/ 2/	2/ 2/	2/ 2/	2/ 2/	2/
8	1/3 1/2	1/3 1/3	1/3 1/3	1/3 1/3	1/3 1/3	1/3 1/3	1,2,3,4
9	3/4 3/1	3/4 3/1	3/4 3/1	3/4 3/1	3/4 3/1	3/4 3/1	3/1
10	4/3 4/1	4/3 4/2	4/3 4/2	4/3 4/2	4/3 4/2	4/3 4/2	4/3
11	1/3 1/3	1/3 1/3	1/3 1/3	1/3 1/3	1/3 1/3	1/3 1/3	1/3
12	1/2 1/2	3/1 1/3	3/1 3/1	3/1 3/1	3/1 3/1	3/1 3/1	3,4/
13	1/2 1/4	2/1 1/4	2/1 1/4	2/4 2/4	2/4 2/4	2/4 2/4	1,2/4
14	2/4 2/3	2/4 2/4	2/3 2/3	2/4 2/4	2/4 2/4	2/4 2/4	1,2,3,4
15	4/2 2/4	2/4 4/2	2/4 2/4	2/4 2/4	2/4 2/4	2/4 2/4	3/1,2,4
16	4/2 2/4	4/2 4/2	1/4 1/2	1/4 1/4	1/4 1/4	1/4 1/4	1,2,3
17	1/4 1/2	1/4 1/4	1/3 1/3	1/4 1/3	1/4 1/2	1/4 1/2	1,4/2
18	3/4 4/3	1/3 1/3	1/3 1/3	1/3 1/3	1/3 1/3	3/1 3/1	3/2,4
19	1/4 1/4	1/4 1/4	1/4 1/4	1/4 1/4	4/1 4/1	4/1 4/1	1/2,3
20	2/1 2/1	2/1 2/1	2/1 2/1	2/1 2/1	1/2 2/1	1/2 2/1	1/4
C.R.	60 55	60 55	70 65	65 65	70 65	75 70	

EDS model because of its simplicity. According to our computational results, the two models have almost no significant difference in system response. Thus we may conclude that the Linear System is an adequate model for human behavioral psychology.

5.5.3 Given Weight Vector $\vec{\omega}$

It is clear that each feature should have a different weight to achieve a better system response. However, the system response obtained with weight $\omega_i = 1$, for all i , matches the average human response in about 60 to 75% of the cases. Weight vector number 4, which is derived by solving the Linear Programming Problem to satisfy the average human response as closely as possible, gives a better system response than with any other weight vector. The system matches the average human response in 70 to 90% of the cases no matter what other parts of the system are changed.

From weight vector number 3, we may conclude that form invariance - perimeter of the shape divided by the square root of the area - which has been thought important for a long time by many psychologists, is not very significant for shape perception. The most important features (judging by their assigned weights) are: (a) the number of vertices and the number of concave and convex vertices, (b) the degree of matching on $(n-1)$ shapes, and (c) the scattering of the shape, $\sum_{i=0}^{N-1} |s_i - \bar{s}|$ (if the shape is a circle, then the value is 0).

From weight vector number 6, we conclude that the following features which are extracted from a pattern sequence, $S_r(x_0)$, are significant: (a) the number of maximal (or minimal) points in the sequence, (b) the number of alternations in the sequence with respect to $\bar{s}$, and (c) the dispersion of a shape, $\sum_{i=0}^{N-1} (s_i - \bar{s})^2$.

By comparing weight vectors numbers 3, 5 and 6 we see that: (a) the

number of alternations and the number of maximal points in the pattern sequences are independent features; (b) $\sum_{i=0}^{N-1} |s_i - \bar{s}|$ and $\sum_{i=0}^{N-1} (s_i - \bar{s})^2$ are quite dependent features; and (c) the number of maximal points in the pattern sequence strongly corresponds to the number of convex vertices.

5.5.4 D-table and T-table

The system response given in terms of the D-table is better than the system response given in terms of the T-table regardless of the other parts of the system (e.g. weight vector, attention mechanism, separation method, etc.). The system analysis for the T-table, however, is simpler than for the D-table.

5.5.5 Attention Mechanism

We see that the system response using some kind of attention mechanism (in which the attention factor, A_i , is non-decreasing on the value $\beta_i - \alpha_i$) is better than the system response using no such mechanism. Thus we may conclude that the attention function, ϕ ,

$$\phi: (\beta_i - \alpha_i) \rightarrow A_i$$

such that $\beta_i - \alpha_i > \beta'_i - \alpha'_i$ implies $(\beta_i - \alpha_i) \geq (\beta'_i - \alpha'_i)$, which modifies the given weight vector, is not a bad choice for our model.

It is sufficient to set $k \geq 2$ for the attention function of form, $(\beta_i - \alpha_i)^k$, but a slightly better function has the form

$$[C_1 \cdot \sin(\pi + C_2(\beta_i - \alpha_i)) + (\beta_i - \alpha_i)]_0^1.$$

The best values obtained from our experiment are $C_1 = 0.2$ and $C_2 = 4.49$ (illustrated in Figure 21), where the system response matches the average human response in 90% of the cases.

None of the students responded exactly the same as the average human response; their correct response ranged from 65% to 90% (mostly 80 to 85%). Therefore, we see that the system response given by our model reflects the average human response on the odd shape/form detection.

The procedure described in this report was written in PL/1 and implemented on an IBM/360 model 75 computer at the Department of Computer Science, University of Illinois at Urbana-Champaign.

6. CONCLUSION

The procedure described in this report for the detection of an odd shape from a given set of shapes, is based upon the following:

- (1) A shape encoding method called pattern sequence, $S_0(x_0)$.

This method allows us to extract some features which have not previously been considered by psychologists. All of the features listed in Table IV have been extracted from the pattern sequence rather than from the shape representation used as input data, i.e., a sequence of point coordinates.

- (2) Definition 1 (D-interval) and Definition 2 (Dispersion) of an odd shape in a given set of shapes on the basis of one single specified feature.

- (3) Weighting different features.

- (4) The attention mechanism in which attention factors are a function of $(\beta_i - \alpha_i)$ and which modifies the original weight vector.

It has been known for some time that any system response for shape perception can be improved by assigning an appropriate weight for each feature as well as by the selection of appropriate features. In this work we see that the above statement is again confirmed. However, even if assigned weights are not optimal, we can get some improvement on the system response by an attention mechanism which modifies the assigned weight vector according to the given set of shapes. We hope that the model of our attention mechanism will provide some clues for the solution of problems in human form perception: how humans pay attention and how humans reach decisions. The shape representation, a pattern sequence, which is an approximate contour abstraction of a shape unless it is in the class of angularly simple polygons, can be used extensively for the solutions of many other geometric problems

(a good example of an application of this representation can be found in Maruyama 1971 a).

Some related problems are the construction of a system to decide whether a given pair of shapes are near similar or dissimilar, shape clustering, naming of corresponding shapes, and naming of geometrical regions of complicated figures using a given textbook or atlas illustrations.

LIST OF REFERENCES

- Arnoult, M.D., "Shape Discrimination As a Function of the Angular Orientation of the Stimuli", Journal of Experimental Psychology, vol. 47, no. 5, 1954, pp. 323-328.
- Attneave, F., "Dimensions of Similarity", American Journal of Psychology, vol. 63, 1950, pp. 516-556.
- _____, "Some Informational Aspects of Visual Perception", Psychology Review, vol. 61, no. 3, 1954, pp. 183-193.
- Attneave, H., Arnoult, M.D., "The Quantitative Study of Shape and Pattern Perception", Psychology Bulletin, vol. 53, no. 6, 1956, pp. 452-471.
- Bartley, S.H., Principles of Perception, Harper and Row, New York, 1969.
- Bobbitt, J.M., "An Experimental Study of the Phenomenon of Closure as a Threshold Function", Journal of Experimental Psychology, vol. 30, 1942, pp. 273-294.
- Brown, D.R. and Owen, D.H., "The Metrics of Visual Form: Methodological Dyspepsia", Psychology Bulletin, vol. 68, no. 4, 1967, pp. 243-259.
- Calvert, T.W., "Nonorthogonal Projections for Feature Extractions in Pattern Recognition", IEEE Transactions on Computers, May 1970, pp. 447-452.
- Casperson, R.C., "The Visual Discrimination of Geometric Forms", Journal of Experimental Psychology, vol. 40, 1950, pp. 668-681.
- Cohen, G., "Pattern Recognition: Differences Between Matching Patterns to Patterns and Matching Descriptions to Patterns", Journal of Experimental Psychology, vol. 82, no. 3, 1969, pp. 427-434.
- Deutsch, J.A., "A Theory of Shape Recognition", British Journal of Psychology, vol. 46, 1955, pp. 30-37.
- _____, "A System for Shape Recognition", Psychological Review, vol. 69, no. 6, 1962, pp. 492-506.
- Dodwell, P.C., "Coding and Learning in Shape Discrimination", Psychological Review, vol. 68, 1961, pp. 373-382.
- Fitts, P.M. and Leonard, J.A., Stimulus Correlates of Visual Pattern Recognition: A Probability Approach, Ohio State University, Columbus, Ohio, 1957.
- Freeman, H., "On the Encoding of Arbitrary Geometric Configurations", IRE Transactions on Electronic Computers, vol. EC-10, June 1961, pp. 260-268.

- _____, "Apictorial Jigsaw Puzzles: The Computer Solution of a Problem in Pattern Recognition", IEEE Transactions on Electronic Computers, vol. EC-13, April 1964, pp. 118-127.
- Jones, L.E., "Pattern Recognition In Ciological and Technical Systems", Department of Computer Science Seminar, University of Illinois, Urbana, Nov. 17, 1971.
- Gibson, J.J., "What is a Form?", Psychology Review, vol. 58, 1951, pp. 403-412.
- Guzman, A., "Decomposition of Scenes into Bodies", AFIPS Conference Proceedings 33, Part One, December 1968, pp. 291-304.
- Hake, H.W., "Form Discrimination and the Invariance of Form", WADC Technical Report 57-621, October 1957, pp. 60-79.
- Koffka, K., "Points and Lines as Stimuli", in Principles of Gestalt Psychology by Koffka, K., Harcourt, Brace and Co., Inc., 1935.
- Maruyama, K., "A Method For Solving SOFA Problems by Computers", Department of Computer Science, University of Illinois, Urbana, Illinois, Report UIUCDCS-R-71-489, 1971(a).
- Maruyama, K., "A Study of Computational Aspects in Geometry", Ph.D. Proposal, Department of Computer Science, University of Illinois, Urbana, Illinois, may 1971 (b).
- Mowatt, M.H., "Configurational Properties Considered 'Good' by Naive S Objects", American Journal of Psychology, vol. 53, 1940, pp. 46-69.
- Shepard, R.N., "The Analysis of Proximities: Multidimensional Scaling with an Unknown Distance Function I", Psychometrika, vol. 27, no. 2, June 1962, pp. 125-140.
- Shepard, R.N. and Jacqueline, M., "Mental Rotation of Three-Dimensional Objects", Science, vol. 171, no. 3972, February 1971, pp. 701-703.
- Sleight, R.R., and Mowbray, G.H., "Discriminability Between Geometric Figures Under Complex Conditions", Journal of Psychology, vol. 31, 1951, pp. 121-127.
- Somnapan, R., "Development of Sets of Mutually Equally Discriminable Random Shapes", Journal of Experimental Psychology, vol. 76, no. 2, 1968, pp. 297-302.
- Uhr, L. (Ed.), Pattern Recognition, New York, Wiley, 1966.
- Wertheimer, M., "Principles of Perceptual Organization", Psychol. Forsch., vol. 4, 1923, pp. 301-350.
- Zahn, C.T., "Graph-Theoretical Methods for Detecting and Describing Gestalt Clusters", IEEE Transactions on Computers, vol. C-20, no. 1, January 1971, pp. 68-86.

Zigler, M.J., and Northup, K.M., "The Tactual Perception of Forms", American Journal of Psychology, vol. 37, 1926, pp. 391-397.

Zusne, L., "Moments of Area and of the Perimeter of Visual Form as Predictors of Discrimination Performance", Journal of Experimental Psychology, vol. 69, 1965, pp. 213-220.

