Symmetry and Complementarity – a Discussion and A Qualitative Demonstration with Computer Generated Infinite Patterns of Natural Scenes

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Abstract

Pragnanz and Gestalt principles of visual perception, offer an explanation to perceptual phenomena and organization processes of segregated objects in the global surround, but are perhaps insufficient in explaining the densely packed infinite environment, such as seen in micro-world images or in decorative art patterns. By examining principles of crystallography, related phenomena of auditory perception in comparison to visual organization processes, a possible explanation to the ambiguities and illusions in perceiving infinite patterns is offered. In addition, computer generated pictures of infinite patterns qualitatively demonstrate the phenomena and explanation.

1. Background

The ultimate goal of visual perception is the definition of the surrounding- the global whole, which constitutes separate wholes, made of parts and element, within global and local relationships, in order to establish knowledge about the utility and functionality of objects in the environment. Since the essence of the process is derived from the natural need to utilize objects in the surrounding, it aims at the isolation of wholes through distinguishing their particular attributes from their neighbours and establishing an understanding of their relationships (such as figure vs. ground), which result in hierarchical order, grouping and attention.

2. Gestalt Principles

Gestalt school of psychology defined Pragnanz as the goodness and simplicity of shapes, resulting from the most stable visual organization of information, based on cues such as proximity, area, similarity, symmetry, continuity, etc. (Werheimer 1923). But how can gestalt principles address the environment, which is an "infinite' composition of congruent wholes, elements and parts- an environment, such as has been revealed to us by microscopic images of molecular lattices or crystals. Their functional attributes are at the reach of our intellectual understanding and industrial use, but although we are exposed to such images, and while they are beyond the individual's direct object-utilization, they are highly aesthetic and attractive, and play a history-long role in decorative art.

Throughout the history of art, artists and scientists alike were engaged in defining and manipulating geometrical forms and attributes of similarity, repetition in rhythm and symmetry to create and understand art form composition and enhance its symbolic effect.

3. Biologically Based Symmetry

The 19th century biologist Ernst Haeckel, through investigation of marine unicellular organisms, plants, animals and the human body, went as far as to declare symmetry to be the source for kinship of all living forms. And based on these observations (Figure 1), in *General Morphology of Organisms* (1866), Haeckel deduced that all species represent stages in the development of a unified genealogy (even before the acceptance of Darwinism).

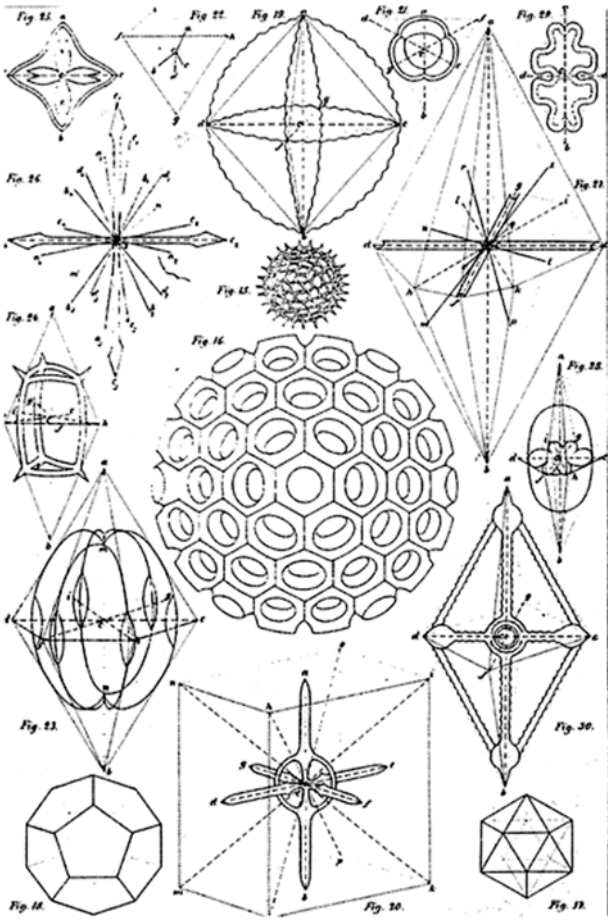

Figure 1: Plate II in Haeckel's Generelle Morphologie der Organismen, Vol.1, 1866

