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THE FORMAL GENERATORS OF STRUCTURE*

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Illustrations drawn by G. T. Crabtree under the direction of the author.

Abstract—*The paper consists of six basic parti. Horizontal planar forms through historic repetition have evolved a formal tradition. The forms are: the* square, *the* rectangle, *the* cruciform, *the* pinwheel, *the* linked figure *and the* lozenge.

Four formal problems are simultaneously attacked in the paper:

What does a planar figure become volumetrically?
How does the structure reinforce axial properties?
What are the architectonic implications of axial reinforcement?
What are the phenomenological implications of multiple axonometrics?

Two fields are employed: Sparsity (single space/volume) and density (multiple spaces/volumes).

The first five parti represent rectilinear notions of the forms: the square, *the* rectangle, *the* cruciform, *the* pinwheel *and the* linked figure.

The sixth parti introduces the diagonal phenomena of the lozenge.

As the world of art, as well as that of science comes to grips with 'Systems Analysis' and 'The Field Theory', it is necessary to formally analyze certain two dimensional, man-made diagrams to ascertain their fundamental characteristics to better understand the role they will play in the forthcoming computerised world of networks and lattices.

Our fields of vision were secured early this century. Refinement or reaction have been the issues ever since. Now, for the first time, the constellating of the new optical qualities suggests liberation.

Two rationalizations of the Western World have focused on the unchanging qualities of the right angle. One has been synthesised in art as a formal universality in the form of the square. The other has been synthesised in religion as a spiritual universality in the form of the cross. The two visual symbols form the bases of a large part of those forms historically evolved by creative man.

The square, rectangle, cruciform, pinwheel, linked figure and lozenge are six of the more basic figures concerned with man's orthogonal preconceptions. Each, in its own way, while finite unto itself is linked with the others. The first five represent rectilinear notions while the sixth, the lozenge, introduces the diagonal phenomena.

By exploring four formal issues common to each of the six figures, certain characteristics of their respective geometries may be revealed:

Volumetric implications of planar extensions.
Axial properties of form reinforced by structure.
Architectonic extensions of axially reinforced figures.
Optical qualities of multiple axonometrics.

The square, as a discreet rectangle having four equal sides, has imaginary lines perpendicular to and through the center of its sides which forms its bilaterally symmetrical properties. The plans of the churches at Santa Sophia and San Lorenzo [1] are two examples of architects responding to the insistent geometry of the square. The four columns centered on each side of Mies' fifty by fifty house [2] honor the axial properties of the figure while simultaneously contending with the asymmetrical superimposition of the core, which lies in a state of shear relative to the structure. Albers' 'Homage to the Twilight Square' of 1951 [3] superimposes the notion of depth perspective onto the flat plane of multiple squares. Rowe and Slutzky [4] note Kepes' commentary on figure-ground phenomena: 'If one sees two or more figures overlapping one another, and each one of them claims for itself the common overlapped part, then one is confronted with a

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contradiction of spatial dimensions. To resolve this contradiction one must assume the presence of a new optical quality'. Max Bill's 'White Element' [5] extends the axes of the square to a position that when new points are connected, a rotated square appears, while Mondrian's 'Lozenge with Gray Lines' of 1918 [6] deals with the square as a field phenomena terminated by the lozenge and thus implying extension. Vasarely extends the square toward three dimensions [7] while Bourgoin [8] documents many of the 'field' possibilities inherent in the two dimensional square, extended, connected and transformed. Clearly, the implications, extensions and potential deformations of the square have occupied a large segment of creative man's mind.

Illustrations 1a, 3a and 5a (Figs. 1, 3 and 5) deal with three extensions of the single space square. The sparse square in Fig. 1a is structured by points (columns). The abstract square on the upper left demonstrates Kepes' definition of figure-ground phenomena through four axonometric extensions of the square toward its inevitable three dimensional cubes. An optical quality different than Munari's cube-hexagon [9] is thus achieved. In addition, multiple axonometrics allow the perceiving of all faces of the cube simultaneously.