_____, Visual Perception of Form, Academic Press, New York, 1970.

APPENDIX A

Twenty Sets of Four Shapes Used
in the Experiment

SET - 1

SET - 2

SET - 3

SET - 4

SET - 5

SET - 6

SET - 7

SET - 8

SET - 9

SET - 10

SET - 11

SET - 12

SET - 13

SET - 14

SET - 15

SET - 16

SET - 17

SET - 18

SET - 19

SET - 20

APPENDIX B

Computer Extracted Feature Values for
the Twenty Sets of Shapes Illustrated in Appendix A

Set 1

OBJECT NO =	1	2	3	4
MAXAMP =	0.1662	0.2929	0.3636	0.2257
MEANVCN =	0.8748	0.7958	0.7527	0.8362
DIVE# =	0.0395	0.0728	0.0890	0.0563
DSQUARE =	0.0025	0.0076	0.0114	0.0047
AVDIVE# =	0.0452	0.0914	0.1182	0.0674
ALT# =	8	8	8	8
MAXIMAL# =	8	4	4	4
VERTEX# =	8	4	8	8
CCNVEXV# =	8	4	4	8
CCNCAVEV# =	0	0	4	0
D_EDGES =	0.0025	0.0009	0.0005	0.0009
PERIMETER =	5.7833	5.6621	5.6879	5.6905
AREA# =	1922.0845	1601.6157	1441.7715	1761.2190
P OVER A =	2.4071	2.8281	3.1560	2.5848
P**2 / A =	13.9209	16.0131	17.9512	14.7085
P_SRA =	3.7311	4.0016	4.2365	3.8352
P_A_S =	0.0499	0.1141	0.1633	0.0757
	SYMMETRIC	SYMMETRIC	SYMMETRIC	SYMMETRIC
	CCNVEX	CONVEX	CONCAVE	CONVEX
IDS =	4.0100	5.8601	3.7922	5.8601

Set 2

OBJECT NO =	1	2	3	4
MAXAMP =	0.2929	0.5691	0.2067	0.5199
MEANVCN =	0.8025	0.6695	0.8737	0.7028
DIVE# =	0.0680	0.1187	0.0602	0.1106
DSQUARE =	0.0065	0.0223	0.0049	0.0183
AVDIVE# =	0.0847	0.1773	0.0689	0.1573
ALT# =	8	6	8	6
MAXIMAL# =	4	4	4	4
VERTEX# =	5	7	12	7
CCNVEXV# =	5	6	8	6
CCNCAVEV# =	0	1	4	1
D_EDGES =	0.3002	0.6209	0.9519	0.6358
PERIMETER =	5.5629	4.8950	6.1563	5.0436
AREA# =	1578.6089	1577.7517	1525.8011	1588.8596
P OVER A =	2.7353	3.3322	2.5643	3.1521
P**2 / A =	15.2162	16.3112	15.7864	15.8979
P_SRA =	3.9008	4.0387	3.9732	3.9872
P_A_S =	0.0912	0.1223	0.1078	0.1109
	SYMMETRIC	SYMMETRIC	SYMMETRIC	SYMMETRIC
	CCNVEX	CONCAVE	CONCAVE	CONCAVE
IDS =	9.8010	11.4500	9.5254	12.7994

Set 3

OBJECT NO =	1	2	3	4
MAXAMP =	0.4845	0.5006	0.3572	0.5781
MEANVDN =	0.6792	0.6344	0.7377	0.5758
DIVE# =	0.1209	0.1128	0.0816	0.1269
DSQUARE =	0.0213	0.0196	0.0102	0.0253
AVDIVE# =	0.1780	0.1779	0.1106	0.2204
ALT# =	6	6	6	6
MAXIMAL# =	3	3	4	3
VERTEX# =	4	3	6	6
CONVEXV# =	4	3	6	3
CONCAVEV# =	0	0	0	3
D_EDGES =	0.3930	0.0045	0.0046	0.0051
PERIMETER =	5.2476	5.1985	5.3310	5.2192
AREA# =	956.2048	693.8628	916.6936	583.5623
P OVER A =	3.4894	3.9633	3.0800	4.7312
P**2 / A =	18.3108	20.6034	16.4197	24.6932
P_SRA =	4.2791	4.5391	4.0521	4.9692
P_A_S =	0.1716	0.2190	0.1252	0.2866
	SYMMETRIC	SYMMETRIC	SYMMETRIC	SYMMETRIC
	CONVEX	CONVEX	CONVEX	CONCAVE
IDS =	7.7731	14.4031	12.5530	12.3601

Set 4

OBJECT NO =	1	2	3	4
MAXAMP =	0.7196	0.4588	0.5050	0.2652
MEANVDN =	0.6072	0.8498	0.6568	0.8937
DIVE# =	0.2482	0.1533	0.1199	0.0510
DSQUARE =	0.0731	0.0275	0.0211	0.0047
AVDIVE# =	0.4087	0.1804	0.1825	0.0570
ALT# =	8	8	8	16
MAXIMAL# =	4	8	4	8
VERTEX# =	12	12	8	12
CONVEXV# =	8	8	4	8
CONCAVEV# =	4	4	4	4
D_EDGES =	0.3045	0.1272	0.0010	0.5377
PERIMETER =	7.4614	7.4242	5.9000	6.7795
AREA# =	548.5852	1017.0613	1121.2937	1336.4131
P OVER A =	5.5349	3.1906	4.2093	2.7057
P**2 / A =	41.2979	23.6879	24.8349	18.3432
P_SRA =	6.4263	4.8670	4.9835	4.2829
P_A_S =	0.4484	0.2717	0.2887	0.1723
	SYMMETRIC	SYMMETRIC	SYMMETRIC	SYMMETRIC
	CONCAVE	CONCAVE	CONCAVE	CONCAVE
IDS =	17.4725	17.9097	22.3339	21.8335

Set 5

OBJECT NO =	1	2	3	4
MAXAMP =	0.4596	0.3771	0.4804	0.5566
MEANVDN =	0.6271	0.7053	0.7389	0.5446
DIVE# =	0.0824	0.0703	0.1548	0.1058
DSQUARE =	0.0121	0.0081	0.0283	0.0194
AVDIVE# =	0.1315	0.0996	0.2095	0.1942
ALT# =	8	8	4	4
MAXIMAL# =	4	4	4	4
VERTEX# =	4	4	4	4
CCNVEXV# =	4	4	4	4
CONCAVEV# =	0	0	0	0
D_EDGES =	0.0101	0.0087	0.2534	0.0042
PERIMETER =	4.7210	5.1063	5.4684	4.4446
AREA# =	769.8030	961.8596	955.7085	576.6201
P OVER A =	3.7377	3.2356	3.0517	4.5327
P**2 / A =	17.6458	16.5217	16.6880	20.1460
P_SRA =	4.2007	4.0647	4.0851	4.4884
P_A_S =	0.1561	0.1279	0.1322	0.2102
	SYMMETRIC	SYMMETRIC	SYMMETRIC	SYMMETRIC
	CCNVEX	CONVEX	CONVEX	CONVEX
IDS =	12.3572	10.5421	7.7490	9.0530

Set 6

OBJECT NO =	1	2	3	4
MAXAMP =	0.3521	0.4148	0.3521	0.5855
MEANVDN =	0.7912	0.7463	0.7912	0.6032
DIVE# =	0.0785	0.1183	0.0785	0.1230
DSQUARE =	0.0094	0.0189	0.0094	0.0243
AVDIVE# =	0.0992	0.1585	0.0992	0.2040
ALT# =	6	6	6	6
MAXIMAL# =	4	4	4	3
VERTEX# =	5	4	5	5
CCNVEXV# =	5	4	5	5
CONCAVEV# =	0	0	0	0
D_EDGES =	0.2720	0.2908	0.2720	0.6376
PERIMETER =	5.4524	5.4628	5.4524	4.7789
AREA# =	1431.9861	1113.3801	1431.9861	1016.0078
P OVER A =	2.7447	3.0396	2.7447	3.9560
P**2 / A =	14.9652	16.6046	14.9652	18.9053
P_SRA =	3.8685	4.0749	3.8685	4.3480
P_A_S =	0.0837	0.1301	0.0837	0.1847
	SYMMETRIC	SYMMETRIC	SYMMETRIC	SYMMETRIC
	CCNVEX	CONVEX	CONVEX	CONVEX
IDS =	15.4281	11.1467	15.4281	9.5501

Set 7

OBJECT NO =	1	2	3	4
MAXAMP =	0.8380	0.5781	0.8380	0.8380
MEANVDN =	0.3289	0.5758	0.3289	0.3289
DIVE# =	0.1504	0.1269	0.1504	0.1504
DSQUARE =	0.0436	0.0253	0.0436	0.0436
AVDIVE# =	0.4573	0.2204	0.4573	0.4573
ALT# =	6	6	6	6
MAXIMAL# =	3	3	3	3
VERTEX# =	6	6	6	6
CCNVEXV# =	3	3	3	3
CONCAVEV# =	3	3	3	3
D_EDGES =	0.0075	0.0051	0.0075	0.0075
PERIMETER =	5.5440	5.2192	5.5440	5.5440
AREA# =	226.7480	583.5623	226.7480	226.7480
P OVER A =	12.9339	4.7312	12.9339	12.9339
P*2 / A =	71.7050	24.6932	71.7050	71.7050
P_SRA =	8.4679	4.9692	8.4679	8.4679
P_A_S =	0.5814	0.2866	0.5814	0.5814
	SYMMETRIC	SYMMETRIC	SYMMETRIC	SYMMETRIC
	CONCAVE	CONCAVE	CONCAVE	CONCAVE
IDS =	11.8503	0.0000	11.8503	11.8503

Set 8

OBJECT NO =	1	2	3	4
MAXAMP =	0.1662	0.2929	0.2067	0.2929
MEANVDN =	0.8748	0.7958	0.8737	0.8025
DIVE# =	0.0395	0.0728	0.0602	0.0680
DSQUARE =	0.0025	0.0076	0.0049	0.0065
AVDIVE# =	0.0452	0.0914	0.0689	0.0847
ALT# =	8	8	8	8
MAXIMAL# =	8	4	4	4
VERTEX# =	8	4	12	5
CONVEXV# =	8	4	8	5
CONCAVEV# =	0	0	4	0
D_EDGES =	0.0025	0.0009	0.9519	0.3002
PERIMETER =	5.7833	5.6621	6.1563	5.5629
AREA# =	1922.0845	1601.6157	1525.8611	1578.6089
P OVER A =	2.4071	2.8281	2.5643	2.7353
P*2 / A =	13.9209	16.0131	15.7864	15.2162
P_SRA =	3.7311	4.0016	3.9732	3.9008
P_A_S =	0.0499	0.1141	0.1078	0.0912
	SYMMETRIC	SYMMETRIC	SYMMETRIC	SYMMETRIC
	CONVEX	CONVEX	CONCAVE	CONVEX
IDS =	6.9767	7.2632	3.9262	7.5856

Set 9

OBJECT NO =	1	2	3	4
MAXAMP =	0.7196	0.6865	0.1191	0.8380
MEANVDN =	0.6072	0.4305	0.9111	0.3289
DIVE# =	0.2482	0.1253	0.0273	0.1504
DSQUARE =	0.0731	0.0282	0.0012	0.0436
AVDIVE# =	0.4087	0.2911	0.0299	0.4573
ALT# =	8	4	16	6
MAXIMAL# =	4	4	8	3
VERTEX# =	12	4	8	6
CONVEXV# =	8	4	8	3
CCNCAVEV# =	4	0	0	3
D_EDGES =	0.3045	0.0047	0.0024	0.0075
PERIMETER =	7.4614	4.1925	5.9203	5.5440
AREA# =	548.5852	384.5632	2081.8154	226.7480
P OVER A =	5.5349	6.4110	2.2750	12.9339
P**2 / A =	41.2979	26.8779	13.4688	71.7050
P_SRA =	6.4263	5.1844	3.6700	8.4679
P_A_S =	0.4484	0.3162	0.0341	0.5814
	SYMMETRIC	SYMMETRIC	SYMMETRIC	SYMMETRIC
	CCNCAVE	CONVEX	CONVEX	CONCAVE
IDS =	30.5607	30.4554	18.1797	24.1289

Set 10

OBJECT NO =	1	2	3	4
MAXAMP =	0.2929	0.3448	0.3771	0.5691
MEANVDN =	0.7958	0.8011	0.7053	0.6695
DIVE# =	0.0728	0.1074	0.0703	0.1187
DSQUARE =	0.0076	0.0144	0.0081	0.0223
AVDIVE# =	0.0914	0.1340	0.0996	0.1773
ALT# =	8	6	8	6
MAXIMAL# =	4	4	4	4
VERTEX# =	4	4	4	7
CONVEXV# =	4	4	4	6
CCNCAVEV# =	0	0	0	1
D_EDGES =	0.0009	0.1951	0.0087	0.6209
PERIMETER =	5.6621	5.6389	5.1063	4.8950
AREA# =	1601.6157	1270.8953	961.8596	1577.7517
P OVER A =	2.8281	2.7498	3.2356	3.3322
P**2 / A =	16.0131	15.5060	16.5217	16.3112
P_SRA =	4.0016	3.9378	4.0647	4.0387
P_A_S =	0.1141	0.0998	0.1279	0.1223
	SYMMETRIC	SYMMETRIC	SYMMETRIC	SYMMETRIC
	CONVEX	CONVEX	CONVEX	CONCAVE
IDS =	11.1352	10.5374	11.7781	9.3491

Set 11

OBJECT NO =	1	2	3	4
MAXAMP =	0.2929	0.6316	0.5199	0.6687
MEANVDN =	0.8105	0.6482	0.7028	0.6223
DIVE# =	0.0610	0.1413	0.1106	0.1477
DSQUARE =	0.0061	0.0329	0.0183	0.0371
AVDIVE# =	0.0753	0.2181	0.1573	0.2373
ALT# =	8	8	6	8
MAXIMAL# =	5	4	4	4
VERTEX# =	5	7	7	7
CONVEXV# =	5	6	6	6
CONCAVEV# =	0	1	1	1
D_EDGES =	0.2387	0.5945	0.6358	0.5845
PERIMETER=	5.5507	4.9446	5.0436	4.8495
AREA# =	1544.4607	1524.7361	1588.8596	1482.3557
P OVER A =	2.6775	3.5004	3.1521	3.6685
P**2 / A =	14.8619	17.3084	15.8979	17.7904
P_SRA =	3.8551	4.1603	3.9872	4.2179
P_A_S =	0.0805	0.1479	0.1109	0.1596
	SYMMETRIC	SYMMETRIC	SYMMETRIC	SYMMETRIC
	CONVEX	CONCAVE	CONCAVE	CONCAVE
IDS =	14.2190	12.8305	17.9738	14.9869