His revolutionary outline of biology and principles of evolution were rejected by the scientific community, but his drawings and descriptions of radiolarian organisms, published in *Art Forms in Nature* (1899-1904), inspired Jugendstil and Art Nouveau designers, such as Rene Binet, Tiffany, Olbrich and many others.

Santayana (1896) proposed that the outlines of most things are perceived as symmetrical, by the choice of what symmetrical lines we find to be the boundaries of objects- their symmetry being the condition of their unity and their unity of their individuality and separate existence, because symmetry contributes to the completeness, the intrinsic inwardness and solidity of forms. Symmetry lays emphasis upon the recurring elements, cuts up the field into determinate units- all that lies between the beats is one interval, one individual. Thus, without symmetry there would be no recurrent impressions or corresponding elements and the perceptual field would remain a fluid continuum, without defined and recognizable divisions.

4. Symmetry- The Mechanism

According to Santayana and Haeckel, symmetry is more than an aesthetic experience, but can be considered a biologically based mechanism. Such a view would be in line with recent theories proposing a neurological base to art and aesthetic experience (Ramachandran and Hirstein 1999, Zeki 1999).

Symmetry, as a mechanism would similar in its aim to all object defining perceptual mechanisms. Foe example: colour appearance phenomena, such as: *colour constancy*- objects tend to retain the same perceived colour through different illuminations, *simultaneous contrast*- causes a stimulus to shift in lightness or colour appearance with the variation in the luminance or colour of its background (Evans 1948, Albers 1963, Boynton 1979, Hurvich 1981, Blackwell and Buchsbaum 1988, Cornelissen and Brenner 1991, Robertson 1996), *crispening*- the increase in magnitude of colour differences when the background of compared stimuli is similar in colour to the stimuli themselves (Semmelroth 1970). Both simultaneous contrast and crispening function to enhance individuation and definition of separate objects. Another phenomane, that may appear to be opposite to them, is *spreading*- the apparent fusion of colour stimulus with its background, caused by the increase of stimuli's spatial frequency or size to diminish simultaneous contrast effect.

Rethinex theory of color (and lightness) constancy proposes that lightness and color of objects are determined by the integration of the object into the global whole, and most affected by the ratios at the edges. Accordingly, it is possible to show that in fact, the three phenomena function in a complementary mode to determine and enhance local wholes as separate entities from the global one. While *spreading* determines whether an object starts to or ceases from being a separate entity (like a threshold)- that is a minimum ratio at edge for segregation vs. unification, *simultaneous contrast* and *crispening* further enhance and emphasize the ratio at edge between form and its surround.

In a similar way, the variety of forms depends on the character of their elements and the variety of possible combinations of unification. If the elements are all alike and their only diversity is numerical, their unity would be merely their uniformity. Thus, the distinction between the perception of form and formless depends on the organization of the elements.

Symmetry is a mechanism, which emphasized unity in variety, where a whole is determined by the rhythmic repetition of similar parts. Therefore, symmetry is effective as long as it aids unification of form, and loses its value when it cannot, on account of the size of the object, to contribute to its unity, such as the inability to perceive the molecular structures composing what we perceive as uniform matter or on the other hand the difficulty to perceive unification of forms in the cosmos.

The fact that we can have the sense of space also without the sense of boundaries, leads to the declaration that space is infinite. A distinction and association of wholes, the consciousness of their coexistence and distinction is the direct experience of the organization process, the feeling of order, with its gratifying sense of aesthetic experience (Ramachandran and Hirstein 1999, Zeki 2000). From Phoenician and Assyrian decorative art, through Muslim art and Escher, artists have always challenged the constrains of space, and geometry to create patterns, made of lattices that can be infinitely extended in all directions, using triangles, squares, rhomboids or hexagons (Gombrich 1979), and introduce the micro-world order in a macro-world size.