The structured and architectonic examples in Fig. 1a (top center and right) support the axial properties of the cube through the use of columns. The appropriate form of the column relative to the cube is necessarily square. Thus, if the column expands or contracts in scale, a similar residual space is left. The optical qualities obtained through equivocal figures has been supported historically by both 'Schröder's reversible staircase' and 'Thiery's figure' [10] which when seen in the light of Albers' constructions [11] begin to shed light on that which is phenomenologically extendable. 'Reye's configuration' [12] (the juxtaposition of lines and planes which form a cube) contain as matrix the potential of extension to a three dimensional network similar to the expansion potential of the square in Fig. 1a.

The square defined by planes illustrated in Fig. 3a continues the principle of tri-lateral axial reinforcement through extension into three dimensions. In this case, the wall thickness is such that through planar termination the negative space of the opening is also a square. Thus, while any wall thickness might have been employed, similar performance can be had only if the termination of the planes were to form a square. The architectonic extensions of the walled square in Fig. 3a (upper right) begin to demonstrate the spatial implications of trilateral symmetry as defined by clusters of planes constellating into L shaped elements.

The buttressed sparse square, curiously, begins to imply the cruciform which, as the square, is bilaterally symmetrical. This is natural since the form of four planar buttresses when disposed about a square, necessarily resemble a cruciform (Fig. 5a, center). It should be noted however, that the juxtaposition of multiple buttresses containing a cube imply the cube rather than the cruciform (Fig. 5a right).

The rectangle, architecturally speaking, has as its formal origins the Gothic style. The linear characteristics of this style reinforce a single axis, the termination of which has continued to be of considerable difficulty. The plan of the chapel of Saint Stephen [13] simply terminates the parti after five structural bays, while that of Sainte Chapelle weights one end of the axis by actually closing the other. Notre Dame, while similar to Sainte Chapelle, recognises a minor axis perpendicular to the nave [14]. If one assumes that the square is simply a discrete rectangle, then elongated forms of similar geometry may well contain similar properties. Thus, illustrations 1b, 3b and 5b show the articulation of the rectangle composed of two squares, weighting one axis more than the other due to the obvious effects of elongation.

The rectangle, like the Gothic parti has major and minor axes; thus when the figure is extended into space, the major axial termination becomes bilaterally symmetrical (similar to the cube). Thus, the longitudinal planar extensions are of the same proportion as the sides of the rectangle. That a close relationship exists between the rectangle and the square is inevitable.

While the columned sparse rectangle and the walled sparse rectangle focus on the linear aspects of the Gothic parti, the buttressed sparse rectangle in Fig. 5b (right) three dimensionally wraps the minor centroid, so that, while the major axis in all three cases deals with subjective visual penetration through the opening at either end of the form, a feeling of compression is established in the buttressed rectangle articulating its minor axial properties.

As the rectangle is an extension of the square in terms of its being the agglommeration of two squares, the cruciform is the agglommeration of three, two-square rectangles mutually and simultaneously disposed about the x, y and z axes. It, as well as the square, is trilaterally symmetrical in three dimensional terms to the extent that the negative space achieved by the juxtaposition of the four axonometrics form a cruciform as well (Figs. 1c, 3c and 5c).

Historically, the plan of the chapel at San Spirito in Florence [15] is an interesting demonstration of the transition from the Gothic to the Renaissance (or indeed the rectangle to the cruciform). San Spirito, while cruciform in plan, has its nave slightly elongated, thus combining the rectangle and the cruciform in an interesting manner. The history of classical city planning has shown the use of cruciform potentialities as at Versailles [16] and in the overall plan for San Pietro's [17]. J. Bourgoin has shown the use of this figure also in Arabian art decoration [18]. His 'Les Elements de l'Art Arabe' shows many permutations of the cruciform and other bilaterally symmetrical figures.

The cruciform structured by columns, Fig. 1c, continues the principles of the cube structured by columns. In Figs. 1c (right), 3c (right) and 5c (right) the architectonic extensions of the cruciform are made with a flemish bond, as this is also a cruciform in organization. In Figs. 3c and 5c the negative spaces resulting from the walled and buttressed containers have protruding and receding spaces reinforcing the cruciform notion as well. In Fig. 3c (the walled cruciform) it should be noted that the proportion of the angle-shaped containing planes, while having similar sides, define a 2:1 axial entry to the center square, this proportion being consistent with the 2:1 three-rectangle juxtaposition forming the structure of the basic figure.