Set 12

OBJECT NO =	1	2	3	4
MAXAMP =	0.5381	0.2929	0.4845	0.3636
MEANVDN =	0.7065	0.7958	0.6792	0.7527
DIVE# =	0.1913	0.0728	0.1209	0.0890
DSQUARE =	0.0420	0.0076	0.0213	0.0114
AVDIVE# =	0.2708	0.0914	0.1780	0.1182
ALT# =	4	8	6	8
MAXIMAL# =	4	4	3	4
VERTEX# =	4	4	4	8
CONVEXV# =	4	4	4	4
CONCAVEV# =	0	0	0	4
D_EDGES =	0.3474	0.0009	0.3930	0.0005
PERIMETER=	5.3191	5.6621	5.2476	5.6879
AREA# =	790.5614	1601.6157	956.2048	1441.7715
P OVER A =	3.1515	2.8281	3.4894	3.1560
P**2 / A =	16.7632	16.0131	18.3108	17.9512
P_SRA =	4.0943	4.0016	4.2791	4.2369
P_A_S =	0.1342	0.1141	0.1716	0.1633
	SYMMETRIC	SYMMETRIC	SYMMETRIC	SYMMETRIC
	CONVEX	CONVEX	CONVEX	CONCAVE
IDS =	9.0346	12.5681	10.4528	13.0077

Set 13

OBJECT NO =	1	2	3	4
MAXAMP =	0.5381	0.7489	0.6865	0.7196
MEANVDN =	0.7065	0.4260	0.4305	0.6072
DIVE# =	0.1913	0.1491	0.1253	0.2482
DSQUARE =	0.0420	0.0381	0.0282	0.0731
AVDIVE# =	0.2708	0.3500	0.2911	0.4087
ALT# =	4	6	4	8
MAXIMAL# =	4	3	4	4
VERTEX# =	4	6	4	12
CONVEXV# =	4	3	4	8
CONCAVEV# =	0	3	0	4
D_EDGES =	0.3474	0.0125	0.0047	0.3045
PERIMETER=	5.3191	5.3844	4.1925	7.4614
AREA# =	790.5614	347.9614	384.5632	548.5852
P OVER A =	3.1515	8.1859	6.4110	5.5349
P**2 / A =	16.7632	44.0767	26.8779	41.2979
P_SRA =	4.0943	6.6390	5.1844	6.4263
P_A_S =	0.1342	0.4661	0.3162	0.4484
	SYMMETRIC	SYMMETRIC	SYMMETRIC	SYMMETRIC
	CCNVEX	CCNCAVE	CONVEX	CONCAVE
IDS =	15.6791	18.8120	22.5479	18.8217

Set 14

OBJECT NO =	1	2	3	4
MAXAMP =	0.2067	0.2929	0.3294	0.2257
MEANVDN =	0.8737	0.8095	0.7923	0.8362
DIVE# =	0.0602	0.0640	0.0777	0.0563
DSQUARE =	0.0049	0.0068	0.0088	0.0047
AVDIVE# =	0.0689	0.0790	0.0980	0.0674
ALT# =	8	6	8	8
MAXIMAL# =	4	5	4	4
VERTEX# =	12	5	4	8
CCNVEXV# =	8	5	4	8
CONCAVEV# =	4	0	0	0
U_EDGES =	0.9519	0.2552	0.0884	0.0009
PERIMETER=	6.1563	5.5303	5.5914	5.6905
AREA# =	1525.8611	1495.0222	1436.1384	1761.2190
P OVER A =	2.5643	2.6709	2.8112	2.5848
P**2 / A =	15.7864	14.7707	15.7182	14.7085
P_SRA =	3.9732	3.8433	3.9646	3.8352
P_A_S =	0.1078	0.0776	0.1059	0.0757
	SYMMETRIC	SYMMETRIC	SYMMETRIC	SYMMETRIC
	CCNCAVE	CONVEX	CONVEX	CONVEX
IDS =	7.3885	8.0639	7.0086	8.3878

Set 15

OBJECT NO =	1	2	3	4
MAXAMP =	0.3636	0.2929	0.2929	0.6687
MEANVDN =	0.7527	0.8095	0.7958	0.6223
DIVE# =	0.0890	0.0640	0.0728	0.1477
DSQUARE =	0.0114	0.0068	0.0076	0.0371
AVDIVE# =	0.1182	0.0790	0.0914	0.2373
ALT# =	8	6	8	8
MAXIMAL# =	4	5	4	4
VERTEX# =	8	5	4	7
CONVEXV# =	4	5	4	6
CONCAVEV# =	4	0	0	1
D_EDGES =	0.0005	0.2552	0.0009	0.5845
PERIMETER=	5.6879	5.5303	5.6621	4.8495
AREA# =	1441.7715	1495.0222	1601.6157	1482.3557
P OVER A =	3.1560	2.6709	2.8281	3.6685
P*2 / A =	17.9512	14.7707	16.0131	17.7904
P_SRA =	4.2369	3.8433	4.0016	4.2179
P_A_S =	0.1633	0.0776	0.1141	0.1596
	SYMMETRIC	SYMMETRIC	SYMMETRIC	SYMMETRIC
	CONCAVE	CONVEX	CONVEX	CONCAVE
IDS =	13.1888	12.5351	13.7367	3.9435

Set 16

OBJECT NO =	1	2	3	4
MAXAMP =	0.4588	0.3294	0.4343	0.5781
MEANVDN =	0.8498	0.7923	0.7064	0.5758
DIVE# =	0.1533	0.0777	0.1049	0.1269
DSQUARE =	0.0275	0.0088	0.0159	0.0253
AVDIVE# =	0.1804	0.0980	0.1486	0.2204
ALT# =	8	8	8	6
MAXIMAL# =	8	4	4	3
VERTEX# =	12	4	8	6
CONVEXV# =	8	4	4	3
CONCAVEV# =	4	0	4	3
D_EDGES =	0.1272	0.0884	0.0005	0.0051
PERIMETER=	7.4242	5.5914	5.7658	5.2192
AREA# =	1017.0613	1436.1384	1281.0527	583.5623
P OVER A =	3.1906	2.8112	3.6006	4.7312
P*2 / A =	23.6879	15.7183	20.7602	24.6932
P_SRA =	4.8670	3.9646	4.5563	4.9692
P_A_S =	0.2717	0.1059	0.2220	0.2866
	SYMMETRIC	SYMMETRIC	SYMMETRIC	SYMMETRIC
	CONCAVE	CONVEX	CONCAVE	CONCAVE
IDS =	15.4365	19.0403	16.6637	14.3453

Set 17

OBJECT NO =	1	2	3	4
MAXAMP =	0.5781	0.5381	0.3771	0.2067
MEANVDN =	0.5758	0.7065	0.7053	0.8737
DIVE# =	0.1269	0.1913	0.0703	0.0602
DSQUARE =	0.0253	0.0420	0.0081	0.0049
AVDIVE# =	0.2204	0.2708	0.0996	0.0689
ALT# =	6	4	8	8
MAXIMAL# =	3	4	4	4
VERTEX# =	6	4	4	12
CCNVEXV# =	3	4	4	8
CONCAVEV# =	3	0	0	4
D_EDGES =	0.0051	0.3474	0.0087	0.9519
PERIMETER =	5.2192	5.3191	5.1063	6.1563
AREA# =	583.5623	790.9614	961.8596	1525.8611
P OVER A =	4.7312	3.1515	3.2356	2.5643
P**2 / A =	24.6932	16.7632	16.5217	15.7864
P_SRA =	4.9692	4.0943	4.0647	3.9732
P_A_S =	0.2866	0.1342	0.1279	0.1078
	SYMMETRIC	SYMMETRIC	SYMMETRIC	SYMMETRIC
	CONCAVE	CONVEX	CONVEX	CONCAVE
IDS =	14.5037	16.6524	19.3308	14.2746

Set 18

OBJECT NO =	1	2	3	4
MAXAMP =	0.5855	0.6865	0.7196	0.3521
MEANVDN =	0.6032	0.4305	0.6072	0.7912
DIVE# =	0.1230	0.1253	0.2482	0.0785
DSQUARE =	0.0243	0.0282	0.0731	0.0094
AVDIVE# =	0.2040	0.2911	0.4087	0.0992
ALT# =	6	4	8	6
MAXIMAL# =	3	4	4	4
VERTEX# =	5	4	12	5
CONVEXV# =	5	4	8	5
CONCAVEV# =	0	0	4	0
D_EDGES =	0.6376	0.0047	0.3045	0.2720
PERIMETER =	4.7789	4.1925	7.4614	5.4524
AREA# =	1016.0078	384.5632	548.5852	1431.9861
P OVER A =	3.9560	6.4110	5.5349	2.7447
P**2 / A =	18.9053	26.8779	41.2979	14.9652
P_SRA =	4.3480	5.1844	6.4263	3.8685
P_A_S =	0.1847	0.3162	0.4484	0.0837
	SYMMETRIC	SYMMETRIC	SYMMETRIC	SYMMETRIC
	CONVEX	CONVEX	CONCAVE	CONVEX
IDS =	20.1313	17.6391	20.8248	16.8610

Set 19

OBJECT NO =	1	2	3	4
MAXAMP =	0.8380	0.6687	0.2989	0.1191
MEANVDN =	0.3289	0.6223	0.7835	0.9111
DIVE# =	0.1504	0.1477	0.0663	0.0273
DSQUARE =	0.0436	0.0371	0.0067	0.0012
AVDIVE# =	0.4573	0.2373	0.0846	0.0299
ALT# =	6	8	8	16
MAXIMAL# =	3	4	6	8
VERTEX# =	6	7	6	8
CCNVEXV# =	3	6	6	8
CCNCAVEV# =	3	1	0	0
D_EDGES =	0.0075	0.5845	0.0046	0.0024
PERIMETER=	5.5440	4.8495	5.4343	5.9203
AREA# =	226.7480	1482.3557	1029.7681	2081.8154
P OVER A =	12.9339	3.6685	2.8012	2.2750
P*2 / A =	71.7050	17.7904	15.2225	13.4688
P_SRA =	8.4679	4.2179	3.9016	3.6700
P_A_S =	0.5814	0.1596	0.0914	0.0341
	SYMMETRIC	SYMMETRIC	SYMMETRIC	SYMMETRIC
	CCNCAVE	CCNCAVE	CONVEX	CONVEX
IDS =	16.2614	28.4270	29.7843	24.5342

Set 20

OBJECT NO =	1	2	3	4
MAXAMP =	0.5050	0.3448	0.4845	0.5006
MEANVDN =	0.6568	0.8011	0.6792	0.6344
DIVE# =	0.1199	0.1074	0.1209	0.1128
DSQUARE =	0.0211	0.0144	0.0213	0.0196
AVDIVE# =	0.1825	0.1340	0.1780	0.1779
ALT# =	8	6	6	6
MAXIMAL# =	4	4	3	3
VERTEX# =	8	4	4	3
CCNVEXV# =	4	4	4	3
CCNCAVEV# =	4	0	0	0
D_EDGES =	0.0010	0.1951	0.3930	0.0045
PERIMETER=	5.9000	5.6389	5.2476	5.1985
AREA# =	1121.2937	1270.8953	956.2048	693.8628
P OVER A =	4.2093	2.7498	3.4894	3.9633
P*2 / A =	24.8349	15.5060	18.3108	20.6034
P_SRA =	4.9835	3.9378	4.2791	4.5391
P_A_S =	0.2887	0.0998	0.1716	0.2190
	SYMMETRIC	SYMMETRIC	SYMMETRIC	SYMMETRIC
	CCNCAVE	CONVEX	CONVEX	CONVEX
IDS =	14.8014	12.7787	13.2050	14.6142

APPENDIX C

Examples of System Response for
the Decision of Oddness

***** ANALYSIS OF ODD SHAPE CR FORM DETECTION

***** THE NUMBER OF SHAPES REPRESENTED IS 4 *****

DIFF(1,1)= 1.00000E+00; DIFF(1,2)= 0.00000E+00; DIFF(1,3)= 1.00000E+00; DIFF(1,4)= 1.00000E+00;
 DIFF(2,1)= 1.00000E+00; DIFF(2,2)= 0.00000E+00; DIFF(2,3)= 1.00000E+00; DIFF(2,4)= 1.00000E+00;
 DIFF(3,1)= 1.00000E+00; DIFF(3,2)= 0.00000E+00; DIFF(3,3)= 1.00000E+00; DIFF(3,4)= 1.00000E+00;
 DIFF(4,1)= 1.00000E+00; DIFF(4,2)= 0.00000E+00; DIFF(4,3)= 1.00000E+00; DIFF(4,4)= 1.00000E+00;
 DIFF(5,1)= 1.00000E+00; DIFF(5,2)= 1.00000E+00; DIFF(5,3)= 1.00000E+00; DIFF(5,4)= 1.00000E+00;
 DIFF(6,1)= 1.00000E+00; DIFF(6,2)= 1.00000E+00; DIFF(6,3)= 1.00000E+00; DIFF(6,4)= 1.00000E+00;
 DIFF(7,1)= 1.00000E+00; DIFF(7,2)= 1.00000E+00; DIFF(7,3)= 1.00000E+00; DIFF(7,4)= 1.00000E+00;
 DIFF(8,1)= 1.00000E+00; DIFF(8,2)= 0.00000E+00; DIFF(8,3)= 1.00000E+00; DIFF(8,4)= 1.00000E+00;
 DIFF(9,1)= 1.00000E+00; DIFF(9,2)= 1.00000E+00; DIFF(9,3)= 1.00000E+00; DIFF(9,4)= 1.00000E+00;
 DIFF(10,1)= 1.00000E+00; DIFF(10,2)= 1.00000E+00; DIFF(10,3)= 1.00000E+00; DIFF(10,4)= 1.00000E+00;
 DIFF(11,1)= 1.00000E+00; DIFF(11,2)= 1.00000E+00; DIFF(11,3)= 1.00000E+00; DIFF(11,4)= 1.00000E+00;
 DIFF(12,1)= 1.00000E+00; DIFF(12,2)= 0.00000E+00; DIFF(12,3)= 1.00000E+00; DIFF(12,4)= 1.00000E+00;
 DIFF(13,1)= 1.00000E+00; DIFF(13,2)= 1.00000E+00; DIFF(13,3)= 1.00000E+00; DIFF(13,4)= 1.00000E+00;
 DIFF(14,1)= 1.00000E+00; DIFF(14,2)= 1.00000E+00; DIFF(14,3)= 1.00000E+00; DIFF(14,4)= 1.00000E+00;
 DIFF(15,1)= 1.00000E+00; DIFF(15,2)= 1.00000E+00; DIFF(15,3)= 1.00000E+00; DIFF(15,4)= 1.00000E+00;
 DIFF(16,1)= 1.00000E+00; DIFF(16,2)= 0.00000E+00; DIFF(16,3)= 1.00000E+00; DIFF(16,4)= 1.00000E+00;
 DIFF(17,1)= 1.00000E+04; DIFF(17,2)= 0.00000E+00; DIFF(17,3)= 1.00000E+04; DIFF(17,4)= 1.00000E+04;