Geometrical lattices raise a sense of the position of every element, which consists of the tensions in the eye, that not only tends to bring that element to the center of vision, but simultaneously feels the suggestion of all other elements, which are related to the given one, to result in visual vibration. On the other hand, when a circle- the geometrical shape that is highest in symmetry, is presented, the eye falls upon its center, as to a center of gravity, due to the balanced attraction of all points (Arnheim 1982); and there is, in that position, an indifference and sameness of sensation in whatever direction the eye moves, which results in stability and unification, unless there is a variation in the combination of the elements, as shown in Figure 2.

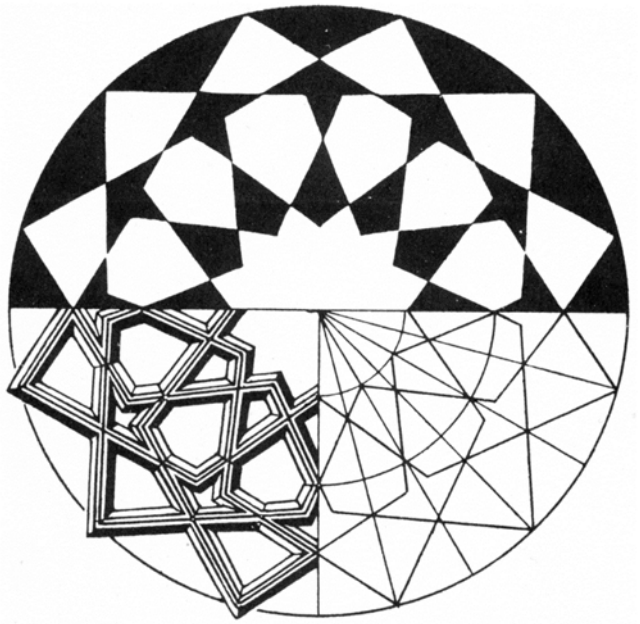

Figure 2: Diagram showing Islamic formula for drawing star elements (A.H. Christie 1929)

Figure 3 demonstrates the fluctuation between the gravity and unity of each individual circle and their intersections. In such an infinite space, while symmetry increases the gravity of the centers and their individuation, a counter-attracting organizational process is needed for the fluctuation between the individual solid centers of the local elements and their global relations, combination and unification to take place. Gestalt demonstrations of visual organization principles do not exceed simplified arrangements of objects or segregated forms with solid backgrounds and therefore, cannot give an explanation to the organization principles' inevitable counter effects.