Mies' *Brick Villa* of 1923 [19] demonstrates a loose compositional way of dealing with the pinwheel, while the plan of Wright's *Suntop House* of 1939 [20] shows a more compact organisation of this figure. There have been many attempts to articulate the shearing aspects of the pinwheel in the plastic arts. Albers' constructions have emphasised this quality through the weighting of lines [21].

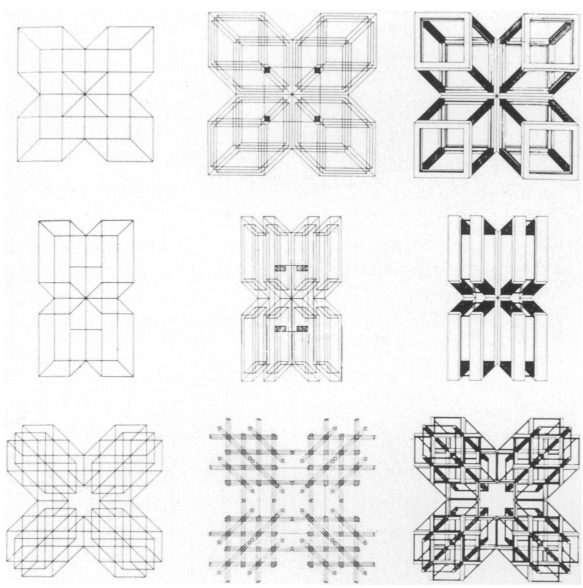

Fig. 1. (a) *The sparse square with columns (top row).*
(b) *The sparse rectangle with columns (middle row).*
(c) *The sparse cruciform with columns (bottom row).*

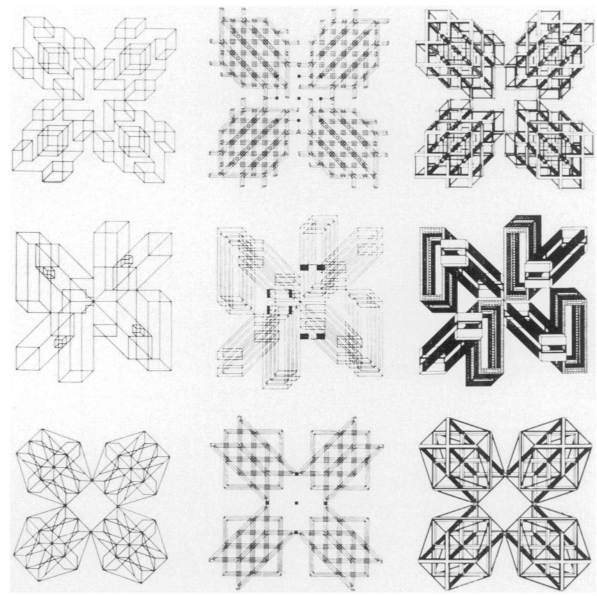

Fig. 2. (a) *The sparse pinwheel with columns (top row).*
(b) *The sparse linked figure with columns (middle row).*
(c) *The sparse lozenge with columns (bottom row).*

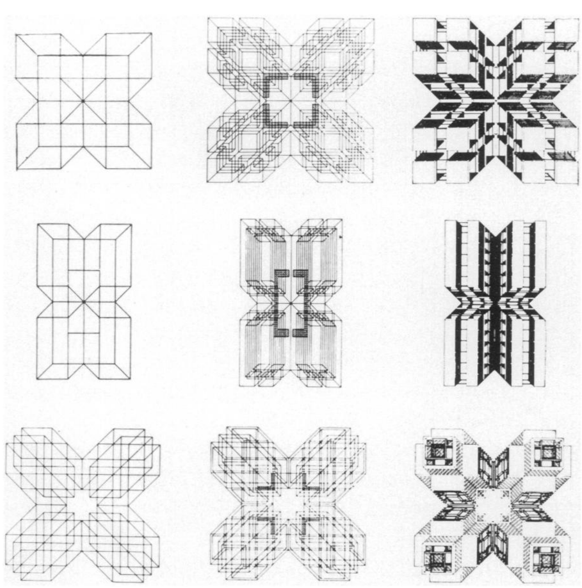

Fig. 3. (a) *The sparse square with planes (top row).*
(b) *The sparse rectangle with planes (middle row).*
(c) *The sparse cruciform with planes (bottom row).*