ODD#(1)= 2;	TEST(1,1)= 0;	TEST(1,2)= 1;	TEST(1,3)= 0;	TEST(1,4)= 0;
ODD#(2)= 2;	TEST(2,1)= 0;	TEST(2,2)= 1;	TEST(2,3)= 0;	TEST(2,4)= 0;
ODD#(3)= 2;	TEST(3,1)= 0;	TEST(3,2)= 1;	TEST(3,3)= 0;	TEST(3,4)= 0;
ODD#(4)= 2;	TEST(4,1)= 0;	TEST(4,2)= 1;	TEST(4,3)= 0;	TEST(4,4)= 0;
ODD#(5)= -100;	TEST(5,1)= 0;	TEST(5,2)= 0;	TEST(5,3)= 0;	TEST(5,4)= 0;
ODD#(6)= -100;	TEST(6,1)= 0;	TEST(6,2)= 0;	TEST(6,3)= 0;	TEST(6,4)= 0;
ODD#(7)= -100;	TEST(7,1)= 0;	TEST(7,2)= 0;	TEST(7,3)= 0;	TEST(7,4)= 0;
ODD#(8)= 2;	TEST(8,1)= 0;	TEST(8,2)= 1;	TEST(8,3)= 0;	TEST(8,4)= 0;
ODD#(9)= -100;	TEST(9,1)= 0;	TEST(9,2)= 0;	TEST(9,3)= 0;	TEST(9,4)= 0;
ODD#(10)= -100;	TEST(10,1)= 0;	TEST(10,2)= 0;	TEST(10,3)= 0;	TEST(10,4)= 0;
ODD#(11)= -100;	TEST(11,1)= 0;	TEST(11,2)= 0;	TEST(11,3)= 0;	TEST(11,4)= 0;
ODD#(12)= 2;	TEST(12,1)= 0;	TEST(12,2)= 1;	TEST(12,3)= 0;	TEST(12,4)= 0;
ODD#(13)= -100;	TEST(13,1)= 0;	TEST(13,2)= 0;	TEST(13,3)= 0;	TEST(13,4)= 0;
ODD#(14)= -100;	TEST(14,1)= 0;	TEST(14,2)= 0;	TEST(14,3)= 0;	TEST(14,4)= 0;
ODD#(15)= -100;	TEST(15,1)= 0;	TEST(15,2)= 0;	TEST(15,3)= 0;	TEST(15,4)= 0;
ODD#(16)= 2;	TEST(16,1)= 0;	TEST(16,2)= 1;	TEST(16,3)= 0;	TEST(16,4)= 0;
ODD#(17)= 2;	TEST(17,1)= 0;	TEST(17,2)= 1;	TEST(17,3)= 0;	TEST(17,4)= 0;

***** TEST # 1 *****

IF I CONSIDER THE SUM OF THE SQUARE OF RACIAL DIFFERENCES AS THE MEAN TO DETECT CDD SHAPE OR FORM, THEN OBJECT = 2 IS THE ONE TO BE CHOSEN BECAUSE THE OBJECT HAS THE SMALL VALUE COMPARED TO THE REST OF OBJECTS

***** TEST # 2 *****

IF I CONSIDER THE SUM OF THE ABSOLUTE VALUE OF DIFFERENCES, THEN OBJECT = 2 IS THE ONE TO BE CHOSEN BECAUSE THE OBJECT HAS THE SMALL VALUE COMPARED TO THE REST OF OBJECTS

***** TEST # 3 *****

IF I CONSIDER THE MEAN PATTERN, THEN OBJECT = 2 IS THE ONE TO BE CHOSEN BECAUSE THE OBJECT HAS THE LARGE VALUE COMPARED TO THE REST OF OBJECTS

***** TEST # 4 *****

IF I CONSIDER THE INVARIANCE : PERIMETER OVER THE SQRT OF AREA, THEN OBJECT = 2 IS THE ONE TO BE CHOSEN BECAUSE THE OBJECT HAS THE SMALL VALUE COMPARED TO THE REST OF OBJECTS

***** TEST # 5 *****

THIS EXPERIMENT IS IGNORED SINCE I DECIDED NOT TO PAY ANY ATTENTION TO IT, THAT IS THIS TEST IS NO SIGNIFICANT FOR THE GIVEN GROUP OF SHAPES

***** TEST # 6 *****

THIS EXPERIMENT IS IGNORED SINCE I DECIDED NOT TO PAY ANY ATTENTION TO IT, THAT IS THIS TEST IS NO SIGNIFICANT FOR THE GIVEN GROUP OF SHAPES

***** TEST # 7 *****

THIS EXPERIMENT IS IGNORED SINCE I DECIDED NOT TO PAY ANY ATTENTION TO IT, THAT IS THIS TEST IS NO SIGNIFICANT FOR THE GIVEN GROUP OF SHAPES

***** TEST # 8 *****

IF I CONSIDER THE AVERAGE DEVIATION, THEN OBJECT = 2 IS THE ONE TO BE CHOSEN BECAUSE THE OBJECT HAS THE SMALL VALUE COMPARED TO THE REST OF OBJECTS

***** TEST # 9 *****

THIS EXPERIMENT IS IGNORED SINCE I DECIDED NOT TO PAY ANY ATTENTION TO IT, THAT IS THIS TEST IS NO SIGNIFICANT FOR THE GIVEN GROUP OF SHAPES

***** TEST # 10 *****

CONVEXITY OR NON CONVEXITY IS NOT IMPORTANT TO BE CONSIDERED FOR THE ODD SHAPE DETECTION

***** TEST # 11 *****

SYMMETRY OR NON SYMMETRY OF OBJECTS IS NOT AN IMPORTANT CRITERION TO DETECT ODD OBJECT IN THIS CASE

***** TEST # 12 *****

IF I CONSIDER THE AREA, THEN OBJECT= 2 IS THE ONE TO BE CHOSEN BECAUSE THE OBJECT HAS THE LARGE VALUE COMPARED TO THE REST OF OBJECTS

***** TEST # 13 *****

THIS EXPERIMENT IS IGNORED SINCE I DECIDED NOT TO PAY ANY ATTENTION TO IT, THAT IS THIS TEST IS NO SIGNIFICANT FOR THE GIVEN GROUP OF SHAPES

***** TEST # 14 *****

THIS EXPERIMENT IS IGNORED SINCE I DECIDED NOT TO PAY ANY ATTENTION TO IT, THAT IS THIS TEST IS NO SIGNIFICANT FOR THE GIVEN GROUP OF SHAPES

***** TEST # 15 *****

THIS EXPERIMENT IS IGNORED SINCE I DECIDED NOT TO PAY ANY ATTENTION TO IT, THAT IS THIS TEST IS NO SIGNIFICANT FOR THE GIVEN GROUP OF SHAPES

***** INTERVAL DIFFERENCE SUM TEST # 16 *****

IF I CONSIDER THE INTERVAL DIFFERENCE SUM, THEN OBJECT= 2 IS THE ONE TO BE CHOSEN BECAUSE THE OBJECT HAS THE SMALL VALUE COMPARED TO THE REST OF OBJECTS

***** FINAL TEST, SIMILARITY *****

AS THE FINAL ANALYSIS, WE FOUND THAT THE FOLLOWING OBJECT IS ODD SHAPE BECAUSE OTHERS ARE SIMILAR SHAPES EXCEPT THE OBJECT= 2

Set 9

*** ANALYSIS OF GCD SHAPE OR FORM DETECTION ***

*** THE NUMBER OF SHAPES REPRESENTED IS 4 ***

DIFF(1,1)= 5.89664E-01; DIFF(1,2)= 1.00000E+00; DIFF(1,3)= 6.24744E-01; DIFF(1,4)= 1.00000E+00;
 DIFF(2,1)= 5.57500E-01; DIFF(2,2)= 1.00000E+00; DIFF(2,3)= 5.56201E-01; DIFF(2,4)= 1.00000E+00;
 DIFF(3,1)= 1.00000E+00; DIFF(3,2)= 1.00000E+00; DIFF(3,3)= 4.78009E-01; DIFF(3,4)= 8.25492E-01;
 DIFF(4,1)= 1.00000E+00; DIFF(4,2)= 1.00000E+00; DIFF(4,3)= 6.84361E-01; DIFF(4,4)= 5.74493E-01;
 DIFF(5,1)= 1.00000E+00; DIFF(5,2)= 8.33333E-01; DIFF(5,3)= 3.23333E-01; DIFF(5,4)= 1.00000E+00;
 DIFF(6,1)= 1.00000E+00; DIFF(6,2)= 1.00000E+00; DIFF(6,3)= 1.00000E+00; DIFF(6,4)= 1.00000E+00;
 DIFF(7,1)= 1.00000E+00; DIFF(7,2)= 1.00000E+00; DIFF(7,3)= 1.00000E+00; DIFF(7,4)= 1.00000E+00;
 DIFF(8,1)= 1.00000E+00; DIFF(8,2)= 1.00000E+00; DIFF(8,3)= 3.89004E-01; DIFF(8,4)= 8.86325E-01;
 DIFF(9,1)= 5.00000E-01; DIFF(9,2)= 7.50000E-01; DIFF(9,3)= 1.00000E+00; DIFF(9,4)= 1.00000E+00;
 DIFF(10,1)= 1.00000E+00; DIFF(10,2)= 1.00000E+00; DIFF(10,3)= 1.00000E+00; DIFF(10,4)= 1.00000E+00;
 DIFF(11,1)= 1.00000E+00; DIFF(11,2)= 1.00000E+00; DIFF(11,3)= 1.00000E+00; DIFF(11,4)= 1.00000E+00;
 DIFF(12,1)= 1.00000E+00; DIFF(12,2)= 1.00000E+00; DIFF(12,3)= 1.73490E-01; DIFF(12,4)= 9.14927E-01;
 DIFF(13,1)= 1.00000E+00; DIFF(13,2)= 1.00000E+00; DIFF(13,3)= 1.00000E+00; DIFF(13,4)= 7.99999E-01;
 DIFF(14,1)= 7.50000E-01; DIFF(14,2)= 1.00000E+00; DIFF(14,3)= 1.00000E+00; DIFF(14,4)= 1.00000E+00;
 DIFF(15,1)= 1.00000E+00; DIFF(15,2)= 1.00000E+00; DIFF(15,3)= 1.00000E+00; DIFF(15,4)= 1.00000E+00;
 DIFF(16,1)= 9.91494E-01; DIFF(16,2)= 1.00000E+00; DIFF(16,3)= 5.19485E-01; DIFF(16,4)= 1.00000E+00;
 DIFF(17,1)= 1.00000E+00; DIFF(17,2)= 1.00000E+00; DIFF(17,3)= 1.00000E+00; DIFF(17,4)= 1.00000E+00;

GCD#(1)= 1;	TEST(1,1)= 1;	TEST(1,2)= 0;	TEST(1,3)= 0;	TEST(1,4)= 0;
GCD#(2)= 3;	TEST(2,1)= 0;	TEST(2,2)= 0;	TEST(2,3)= 1;	TEST(2,4)= 0;
GCD#(3)= 3;	TEST(3,1)= 0;	TEST(3,2)= 0;	TEST(3,3)= 1;	TEST(3,4)= 0;
GCD#(4)= 4;	TEST(4,1)= 0;	TEST(4,2)= 0;	TEST(4,3)= 0;	TEST(4,4)= 1;
GCD#(5)= 3;	TEST(5,1)= 0;	TEST(5,2)= 0;	TEST(5,3)= 1;	TEST(5,4)= 0;
GCD#(6)= -100;	TEST(6,1)= 0;	TEST(6,2)= 0;	TEST(6,3)= 0;	TEST(6,4)= 0;
GCD#(7)= -100;	TEST(7,1)= 0;	TEST(7,2)= 0;	TEST(7,3)= 0;	TEST(7,4)= 0;
GCD#(8)= 3;	TEST(8,1)= 0;	TEST(8,2)= 0;	TEST(8,3)= 1;	TEST(8,4)= 0;
GCD#(9)= 1;	TEST(9,1)= 1;	TEST(9,2)= 0;	TEST(9,3)= 0;	TEST(9,4)= 0;
GCD#(10)= -100;	TEST(10,1)= 0;	TEST(10,2)= 0;	TEST(10,3)= 0;	TEST(10,4)= 0;
GCD#(11)= -100;	TEST(11,1)= 0;	TEST(11,2)= 0;	TEST(11,3)= 0;	TEST(11,4)= 0;
GCD#(12)= 3;	TEST(12,1)= 0;	TEST(12,2)= 0;	TEST(12,3)= 1;	TEST(12,4)= 0;
GCD#(13)= 4;	TEST(13,1)= 0;	TEST(13,2)= 0;	TEST(13,3)= 0;	TEST(13,4)= 1;
GCD#(14)= 1;	TEST(14,1)= 1;	TEST(14,2)= 0;	TEST(14,3)= 0;	TEST(14,4)= 0;
GCD#(15)= -100;	TEST(15,1)= 0;	TEST(15,2)= 0;	TEST(15,3)= 0;	TEST(15,4)= 0;
GCD#(16)= 3;	TEST(16,1)= 0;	TEST(16,2)= 0;	TEST(16,3)= 1;	TEST(16,4)= 0;
GCD#(17)= -100;	TEST(17,1)= 0;	TEST(17,2)= 0;	TEST(17,3)= 0;	TEST(17,4)= 0;

***** TEST # 1 *****

IF I CONSIDER THE SUM OF THE SQUARE OF RACIAL DIFFERENCES AS THE MEAN TO DETECT CDD SHAPE OR FORM, THEN OBJECT = 1 IS THE ONE TO BE CHOSEN BECAUSE THE OBJECT HAS THE LARGE VALUE COMPARED TO THE REST OF OBJECTS

***** TEST # 2 *****

IF I CONSIDER THE SUM OF THE ABSOLUTE VALUE OF DIFFERENCES, THEN OBJECT = 3 IS THE ONE TO BE CHOSEN BECAUSE THE OBJECT HAS THE SMALL VALUE COMPARED TO THE REST OF OBJECTS

***** TEST # 3 *****

IF I CONSIDER THE MEAN PATTERN, THEN OBJECT = 3 IS THE ONE TO BE CHOSEN BECAUSE THE OBJECT HAS THE LARGE VALUE COMPARED TO THE REST OF OBJECTS

***** TEST # 4 *****

IF I CONSIDER THE INVARIANCE : PERIMETER OVER THE SQRT OF AREA, THEN OBJECT = 4 IS THE ONE TO BE CHOSEN BECAUSE THE OBJECT HAS THE LARGE VALUE COMPARED TO THE REST OF OBJECTS

***** TEST # 5 *****

IF I CONSIDER THE ALTERNATION, THEN OBJECT = 3 IS THE ONE TO BE CHOSEN BECAUSE THE OBJECT HAS MORE ALTERNATIONS COMPARED TO OTHERS, IN OTHER WORDS, THE NUMBER OF ALTERNATIONS IS A MEASURE OF COMPLEXITY

***** TEST # 6 *****

THIS EXPERIMENT IS IGNORED SINCE I DECIDED NOT TO PAY ANY ATTENTION TO IT, THAT IS THIS TEST IS NO SIGNIFICANT FOR THE GIVEN GROUP OF SHAPES

***** TEST # 7 *****

THIS EXPERIMENT IS IGNORED SINCE I DECIDED NOT TO PAY ANY ATTENTION TO IT, THAT IS THIS TEST IS NO SIGNIFICANT FOR THE GIVEN GROUP OF SHAPES

***** TEST # 8 *****

IF I CONSIDER THE AVERAGE DEVIATION, THEN OBJECT = 3 IS THE ONE TO BE CHOSEN BECAUSE THE OBJECT HAS THE SMALL VALUE COMPARED TO THE REST OF OBJECTS

***** TEST # 9 *****

IF I CONSIDER THE NUMBER OF VERTICES, THEN OBJECT = 1 IS THE ONE TO BE CHOSEN BECAUSE THE OBJECT HAS MORE VERTICES COMPARED TO THE OTHERS

***** TEST # 10 *****

CONVEXITY OR NON CONVEXITY IS NOT IMPORTANT TO BE CONSIDERED FOR THE CDD SHAPE DETECTION.

***** TEST # 11 *****

SYMMETRY OR NON SYMMETRY OF OBJECTS IS NOT AN IMPORTANT CRITERION TO DETECT CDD OBJECT IN THIS CASE

***** TEST # 12 *****

IF I CONSIDER THE AREA, THEN OBJECT= 3 IS THE ONE TO BE CHOSEN BECAUSE THE OBJECT HAS THE LARGE VALUE COMPARED TO THE REST OF OBJECTS

***** TEST # 13 *****

IF I CONSIDER THE NUMBER OF CONVEX VERTICES, THEN OBJECT= 4 IS THE ONE TO BE CHOSEN BECAUSE THE OBJECT HAS LESS NUMBER OF SUCH VERTICES COMPARED TO THE OTHERS

***** TEST # 14 *****

IF I CONSIDER THE NUMBER OF CONCAVE VERTICES, THEN OBJECT= 1 IS THE ONE TO BE CHOSEN BECAUSE THE OBJECT HAS MORE NUMBER OF SUCH VERTICES COMPARED TO THE OTHERS

***** TEST # 15 *****

THIS EXPERIMENT IS IGNORED SINCE I DECIDED NOT TO PAY ANY ATTENTION TO IT, THAT IS THIS TEST IS NO SIGNIFICANT FOR THE GIVEN GROUP OF SHAPES

***** INTERVAL DIFFERENCE SUM TEST # 16 *****

IF I CONSIDER THE INTERVAL DIFFERENCE SUM, THEN OBJECT= 3 IS THE ONE TO BE CHOSEN BECAUSE THE OBJECT HAS THE SMALL VALUE COMPARED TO THE REST OF OBJECTS

***** FINAL TEST, SIMILARITY *****

THIS EXPERIMENT IS IGNORED SINCE I DECIDED NOT TO PAY ANY ATTENTION TO IT, THAT IS THIS TEST IS NO SIGNIFICANT FOR THE GIVEN GROUP OF SHAPES

***** THE FOLLOWING TABLE SHOWS TEST PRIORITY *****

GIVEN_WEIGHT(1)= 1.00000E+00;
GIVEN_WEIGHT(2)= 1.00000E+00;
GIVEN_WEIGHT(3)= 1.00000E+00;
GIVEN_WEIGHT(4)= 1.00000E+00;
GIVEN_WEIGHT(5)= 1.00000E+00;
GIVEN_WEIGHT(6)= 1.00000E+00;
GIVEN_WEIGHT(7)= 1.00000E+00;
GIVEN_WEIGHT(8)= 1.00000E+00;
GIVEN_WEIGHT(9)= 1.00000E+00;
GIVEN_WEIGHT(10)= 1.00000E+00;
GIVEN_WEIGHT(11)= 1.00000E+00;
GIVEN_WEIGHT(12)= 1.00000E+00;
GIVEN_WEIGHT(13)= 1.00000E+00;
GIVEN_WEIGHT(14)= 1.00000E+00;
GIVEN_WEIGHT(15)= 1.00000E+00;
GIVEN_WEIGHT(16)= 1.00000E+00;
GIVEN_WEIGHT(17)= 1.00000E+00;

TWS_D(1)= 2.90758E+00 TWS_D(2)= 3.20264E+00 TWS_D(3)= 2.22686E+00 TWS_D(4)= 3.04534E+00;
TWS_T(1)= 1.73205E+00 TWS_T(2)= 0.00000E+00 TWS_T(3)= 2.44948E+00 TWS_T(4)= 1.41421E+00;

CONSIDERING ALL OF THE EXPERIMENTS WHICH HAVE DONE ABOVE, WE MAY CONCLUDE THAT THE MOST GDD OBJECT IS
3 BY DIFF TABLE AND 3 BY TEST TABLE.

AND WE MAY CHOSE THE FOLLOWING OBJECT AS THE NEXT POSSIBLE GDD SHAPE OUT OF THE GIVEN GROUP OF SHAPES
1 BY DIFF TABLE AND 1 BY TEST TABLE.

THE FOLLOWING IS A NEW SET OF WEIGHTS WHICH AUTOMATICALLY UPDATED BY ME DURING THE ABOVE EXPERIMENTS.

PAY_ATTEN(1)='1'B	ATTEN_FACT(1)= 1.87297E-01	WEIGHT(1)= 1.87297E-01;
PAY_ATTEN(2)='1'B	ATTEN_FACT(2)= 3.60444E-02	WEIGHT(2)= 3.60444E-02;
PAY_ATTEN(3)='1'E	ATTEN_FACT(3)= 5.89477E-01	WEIGHT(3)= 5.89477E-01;
PAY_ATTEN(4)='1'B	ATTEN_FACT(4)= 3.31463E-01	WEIGHT(4)= 3.31463E-01;
PAY_ATTEN(5)='1'B	ATTEN_FACT(5)= 7.07106E-01	WEIGHT(5)= 7.07106E-01;
PAY_ATTEN(6)='0'B	ATTEN_FACT(6)= 0.00000E+00	WEIGHT(6)= 0.00000E+00;
PAY_ATTEN(7)='0'B	ATTEN_FACT(7)= 0.00000E+00	WEIGHT(7)= 0.00000E+00;
PAY_ATTEN(8)='1'B	ATTEN_FACT(8)= 7.05209E-01	WEIGHT(8)= 7.05209E-01;
PAY_ATTEN(9)='1'B	ATTEN_FACT(9)= 5.00000E-01	WEIGHT(9)= 5.00000E-01;
PAY_ATTEN(10)='0'B	ATTEN_FACT(10)= 0.00000E+00	WEIGHT(10)= 0.00000E+00;
PAY_ATTEN(11)='0'B	ATTEN_FACT(11)= 0.00000E+00	WEIGHT(11)= 0.00000E+00;
PAY_ATTEN(12)='1'B	ATTEN_FACT(12)= 8.61067E-01	WEIGHT(12)= 8.61067E-01;
PAY_ATTEN(13)='1'B	ATTEN_FACT(13)= 4.47213E-01	WEIGHT(13)= 4.47213E-01;
PAY_ATTEN(14)='1'B	ATTEN_FACT(14)= 5.00000E-01	WEIGHT(14)= 5.00000E-01;
PAY_ATTEN(15)='0'B	ATTEN_FACT(15)= 0.00000E+00	WEIGHT(15)= 0.00000E+00;
PAY_ATTEN(16)='1'B	ATTEN_FACT(16)= 6.87029E-01	WEIGHT(16)= 6.87029E-01;
PAY_ATTEN(17)='0'B	ATTEN_FACT(17)= 0.00000E+00	WEIGHT(17)= 0.00000E+00;

TWS_D(1)= 1.75380E+00	TWS_D(2)= 1.77266E+00	TWS_D(3)= 1.06087E+00	TWS_D(4)= 1.70902E+00;
TWS_T(1)= 7.31491E-01	TWS_T(2)= 0.00000E+00	TWS_T(3)= 1.59585E+00	TWS_T(4)= 5.56657E-01;

CONSIDERING ALL OF THE EXPERIMENTS WHICH HAVE DONE ABOVE, WE MAY CONCLUDE THAT THE MOST ODD OBJECT IS
3 BY DIFF TABLE AND 3 BY TEST TABLE.

AND WE MAY CHOSE THE FOLLOWING OBJECT AS THE NEXT POSSIBLE ODD SHAPE OUT OF THE GIVEN GROUP OF SHAPES
4 BY DIFF TABLE AND 1 BY TEST TABLE.

THE FOLLOWING IS A NEW SET OF WEIGHTS WHICH AUTOMATICALLY UP_DATED BY ME DURING THE ABOVE EXPERIMENTS.

PAY_ATTEN(1)='1'B	ATTEN_FACT(1)= 1.23061E-03	WEIGHT(1)= 1.23061E-03;
PAY_ATTEN(2)='1'B	ATTEN_FACT(2)= 1.68792E-06	WEIGHT(2)= 1.68792E-06;
PAY_ATTEN(3)='1'B	ATTEN_FACT(3)= 1.20744E-01	WEIGHT(3)= 1.20744E-01;
PAY_ATTEN(4)='1'B	ATTEN_FACT(4)= 1.20709E-02	WEIGHT(4)= 1.20709E-02;
PAY_ATTEN(5)='1'B	ATTEN_FACT(5)= 2.50000E-01	WEIGHT(5)= 2.50000E-01;
PAY_ATTEN(6)='0'B	ATTEN_FACT(6)= 0.00000E+00	WEIGHT(6)= 0.00000E+00;
PAY_ATTEN(7)='0'B	ATTEN_FACT(7)= 0.00000E+00	WEIGHT(7)= 0.00000E+00;
PAY_ATTEN(8)='1'B	ATTEN_FACT(8)= 2.47328E-01	WEIGHT(8)= 2.47328E-01;
PAY_ATTEN(9)='1'B	ATTEN_FACT(9)= 6.25000E-02	WEIGHT(9)= 6.25000E-02;
PAY_ATTEN(10)='0'B	ATTEN_FACT(10)= 0.00000E+00	WEIGHT(10)= 0.00000E+00;
PAY_ATTEN(11)='0'B	ATTEN_FACT(11)= 0.00000E+00	WEIGHT(11)= 0.00000E+00;
PAY_ATTEN(12)='1'B	ATTEN_FACT(12)= 5.49728E-01	WEIGHT(12)= 5.49728E-01;
PAY_ATTEN(13)='1'B	ATTEN_FACT(13)= 4.00000E-02	WEIGHT(13)= 4.00000E-02;
PAY_ATTEN(14)='1'B	ATTEN_FACT(14)= 6.25000E-02	WEIGHT(14)= 6.25000E-02;
PAY_ATTEN(15)='0'B	ATTEN_FACT(15)= 0.00000E+00	WEIGHT(15)= 0.00000E+00;
PAY_ATTEN(16)='1'B	ATTEN_FACT(16)= 2.22792E-01	WEIGHT(16)= 2.22792E-01;
PAY_ATTEN(17)='0'B	ATTEN_FACT(17)= 0.00000E+00	WEIGHT(17)= 0.00000E+00;

TWS_D(1)= 7.02970E-01	TWS_D(2)= 6.91983E-01	TWS_D(3)= 2.26946E-01	TWS_D(4)= 6.57253E-01;
TWS_T(1)= 8.83969E-02	TWS_T(2)= 0.00000E+00	TWS_T(3)= 7.00062E-01	TWS_T(4)= 4.17816E-02;

CONSIDERING ALL OF THE EXPERIMENTS WHICH HAVE DONE ABOVE, WE MAY CONCLUDE THAT THE MOST CDD OBJECT IS
3 BY DIFF TABLE AND 3 BY TEST TABLE.