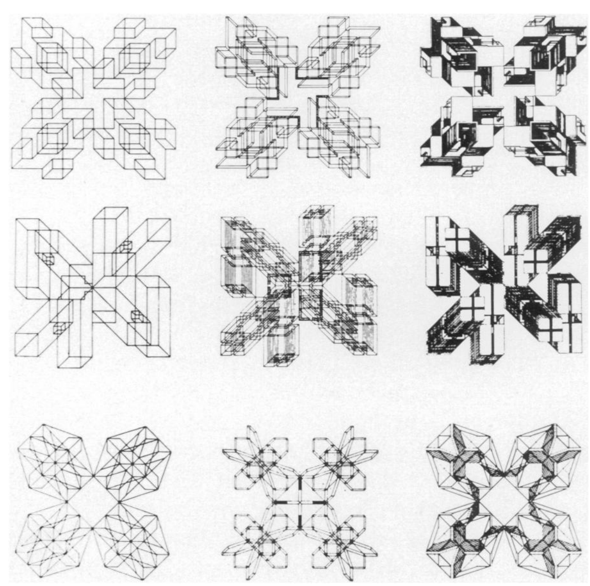

Fig. 4. (a) *The sparse pinwheel with walls (top row).*
(b) *The sparse linked figure with walls (middle row).*
(c) *The sparse lozenge with walls (bottom row).*

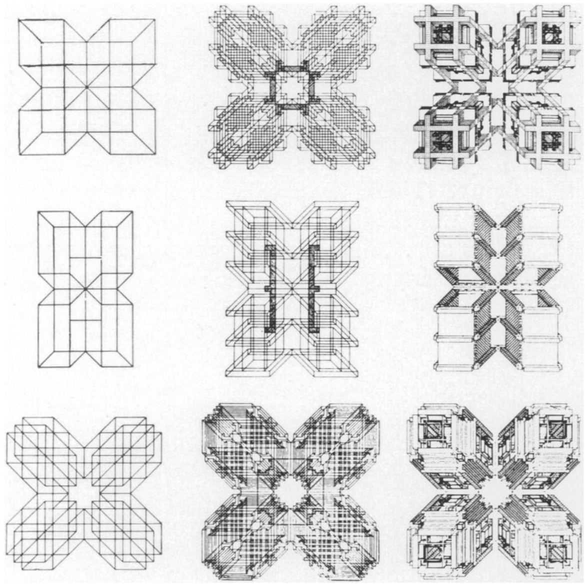

Fig. 5. (a) *The sparse square with buttresses (top row).*
(b) *The sparse rectangle with buttresses (middle row).*
(c) *The sparse cruciform with buttresses (bottom row).*

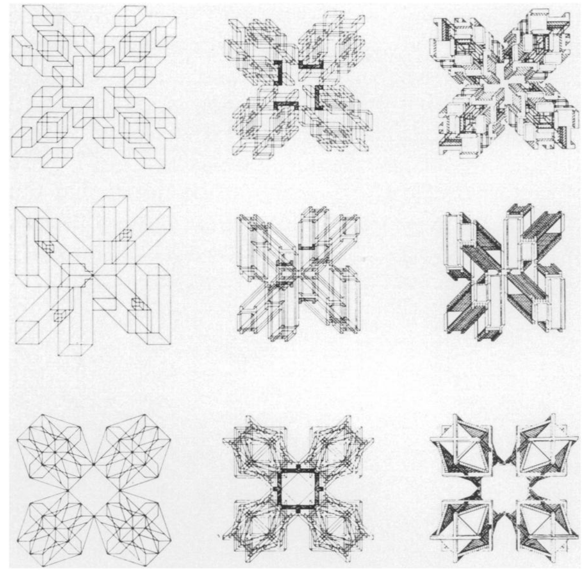

Fig. 6. (a) *The sparse pinwheel with buttresses (top row).*
(b) *The sparse linked figure with buttresses (middle row).*
(c) *The sparse lozenge with buttresses (bottom row).*

The *Rietveld House* at Utrecht of 1923–24 [22] shows some of the three dimensional possibilities of this parti.