AND WE MAY CHOSE THE FOLLOWING OBJECT AS THE NEXT POSSIBLE CDD SHAPE OUT OF THE GIVEN GROUP OF SHAPES
4 BY DIFF TABLE AND 1 BY TEST TABLE.

THE FOLLOWING IS A NEW SET OF WEIGHTS WHICH AUTOMATICALLY UP DATED BY ME DURING THE ABOVE EXPERIMENTS.

PAY_ATTEN(1)='1'B	ATTEN_FACT(1)= 1.51442E-06	WEIGHT(1)= 1.51442E-06;
PAY_ATTEN(2)='1'B	ATTEN_FACT(2)= 2.84909E-12	WEIGHT(2)= 2.84909E-12;
PAY_ATTEN(3)='1'B	ATTEN_FACT(3)= 1.45792E-02	WEIGHT(3)= 1.45792E-02;
PAY_ATTEN(4)='1'B	ATTEN_FACT(4)= 1.45708E-04	WEIGHT(4)= 1.45708E-04;
PAY_ATTEN(5)='1'B	ATTEN_FACT(5)= 6.25000E-02	WEIGHT(5)= 6.25000E-02;
PAY_ATTEN(6)='0'B	ATTEN_FACT(6)= 0.00000E+00	WEIGHT(6)= 0.00000E+00;
PAY_ATTEN(7)='0'B	ATTEN_FACT(7)= 0.00000E+00	WEIGHT(7)= 0.00000E+00;
PAY_ATTEN(8)='1'B	ATTEN_FACT(8)= 6.11712E-02	WEIGHT(8)= 6.11712E-02;
PAY_ATTEN(9)='1'B	ATTEN_FACT(9)= 3.90625E-03	WEIGHT(9)= 3.90625E-03;
PAY_ATTEN(10)='0'B	ATTEN_FACT(10)= 0.00000E+00	WEIGHT(10)= 0.00000E+00;
PAY_ATTEN(11)='0'B	ATTEN_FACT(11)= 0.00000E+00	WEIGHT(11)= 0.00000E+00;
PAY_ATTEN(12)='1'B	ATTEN_FACT(12)= 3.02201E-01	WEIGHT(12)= 3.02201E-01;
PAY_ATTEN(13)='1'B	ATTEN_FACT(13)= 1.60000E-03	WEIGHT(13)= 1.60000E-03;
PAY_ATTEN(14)='1'B	ATTEN_FACT(14)= 3.90625E-03	WEIGHT(14)= 3.90625E-03;
PAY_ATTEN(15)='0'B	ATTEN_FACT(15)= 0.00000E+00	WEIGHT(15)= 0.00000E+00;
PAY_ATTEN(16)='1'B	ATTEN_FACT(16)= 4.96364E-02	WEIGHT(16)= 4.96364E-02;
PAY_ATTEN(17)='0'B	ATTEN_FACT(17)= 0.00000E+00	WEIGHT(17)= 0.00000E+00;

TWS_D(1)= 3.18783E-01	TWS_D(2)= 3.16990E-01	TWS_D(3)= 6.70494E-02	TWS_D(4)= 2.93145E-01;
TWS_T(1)= 5.52427E-03	TWS_T(2)= 0.00000E+00	TWS_T(3)= 3.18826E-01	TWS_T(4)= 1.60662E-03;

CONSIDERING ALL OF THE EXPERIMENTS WHICH HAVE DONE ABOVE, WE MAY CONCLUDE THAT THE MOST ODD OBJECT IS
3 BY DIFF TABLE AND 3 BY TEST TABLE.

AND WE MAY CHOSE THE FOLLOWING OBJECT AS THE NEXT POSSIBLE ODD SHAPE OUT OF THE GIVEN GROUP OF SHAPES.
4 BY DIFF TABLE AND 1 BY TEST TABLE.

AS THE END OF COMPUTER ANALYSIS I HOPE THE DECISION MADE BY ME IS CLOSE TO THE RESULT GIVEN BY HUMAN SAMPLES, BY THE WAY WHO AM I ?????

*** EXECUTE= 2240

***** THE FOLLOWING TABLE SHOWS TEST PRIORITY *****

GIVEN_WEIGHT(1)= 2.00000E+00;
GIVEN_WEIGHT(2)= 5.00000E+00;
GIVEN_WEIGHT(3)= 1.00000E+00;
GIVEN_WEIGHT(4)= 2.00000E+00;
GIVEN_WEIGHT(5)= 1.00000E+00;
GIVEN_WEIGHT(6)= 2.00000E+00;
GIVEN_WEIGHT(7)= 1.00000E+00;
GIVEN_WEIGHT(8)= 2.00000E+00;
GIVEN_WEIGHT(9)= 1.00000E+01;
GIVEN_WEIGHT(10)= 3.00000E+00;
GIVEN_WEIGHT(11)= 3.00000E+00;
GIVEN_WEIGHT(12)= 1.00000E+00;
GIVEN_WEIGHT(13)= 1.30000E+01;
GIVEN_WEIGHT(14)= 4.00000E+00;
GIVEN_WEIGHT(15)= 1.00000E+00;
GIVEN_WEIGHT(16)= 1.20000E+01;
GIVEN_WEIGHT(17)= 2.00000E+01;

TWS_D(1)= 1.91869E+01 TWS_D(2)= 2.08752E+01 TWS_D(3)= 1.84230E+01 TWS_D(4)= 2.03750E+01;
TWS_T(1)= 1.09544E+01 TWS_T(2)= 0.00000E+00 TWS_T(3)= 1.36747E+01 TWS_T(4)= 1.31529E+01;

CONSIDERING ALL OF THE EXPERIMENTS WHICH HAVE DONE ABOVE, WE MAY CONCLUDE THAT THE MOST GOOD OBJECT IS
3 BY DIFF TABLE AND 3 BY TEST TABLE.

AND WE MAY CHOSE THE FOLLOWING OBJECT AS THE NEXT POSSIBLE GOOD SHAPE OUT OF THE GIVEN GROUP OF SHAPES
1 BY DIFF TABLE AND 4 BY TEST TABLE.

THE FOLLOWING IS A NEW SET OF WEIGHTS WHICH AUTOMATICALLY UP DATED BY ME DURING THE ABOVE EXPERIMENTS.

PAY_ATTEN(1)='1'B	ATTEN_FACT(1)= 1.87297E-01	WEIGHT(1)= 3.74594E-01;
PAY_ATTEN(2)='1'B	ATTEN_FACT(2)= 3.60444E-02	WEIGHT(2)= 2.16266E-01;
PAY_ATTEN(3)='1'B	ATTEN_FACT(3)= 5.85477E-01	WEIGHT(3)= 5.89477E-01;
PAY_ATTEN(4)='1'B	ATTEN_FACT(4)= 3.31463E-01	WEIGHT(4)= 6.62926E-01;
PAY_ATTEN(5)='1'B	ATTEN_FACT(5)= 7.07106E-01	WEIGHT(5)= 7.07106E-01;
PAY_ATTEN(6)='0'B	ATTEN_FACT(6)= 0.00000E+00	WEIGHT(6)= 0.00000E+00;
PAY_ATTEN(7)='0'B	ATTEN_FACT(7)= 0.00000E+00	WEIGHT(7)= 0.00000E+00;
PAY_ATTEN(8)='1'B	ATTEN_FACT(8)= 7.05209E-01	WEIGHT(8)= 1.41041E+00;
PAY_ATTEN(9)='1'B	ATTEN_FACT(9)= 5.00000E-01	WEIGHT(9)= 5.00000E+00;
PAY_ATTEN(10)='0'B	ATTEN_FACT(10)= 0.00000E+00	WEIGHT(10)= 0.00000E+00;
PAY_ATTEN(11)='0'B	ATTEN_FACT(11)= 0.00000E+00	WEIGHT(11)= 0.00000E+00;
PAY_ATTEN(12)='1'B	ATTEN_FACT(12)= 8.61067E-01	WEIGHT(12)= 8.61067E-01;
PAY_ATTEN(13)='1'B	ATTEN_FACT(13)= 4.47213E-01	WEIGHT(13)= 5.81377E+00;
PAY_ATTEN(14)='1'B	ATTEN_FACT(14)= 5.00000E-01	WEIGHT(14)= 2.00000E+00;
PAY_ATTEN(15)='0'B	ATTEN_FACT(15)= 0.00000E+00	WEIGHT(15)= 0.00000E+00;
PAY_ATTEN(16)='1'B	ATTEN_FACT(16)= 6.87029E-01	WEIGHT(16)= 8.24434E+00;
PAY_ATTEN(17)='0'B	ATTEN_FACT(17)= 0.00000E+00	WEIGHT(17)= 0.00000E+00;
TWS_D(1)= 1.06355E+01	TWS_D(2)= 1.11303E+01	TWS_D(3)= 9.04853E+00
TWS_T(1)= 5.39817E+00	TWS_T(2)= 0.00000E+00	TWS_T(3)= 8.46133E+00
TWS_D(4)= 1.10387E+01;	TWS_T(4)= 5.85144E+00;	

CONSIDERING ALL OF THE EXPERIMENTS WHICH HAVE DONE ABOVE, WE MAY CONCLUDE THAT THE MOST ODD OBJECT IS
3 BY DIFF TABLE AND 3 BY TEST TABLE.

AND WE MAY CHOSE THE FOLLOWING OBJECT AS THE NEXT POSSIBLE ODD SHAPE OUT OF THE GIVEN GROUP OF SHAPES
1 BY DIFF TABLE AND 4 BY TEST TABLE.

THE FOLLOWING IS A NEW SET OF WEIGHTS WHICH AUTOMATICALLY UP DATED BY ME DURING THE ABOVE EXPERIMENTS.

PAY_ATTEN(1)='1'B	ATTEN_FACT(1)= 1.23081E-03	WEIGHT(1)= 2.46123E-03;
PAY_ATTEN(2)='1'B	ATTEN_FACT(2)= 1.68792E-06	WEIGHT(2)= 1.01275E-05;
PAY_ATTEN(3)='1'B	ATTEN_FACT(3)= 1.20744E-01	WEIGHT(3)= 1.20744E-01;
PAY_ATTEN(4)='1'B	ATTEN_FACT(4)= 1.20709E-02	WEIGHT(4)= 2.41419E-02;
PAY_ATTEN(5)='1'B	ATTEN_FACT(5)= 2.50000E-01	WEIGHT(5)= 2.50000E-01;
PAY_ATTEN(6)='0'B	ATTEN_FACT(6)= 0.00000E+00	WEIGHT(6)= 0.00000E+00;
PAY_ATTEN(7)='0'B	ATTEN_FACT(7)= 0.00000E+00	WEIGHT(7)= 0.00000E+00;
PAY_ATTEN(8)='1'B	ATTEN_FACT(8)= 2.47328E-01	WEIGHT(8)= 4.94656E-01;
PAY_ATTEN(9)='1'B	ATTEN_FACT(9)= 6.25000E-02	WEIGHT(9)= 6.25000E-01;
PAY_ATTEN(10)='0'B	ATTEN_FACT(10)= 0.00000E+00	WEIGHT(10)= 0.00000E+00;
PAY_ATTEN(11)='0'B	ATTEN_FACT(11)= 0.00000E+00	WEIGHT(11)= 0.00000E+00;
PAY_ATTEN(12)='1'B	ATTEN_FACT(12)= 5.49728E-01	WEIGHT(12)= 5.49728E-01;
PAY_ATTEN(13)='1'B	ATTEN_FACT(13)= 4.00000E-02	WEIGHT(13)= 5.20000E-01;
PAY_ATTEN(14)='1'B	ATTEN_FACT(14)= 6.25000E-02	WEIGHT(14)= 2.50000E-01;
PAY_ATTEN(15)='0'B	ATTEN_FACT(15)= 0.00000E+00	WEIGHT(15)= 0.00000E+00;
PAY_ATTEN(16)='1'B	ATTEN_FACT(16)= 2.22792E-01	WEIGHT(16)= 2.67350E+00;
PAY_ATTEN(17)='0'B	ATTEN_FACT(17)= 0.00000E+00	WEIGHT(17)= 0.00000E+00;

TWS_D(1)= 2.83801E+00	TWS_D(2)= 2.88196E+00	TWS_D(3)= 1.64593E+00	TWS_D(4)= 2.87952E+00;
TWS_T(1)= 6.73150E-01	TWS_T(2)= 0.00000E+00	TWS_T(3)= 2.78776E+00	TWS_T(4)= 5.20560E-01;

CONSIDERING ALL OF THE EXPERIMENTS WHICH HAVE DONE ABOVE, WE MAY CONCLUDE THAT THE MOST ODD OBJECT IS
3 BY DIFF TABLE AND 3 BY TEST TABLE.

AND WE MAY CHOSE THE FOLLOWING OBJECT AS THE NEXT POSSIBLE ODD SHAPE CUT OF THE GIVEN GROUP OF SHAPES
1 BY DIFF TABLE AND 1 BY TEST TABLE.

THE FOLLOWING IS A NEW SET OF WEIGHTS WHICH AUTOMATICALLY UP-DATED BY ME DURING THE ABOVE EXPERIMENTS.

PAY_ATTEN(1)='1'B	ATTEN_FACT(1)= 1.51442E-06	WEIGHT(1)= 3.02885E-06;
PAY_ATTEN(2)='1'B	ATTEN_FACT(2)= 2.84909E-12	WEIGHT(2)= 1.70945E-11;
PAY_ATTEN(3)='1'B	ATTEN_FACT(3)= 1.45792E-02	WEIGHT(3)= 1.45792E-02;
PAY_ATTEN(4)='1'B	ATTEN_FACT(4)= 1.45708E-04	WEIGHT(4)= 2.91416E-04;
PAY_ATTEN(5)='1'B	ATTEN_FACT(5)= 6.25000E-02	WEIGHT(5)= 6.25000E-02;
PAY_ATTEN(6)='0'B	ATTEN_FACT(6)= 0.00000E+00	WEIGHT(6)= 0.00000E+00;
PAY_ATTEN(7)='0'B	ATTEN_FACT(7)= 0.00000E+00	WEIGHT(7)= 0.00000E+00;
PAY_ATTEN(8)='1'B	ATTEN_FACT(8)= 6.11712E-02	WEIGHT(8)= 1.22342E-01;
PAY_ATTEN(9)='1'B	ATTEN_FACT(9)= 3.90625E-03	WEIGHT(9)= 3.90625E-02;
PAY_ATTEN(10)='0'B	ATTEN_FACT(10)= 0.00000E+00	WEIGHT(10)= 0.00000E+00;
PAY_ATTEN(11)='0'B	ATTEN_FACT(11)= 0.00000E+00	WEIGHT(11)= 0.00000E+00;
PAY_ATTEN(12)='1'B	ATTEN_FACT(12)= 3.02201E-01	WEIGHT(12)= 3.02201E-01;
PAY_ATTEN(13)='1'B	ATTEN_FACT(13)= 1.60000E-03	WEIGHT(13)= 2.08000E-02;
PAY_ATTEN(14)='1'B	ATTEN_FACT(14)= 3.90625E-03	WEIGHT(14)= 1.56250E-02;
PAY_ATTEN(15)='0'B	ATTEN_FACT(15)= 0.00000E+00	WEIGHT(15)= 0.00000E+00;
PAY_ATTEN(16)='1'B	ATTEN_FACT(16)= 4.96364E-02	WEIGHT(16)= 5.95637E-01;
PAY_ATTEN(17)='0'B	ATTEN_FACT(17)= 0.00000E+00	WEIGHT(17)= 0.00000E+00;

TWS_C(1)= 6.78335E-01	TWS_D(2)= 6.82303E-01	TWS_D(3)= 3.21625E-01	TWS_D(4)= 6.70140E-01;
TWS_T(1)= 4.20715E-02	TWS_T(2)= 0.00000E+00	TWS_T(3)= 6.82052E-01	TWS_T(4)= 2.08020E-02;

CONSIDERING ALL OF THE EXPERIMENTS WHICH HAVE DONE ABOVE, WE MAY CONCLUDE THAT THE MOST ODD OBJECT IS
3 BY DIFF TABLE AND 3 BY TEST TABLE.

AND WE MAY CHOSE THE FOLLOWING OBJECT AS THE NEXT POSSIBLE ODD SHAPE OUT OF THE GIVEN GROUP OF SHAPES
4 BY DIFF TABLE AND 1 BY TEST TABLE.

AS THE END OF COMPUTER ANALYSIS I HOPE THE DECISION MADE BY ME IS CLOSE TO THE RESULT GIVEN BY HUMAN SAMPLES, BY THE WAY WHO AM I ?????

***** EXECTIME= 2940

APPENDIX D

Some Other System Responses
Under Various Criterion

Table I Some System Responses: EDS, D-Interval

SET No.	WEIGHT VECTOR No. 1		WEIGHT VECTOR No. 2		WEIGHT VECTOR No. 3		WEIGHT VECTOR No. 4		H.R.		
	$\gamma^{1/2}$		γ		γ^2		γ^3			γ^4	
	D	T	D	T	D	T	D	T		D	T
1	3/1	3/1	3/2	3/2	3/2	3/2	3/2	3/2	3/2	3/2	2/1,3
2	3/1	3/2	3/1	3/1	3/1	3/1	1/3	1/3	1/3	1/3	1,3/
3	3/4	3/4	4/3	3/4	4/3	4/3	4/3	4/3	4/3	4/3	1,3/
4	1/3	1/3	3/4	3/1	3/4	3/4	3/4	3/4	3/4	3/4	3/
5	3/4	4/3	4/3	4/3	4/3	4/3	4/3	4/3	4/2	4/3	3/
6	4/2	4/2	4/2	4/2	2/4	4/2	2/4	2/4	2/4	2/4	2/4
7	2/	2/	2/	2/	2/	2/	2/	2/	2/	2/	2/
8	1/3	1/2	3/1	3/1	3/1	3/1	3/1	3/1	3/1	3/1	1,2,3,4
9	3/1	3/1	3/4	3/1	3/4	3/1	3/4	3/1	3/4	3/1	3/1
10	4/3	4/3	4/3	4/3	4/3	4/3	4/3	4/3	4/3	4/3	4/3
11	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3
12	1/4	1/4	1/4	1/4	4/1	4/1	4/1	4/1	4/1	4/1	3,4/
13	4/1	4/1	4/1	4/1	4/1	4/1	4/2	4/1	4/2	4/1	1,2/4
14	3/1	3/1	1/3	1/3	1/2	1/2	1/2	1/2	1/2	1/2	1,2,3,4
15	4/2	4/2	4/2	4/2	2/4	2/4	2/4	2/4	2/4	2/4	3/1,2,4
16	2/1	2/1	2/1	2/1	2/1	2/1	2/4	2/4	2/4	2/4	1,2,3
17	4/2	4/2	4/1	4/2	4/1	4/1	4/1	4/1	4/1	4/1	1,4/2
18	3/4	3/4	3/	3/	3/	3/	3/	3/	3/	3/	3/2,4
19	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/2,3
20	1/2	1/2	1/2	1/2	1/2	1/2	1/4	1/4	1/4	1/4	1/4
C.R.	70	65	65	70	75	70	75	75	75	75	

Table II Some System Responses: EDS, D-Interval

SET No.	WEIGHT VECTOR No. 2				WEIGHT VECTOR No. 2				WEIGHT VECTOR No. 2				H.R.
			$\gamma^{1/2}$		γ		γ^2		γ^3		γ^4		
	D	T	D	T	D	T	D	T	D	T	D	T	
1	$\frac{3}{1}$	$\frac{3}{2}$	$\frac{2}{3}$	$\frac{3}{2}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	2/1,3
2	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	1,3/
3	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{4}{3}$	$\frac{3}{4}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	1,3/
4	$\frac{1}{3}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	3/
5	$\frac{3}{4}$	$\frac{1}{4}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{2}$	$\frac{4}{3}$	$\frac{4}{2}$	$\frac{4}{3}$	$\frac{4}{2}$	$\frac{4}{3}$	3/
6	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	2/4
7	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	2/
8	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	1,2,3,4
9	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	3/1
10	$\frac{4}{3}$	$\frac{4}{2}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	4/3
11	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	1/3
12	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{4}{1}$	$\frac{1}{4}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	3,4/
13	$\frac{4}{1}$	$\frac{4}{3}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	1,2/4
14	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1,2,3,4
15	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	3/1,2,4
16	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{4}$	$\frac{2}{1}$	$\frac{2}{4}$	$\frac{2}{1}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	1,2,3
17	$\frac{4}{3}$	$\frac{4}{2}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	1,4/2
18	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	3/2,4
19	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	1/2,3
20	$\frac{1}{2}$	$\frac{2}{1}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1/4
C.R.	70	70	75	70	80	80	80	80	80	80	80	80	

Table III Some System Responses: EDS, D-Interval

SET No.	WEIGHT VECTOR No.3				WEIGHT VECTOR No.3				WEIGHT VECTOR No.3				H.R.
			$\gamma^{1/2}$		γ		γ^2		γ^3		γ^4		
	D	T	D	T	D	T	D	T	D	T	D	T	
1	$\frac{2}{3}$	$\frac{3}{2}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	2/1,3
2	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	1,3/
3	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	1,3/
4	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	3/
5	$\frac{3}{1}$	$\frac{1}{3}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{2}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	3/
6	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	2/4
7	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	2/
8	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{4}$	$\frac{3}{2}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	1,2,3,4
9	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	3/1
10	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	4/3
11	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	1/3
12	$\frac{4}{1}$	$\frac{1}{4}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	3,4/
13	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{2}$	$\frac{4}{3}$	$\frac{4}{2}$	$\frac{4}{3}$	$\frac{4}{2}$	$\frac{4}{1}$	$\frac{4}{2}$	$\frac{4}{1}$	$\frac{4}{2}$	$\frac{4}{1}$	1,2/4
14	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{1}{3}$	$\frac{3}{1}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1,2,3,4
15	$\frac{4}{3}$	$\frac{4}{1}$	$\frac{4}{3}$	$\frac{4}{1}$	$\frac{4}{3}$	$\frac{4}{1}$	$\frac{1}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	3/1,2,4
16	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	1,2,3
17	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{1}$	$\frac{4}{3}$	$\frac{4}{1}$	$\frac{4}{3}$	$\frac{4}{1}$	$\frac{4}{1}$	1,4/2
18	$\frac{3}{2}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	3/2,4
19	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	1/2,3
20	$\frac{4}{1}$	$\frac{2}{4}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	1/4
C.R.	85	70	85	85	85	85	85	85	75	75	75	75	

Table IV Some System Responses: LS, D-Interval

SET No.	WEIGHT VECTOR No. 1				WEIGHT VECTOR No. 1				WEIGHT VECTOR No. 1				H.R.
			$C_1 = 0.2$		$C_1 = 0.4$		$C_1 = 0.2$		$C_1 = 0.4$		$C_1 = 0.2$		
			$C_2 = 5.23$		$C_2 = 5.23$		$C_2 = 4.49$		$C_2 = 4.49$		$C_2 = 3.93$		
	D	T	D	T	D	T	D	T	D	T	D	T	
1	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{2}$	2/1,3
2	$\frac{3}{1}$	$\frac{3}{2}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	1,3/
3	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{4}{3}$	$\frac{3}{4}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	1,3/
4	$\frac{3}{1}$	$\frac{1}{3}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	3/
5	$\frac{3}{4}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	3/
6	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{2}{4}$	$\frac{4}{2}$	$\frac{2}{4}$	$\frac{4}{2}$	$\frac{2}{4}$	$\frac{4}{2}$	2/4
7	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	2/
8	$\frac{3}{1}$	$\frac{1}{3}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	1,2,3,4
9	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	3/1
10	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	4/3
11	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	1/3
12	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{4}{1}$	$\frac{1}{4}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{1}{4}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{1}{4}$	3,4/
13	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{2}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{2}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	1,2/4
14	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{3}$	1,2,3,4
15	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{2}{4}$	$\frac{4}{2}$	$\frac{2}{4}$	$\frac{4}{2}$	$\frac{2}{4}$	$\frac{4}{2}$	3/1,2,4
16	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{1}{2}$	$\frac{2}{1}$	$\frac{2}{1}$	1,2,3
17	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{2}$	1,4/2
18	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{2}$	$\frac{3}{4}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{4}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{4}$	$\frac{3}{4}$	3/2,4
19	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	1/2,3
20	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1/4
C.R.	75	65	70	70	70	70	75	65	75	70	75	65	

Table V Some System Responses: LS, D-Interval

SET No.	WEIGHT VECTOR No. 2				WEIGHT VECTOR No. 2				WEIGHT VECTOR No. 2				H.R.
			$C_1 = 0.2$ $C_2 = 5.23$		$C_1 = 0.4$ $C_2 = 5.23$		$C_1 = 0.2$ $C_2 = 4.49$		$C_1 = 0.4$ $C_2 = 4.49$		$C_1 = 0.2$ $C_2 = 3.93$		
	D	T	D	T	D	T	D	T	D	T	D	T	
1	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{3}{2}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	2/1,3
2	$\frac{3}{1}$	$\frac{3}{2}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	1,3/
3	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{4}{3}$	$\frac{3}{4}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{3}{4}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	1,3/
4	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{1}$	3/
5	$\frac{3}{4}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{2}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	3/
6	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{2}{4}$	$\frac{4}{2}$	$\frac{2}{4}$	$\frac{4}{2}$	$\frac{2}{4}$	$\frac{4}{2}$	$\frac{2}{4}$	$\frac{4}{2}$	$\frac{2}{4}$	$\frac{4}{2}$	2/4
7	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	2/
8	$\frac{3}{1}$	$\frac{1}{3}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	1,2,3,4
9	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	3/1
10	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	4/3
11	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	1/3
12	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{4}{1}$	$\frac{1}{4}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	3,4/
13	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	1,2/4
14	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{3}$	1,2,3,4
15	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	3/1,2,4
16	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{1}{2}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{4}$	$\frac{2}{1}$	1,2,3
17	$\frac{4}{1}$	$\frac{4}{2}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	1,4/2
18	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{4}$	$\frac{3}{4}$	3/2,4
19	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	1/2,3
20	$\frac{1}{2}$	$\frac{2}{1}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1/4
C.R.	70	60	80	70	80	75	80	75	80	75	80	75	