The pinwheel in Figs. 2a, 4a and 6a is composed of a series of rectangles the juxtaposition of which constellate about a pinwheel or swastika figure in such a way, that the cruciform, the central negative space formed by the gathering of the four axonometric extensions, also forms a pinwheel. The abstract pinwheel figure in Fig. 2a (left) is a study of the distortions possible in the logical graphic rotation in this figure. More than the square, rectangle or cruciform, this parti justifies the four-axonometric postulate for showing all faces at once. This is a result of the parti not being symmetrical (at least in the sense one thinks of the square or cruciform).

The pinwheel structured by columns in Fig. 2a (center and right) establishes a cubic lattice, only the termination points of which define the pinwheel form. The walled pinwheel of Fig. 4a (center and right) is composed of both solid and void L-shaped forms extending from the planar four walls in Fig. 4a (center plan). The buttressed pinwheel in Fig. 6a (center and right) continues the shearing phenomena of this figure into a complex network of channel shaped containers, the negative spaces of which are also buttressed with channel shaped transparent planes.

The linked figure in Figs. 2b, 4b and 6b is the constellation of perpendicularly oriented rectangles linked and then extended into three dimensional space. If one considers the extension of the lateral elements of Blenheim Palace in Oxfordshire [23] they then form a linked figure with the central hall of the Palace. The Inland Steel Building in Chicago by Skidmore, Owings and Merrill is a clear demonstration of the figure itself with minimum understanding of its axial properties (which might have otherwise created a more appropriate human penetration through entry).

The lozenge, illustrated in Figs. 2c, 4c and 6c, while having historic roots not unlike the five earlier parti, nonetheless have quite different axial properties. Assuming the square-cube to have axes perpendicular to its sides, then its formal generators are established. If the square is tilted 45°, and the x and y axes also turned 45°, the square simply becomes a square turned on its side with no particularly unique properties. However, if when the square is turned 45° the x and y axes remain in their original position, a completely new set of optical rules occur. This was never made more clear historically than in the work of two members of the Dutch movement—De Stijl—Mondrian and van Doesburg. During the years 1918 and 1919 Mondrian did three 'Lozenge' paintings [24] where only the periphery of the canvas was tilted. The interior field remained in a vertical and horizontal position. van Doesburg's reply to this was 'Elementarism' (a humanistic introduction) which in his paintings of 1924 and 1925 [25] the periphery remained orthogonal and the interior field was tilted. The Mondrian postulate has been clearly extended in John Hejduk's *Diamond House* of 1965 [26].

It should be noted in Figs. 2c, 4c and 6c that the axial properties of the lozenge are orthogonal, while the figure itself is the extension into space on the diagonal. One of the curious optical results of this juxtaposition is the completely different way in which axonometric extensions occur. The disposition of these paradoxical sets of principles establishes a new methodology of extension, marrying many of the principles of the square, cruciform and pinwheel, but simultaneously establishing a new visual language.

The square, rectangle, cruciform, pinwheel, linked figure and lozenge through great repetition have, on occasion, uplifted the creative mind to establish an order clearly defining the nature of these forms. The Golden Rectangle and 1st Modulor are but two of the many efforts in this milieu. One must assume that the three-dimensional, topological extensions possible in the future will establish yet another set of values defining the nature of those spaces possible when utilising the basic properties of these six parti.

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Générateurs Formels de Structeurs

Résumé—L'article comprend six éléments fondamentaux. Les formes planes horizontales ont abouti, sous l'influence de la répétition historique, à une tradition formelle. Les figures en question sont: le *carré*, le *rectangle*, la *croix*, la *roue dentée*, la *figure articulée* et la *losange*.

Le présent article traite simultanément de quatre problèmes formels:

Quelle est la transformation volumétrique d'une figure plane?

Comment la structure renforce-t-elle les propriétés axiales d'une figure?

Quelles sont les implications architecturales du renforcement axial?

Quelles sont les implications phénoménologiques de l'axonométrie multiple?

Deux systèmes sont employés: l'économie (espace/volume unique) et la densité (espaces/volumes multiples).

Les cinq premiers éléments représentent des notions rectilignes de la forme: le *carré*, le *rectangle*, la *croix*, la *roue dentée* et la *figure articulée*.

Le sixième élément introduit le phénomène diagonal du *losange*.