Table VI Some System Responses: LS, D-Interval

SET No.	WEIGHT VECTOR No.3				WEIGHT VECTOR No.3				WEIGHT VECTOR No.3				H.R.
			$C_1 = 0.2$ $C_2 = 5.23$		$C_1 = 0.4$ $C_2 = 5.23$		$C_1 = 0.2$ $C_2 = 4.49$		$C_1 = 0.4$ $C_2 = 4.49$		$C_1 = 0.2$ $C_2 = 3.93$		
	D	T	D	T	D	T	D	T	D	T	D	T	
1	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	2/1,3
2	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{1}{3}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	1,3/
3	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{4}{3}$	$\frac{3}{4}$	$\frac{4}{3}$	$\frac{3}{4}$	1,3/
4	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{1}$	3/
5	$\frac{3}{1}$	$\frac{1}{3}$	$\frac{4}{3}$	$\frac{3}{4}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{3}{4}$	$\frac{3}{4}$	3/
6	$\frac{2}{4}$	$\frac{4}{2}$	$\frac{3}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	2/4
7	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	2/
8	$\frac{3}{1}$	$\frac{3}{2}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	1,2,3,4
9	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	3/1
10	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	4/3
11	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	1/3
12	$\frac{4}{1}$	$\frac{1}{4}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	3,4/
13	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{2}$	$\frac{4}{1}$	$\frac{4}{2}$	$\frac{4}{1}$	$\frac{4}{2}$	$\frac{4}{1}$	$\frac{4}{2}$	$\frac{4}{1}$	$\frac{4}{2}$	$\frac{4}{1}$	1,2/4
14	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	1,2,3,4
15	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{1}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	3/1,2,4
16	$\frac{1}{2}$	$\frac{2}{1}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1,2,3
17	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{1}$	$\frac{4}{3}$	$\frac{4}{1}$	$\frac{4}{3}$	$\frac{4}{1}$	$\frac{4}{3}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{3}$	1,4/2
18	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{2}$	$\frac{3}{4}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{4}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{4}$	3/2,4
19	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	1/2,3
20	$\frac{1}{4}$	$\frac{2}{1}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{1}{4}$	$\frac{1}{4}$	1/4
C.R.	85	65	85	90	85	85	90	90	75	80	75	90	

Table VII Some System Responses: LS, D-Interval

SET No.	WEIGHT VECTOR No. 1		WEIGHT VECTOR No. 2		WEIGHT VECTOR No. 3		H.R.
	$C_1 = 0.4$		$C_1 = 0.4$		$C_1 = 0.4$		
	$C_2 = 3.93$		$C_2 = 3.93$		$C_2 = 3.93$		
	D	T	D	T	D	T	
1	$\frac{3}{2}$	$\frac{3}{2}$			$\frac{2}{3}$	$\frac{2}{3}$	2/1,3
2	$\frac{1}{3}$	$\frac{3}{1}$			$\frac{1}{3}$	$\frac{1}{3}$	1,3/
3	$\frac{4}{3}$	$\frac{4}{3}$			$\frac{4}{3}$	$\frac{4}{3}$	1,3/
4	$\frac{3}{4}$	$\frac{3}{4}$			$\frac{3}{4}$	$\frac{3}{4}$	3/
5	$\frac{4}{3}$	$\frac{4}{3}$			$\frac{4}{3}$	$\frac{4}{3}$	3/
6	$\frac{2}{4}$	$\frac{2}{4}$			$\frac{2}{4}$	$\frac{2}{4}$	2/4
7	$\frac{2}{1}$	$\frac{2}{1}$			$\frac{2}{1}$	$\frac{2}{1}$	2/
8	$\frac{3}{1}$	$\frac{3}{1}$			$\frac{3}{1}$	$\frac{3}{1}$	1,2,3,4
9	$\frac{3}{4}$	$\frac{3}{1}$			$\frac{3}{4}$	$\frac{3}{1}$	3/1
10	$\frac{4}{3}$	$\frac{4}{3}$			$\frac{4}{3}$	$\frac{4}{3}$	4/3
11	$\frac{1}{3}$	$\frac{1}{3}$			$\frac{1}{3}$	$\frac{1}{3}$	1/3
12	$\frac{4}{1}$	$\frac{4}{1}$			$\frac{4}{1}$	$\frac{4}{1}$	3,4/
13	$\frac{4}{2}$	$\frac{4}{1}$			$\frac{4}{2}$	$\frac{4}{1}$	1,2/4
14	$\frac{1}{2}$	$\frac{1}{2}$			$\frac{1}{2}$	$\frac{1}{2}$	1,2,3,4
15	$\frac{2}{4}$	$\frac{2}{4}$			$\frac{4}{2}$	$\frac{4}{2}$	3/1,2,4
16	$\frac{2}{4}$	$\frac{2}{1}$			$\frac{2}{1}$	$\frac{2}{1}$	1,2,3
17	$\frac{4}{1}$	$\frac{4}{1}$			$\frac{4}{1}$	$\frac{4}{1}$	1,4/2
18	$\frac{3}{2}$	$\frac{3}{2}$			$\frac{3}{2}$	$\frac{3}{2}$	3/2,4
19	$\frac{1}{4}$	$\frac{1}{4}$			$\frac{1}{4}$	$\frac{1}{4}$	1/2,3
20	$\frac{1}{2}$	$\frac{1}{2}$			$\frac{4}{1}$	$\frac{4}{1}$	1/4
C.R.	75	75			75	75	

Table VIII Some System Responses: LS, Dispersion

SET No.	WEIGHT VECTOR No. 1				WEIGHT VECTOR No. 2				WEIGHT VECTOR No. 3				H.R.
			$C_1 = 0.2$ $C_2 = 5.23$		$C_1 = 0.4$ $C_2 = 5.23$		$C_1 = 0.2$ $C_2 = 4.49$		$C_1 = 0.4$ $C_2 = 4.49$		$C_1 = 0.2$ $C_2 = 3.93$		
	D	T	D	T	D	T	D	T	D	T	D	T	
1	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{2}$	2/1,3
2	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	1,3/
3	$\frac{4}{3}$	$\frac{3}{4}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	1,3/
4	$\frac{3}{1}$	$\frac{1}{3}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	3/
5	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	3/
6	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{2}{4}$	$\frac{4}{2}$	$\frac{2}{4}$	$\frac{4}{2}$	$\frac{2}{4}$	$\frac{4}{2}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{4}{2}$	2/4
7	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	2/
8	$\frac{3}{1}$	$\frac{1}{3}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	1,2,3,4
9	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	3/1
10	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	4/3
11	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	1/3
12	$\frac{4}{1}$	$\frac{1}{4}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	3,4/
13	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{3}$	$\frac{4}{1}$	$\frac{4}{3}$	$\frac{4}{1}$	$\frac{4}{3}$	$\frac{4}{1}$	$\frac{4}{3}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	1,2/4
14	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1,2,3,4
15	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{2}$	3/1,2,4
16	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{4}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{4}$	$\frac{2}{1}$	$\frac{2}{4}$	$\frac{2}{1}$	$\frac{2}{4}$	$\frac{2}{4}$	1,2,3
17	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	1,4/2
18	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{4}$	$\frac{3}{4}$	3/2,4
19	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1/2,3
20	$\frac{1}{2}$	$\frac{2}{1}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1/4
C.R.	75	65	80	75	80	75	80	75	80	80	80	75	

Table IX Some System Responses: LS, Dispersion

SET No.	WEIGHT VECTOR No. 4				WEIGHT VECTOR No. 4				WEIGHT VECTOR No. 4				H.R.
			$\gamma^{1/2}$		γ		γ^3		$C_1 = 0.4$ $C_2 = 5.23$		$C_1 = 0.2$ $C_2 = 4.49$		
	D	T	D	T	D	T	D	T	D	T	D	T	
1	$\frac{1}{3}$	$\frac{3}{1}$	$\frac{1}{3}$	$\frac{3}{1}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{3}$	2/1,3
2	$\frac{3}{2}$	$\frac{1}{3}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	1,3/
3	$\frac{3}{4}$	$\frac{4}{3}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	1,3/
4	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{4}{1}$	$\frac{1}{4}$	$\frac{4}{1}$	$\frac{1}{4}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	3/
5	$\frac{4}{3}$	$\frac{4}{1}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{2}$	$\frac{4}{3}$	$\frac{4}{2}$	$\frac{4}{1}$	$\frac{4}{3}$	$\frac{4}{3}$	3/
6	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	2/4
7	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	2/
8	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	1,2,3,4
9	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	3/1
10	$\frac{4}{3}$	$\frac{4}{1}$	$\frac{4}{3}$	$\frac{4}{2}$	$\frac{4}{3}$	$\frac{4}{2}$	$\frac{4}{3}$	$\frac{4}{2}$	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{4}{3}$	$\frac{4}{2}$	4/3
11	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	1/3
12	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{1}$	$\frac{1}{3}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	3,4/
13	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{2}{1}$	$\frac{1}{4}$	$\frac{2}{4}$	$\frac{2}{1}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	1,2/4
14	$\frac{2}{4}$	$\frac{2}{3}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	1,2,3,4
15	$\frac{4}{3}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{4}{2}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{4}{2}$	$\frac{2}{4}$	$\frac{4}{2}$	3/1,2,4
16	$\frac{4}{2}$	$\frac{2}{4}$	$\frac{4}{2}$	$\frac{4}{2}$	$\frac{4}{1}$	$\frac{4}{2}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	1,2,3
17	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	1,4/2
18	$\frac{3}{4}$	$\frac{4}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	3/2,4
19	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	1/2,3
20	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{1}{2}$	$\frac{2}{1}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{2}{1}$	$\frac{1}{2}$	$\frac{2}{1}$	1/4
C.R.	60	55	60	55	65	60	65	65	60	55	65	60	

Table X Some System Responses: LS, Dispersion

SET No.	WEIGHT VECTOR No.5				WEIGHT VECTOR No.5				WEIGHT VECTOR No.5				H.R.
			$\gamma^{1/2}$		γ		γ^3		$C_1 = 0.4$ $C_2 = 5.23$		$C_1 = 0.2$ $C_2 = 4.49$		
	D	T	D	T	D	T	D	T	D	T	D	T	
1	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{3}$	2/1,3
2	$\frac{3}{4}$	$\frac{4}{2}$	$\frac{3}{4}$	$\frac{4}{2}$	$\frac{3}{4}$	$\frac{4}{3}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{4}$	1,3/
3	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	1,3/
4	$\frac{1}{4}$	$\frac{2}{1}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{4}{1}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	3/
5	$\frac{3}{1}$	$\frac{1}{3}$	$\frac{3}{1}$	$\frac{1}{3}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{2}$	$\frac{4}{1}$	$\frac{4}{3}$	$\frac{4}{3}$	3/
6	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	2/4
7	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	2/
8	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	1,2,3,4
9	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	3/1
10	$\frac{4}{3}$	$\frac{4}{2}$	$\frac{4}{3}$	$\frac{4}{2}$	$\frac{4}{3}$	$\frac{4}{2}$	$\frac{4}{3}$	$\frac{4}{2}$	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{4}{3}$	$\frac{4}{2}$	4/3
11	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	1/3
12	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	3,4/
13	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	1,2/4
14	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	1,2,3,4
15	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	3/1,2,4
16	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{2}$	1,2,3
17	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{3}$	1,4/2
18	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	3/2,4
19	$\frac{1}{4}$	$\frac{4}{1}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	1/2,3
20	$\frac{2}{1}$	$\frac{1}{2}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	1/4
C.R.	70	50	70	60	70	65	65	65	60	60	65	65	

Table XI Some System Responses: LS, Dispersion

SET No.	WEIGHT VECTOR No. 6				WEIGHT VECTOR No. 6				WEIGHT VECTOR No. 6				H.R.
			$\gamma^{1/2}$		γ		γ^3		$C_1 = 0.4$ $C_2 = 5.23$		$C_1 = 0.2$ $C_2 = 4.49$		
	D	T	D	T	D	T	D	T	D	T	D	T	
1	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{3}$	2/1,3
2	$\frac{3}{2}$	$\frac{1}{2}$	$\frac{3}{2}$	$\frac{2}{3}$	$\frac{3}{2}$	$\frac{3}{2}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	1,3/
3	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	1,3/
4	$\frac{4}{1}$	$\frac{2}{1}$	$\frac{4}{1}$	$\frac{1}{4}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	3/
5	$\frac{3}{4}$	$\frac{1}{3}$	$\frac{3}{4}$	$\frac{4}{3}$	$\frac{3}{4}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{4}{3}$	$\frac{3}{4}$	$\frac{4}{3}$	$\frac{3}{4}$	$\frac{3}{4}$	3/
6	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	2/4
7	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	$\frac{2}{1}$	2/
8	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	1,2,3,4
9	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	$\frac{3}{4}$	$\frac{3}{1}$	3/1
10	$\frac{4}{3}$	$\frac{4}{1}$	$\frac{4}{3}$	$\frac{4}{2}$	$\frac{4}{3}$	$\frac{4}{2}$	$\frac{4}{3}$	$\frac{4}{2}$	$\frac{4}{3}$	$\frac{4}{2}$	$\frac{4}{3}$	$\frac{4}{2}$	4/3
11	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	1/3
12	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	$\frac{3}{1}$	3,4/
13	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	1,2/4
14	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	1,2,3,4
15	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	$\frac{2}{4}$	3/1,2,4
16	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	1,2,3
17	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{2}$	1,4/2
18	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{3}{1}$	$\frac{3}{1}$	3/2,4
19	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	$\frac{4}{1}$	1/2,3
20	$\frac{2}{1}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{2}{1}$	$\frac{1}{2}$	$\frac{2}{1}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{2}{1}$	$\frac{1}{2}$	$\frac{2}{1}$	1/4
C.R.	65	65	70	55	70	60	65	60	70	65	75	70	

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16. Abstracts A procedure to determine an odd shape or form in a given set of shapes, each set consisting of more than two shapes, is described. The "oddness" of a shape in a set of shapes on the basis of a specified feature is defined and then the "most odd" shape on the basis of many detected features is defined. To make the system response like an average human response, modification of an assumed weight vector by means of an "attention mechanism" is considered. Some of the results attained for various criteria by the system simulation are as follows: (1) A comparison of Linear Separation and Euclidean Distance Separation methods indicates that the Linear Separation model adequately models psychological form perception. (2) The attention mechanism described in this paper gives better system responses than those given without it. (3) The gestalt measure (emphasized in the psychology literature) which is defined as the function of the perimeter and area of a given shape becomes less important. (4) The shape representation used in this paper, called the pattern sequence, $S_r(x_0)$, has many advantages in the analysis of geometric shapes.			
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