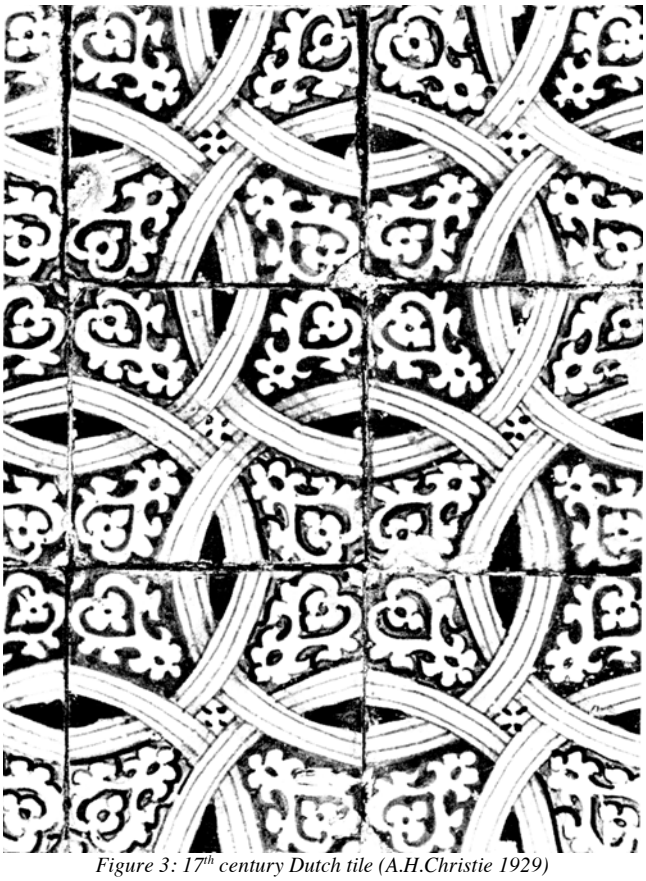

Figure 3: 17th century Dutch tile (A.H.Christie 1929)

Arnheim (1971) indeed employed the idea of entropy to express art in terms of physics world: *order* and *disorder*, but although his theory derived from a universal similarity of tendency in the organic world and human activity, his argument remained centered on the economy of vision and simplicity of nature (pragnanz) with simple economical images respectively.

5. Organization Principles in Crystallography

An alternative approach to the fluctuation and tension between organization processes of infinite patterns is found in the world of crystallography- the way crystals and molecules develop and organize (I. Hargittai and M. Hargittai, 2000). Crystallography teaches that although, the symmetry plane is ubiquitous in nature, as well as in human creation, it has extremely restricted utility whenever good space utilization is concerned in the molecular world, which composes all matter. Crystal structures, interaction of biological molecules etc, demonstrate that symmetry plane is not a common element, and can only be involved in extreme cases when the building elements themselves are of high symmetry. Micro natural models demand *densest packing* of elements to reach structural stability. Although the structures may demonstrate symmetry properties of patterns in two dimensions, densest packing is achieved, in most cases, through *complementarity* in the arrangement of the building elements (such as electrostatic and atomic forces). Therefore, symmetry is a snare and an illusion in understanding dense structures. It is not symmetry, but *systematics* that offers most stability. Indeed, *complementary connectivity* is a better parameter for classifying and understanding dense structures (Hargittai 1994).

An image with densely packed elements, represents the molecular micro world and does not exist in the macro natural environment, in which our visual system dwells, where similarity and symmetry are essential principles in grouping and organizing parts into distinguished objects separated from their surrounding. Therefore, the vibrartion between ambiguities, which we experience when looking at dense grids of infinite patterns, such as Escher's periodic works can perhaps be explained by the fluctuation of the visual system between similarity and symmetry, and the principle of systematic complementary connectivity.

6. Similar Evidence from the Auditory System

Experiments with listening to synthesized simultaneous wavering tones, which physically do not sound like speech, but follow the same contour as bands of energy of sentences (Remez et al. 1981), revealed that the brain can hear speech content in sounds that have only the remotest resemblance to speech. The brain seems to employ two hearing mechanisms for speech, one for hearing sound and one for phonetics. When listening to speech, the two mechanisms compete over which gets to interpret the sound. When the phonetics mechanism wins, it is not sounds that are being perceived, but language, and when the sound mechanism wins, we perceive pitch and loudness. There are also occasions in which, the brain jumps back and forth between the two perceptions. This phenomenon demonstrates the illusion of speech (Pinker 1995)- according to the physical properties of the sound wave of speech, the words run one into the next, without boundaries or silence between them (unlike written text), and the brain determines the fixed word boundaries when the stretch of a sound, by matching the mental dictionary, functions like an edge.

The seamlessness of speech is apparent in *"oronyms"*, which are strings of sounds that can be interpreted into two different rows of words, such as: "The stuffy nose can lead to problems" and "The stuff he knows can lead to problems". (Pinker 1995).

The two auditory perception mechanisms are equivalent to the mechanisms for integrating or segregating an object from its surround. In that respect in the infinite and congruently composed global framework of visual stimuli complementary connectivity is the integrating mechanism (unification with the flow), analogous to sound perception, and symmetry is the segregating (symbolic) mechanism, analogous to language perception.

7. A Qualitative Demonstration of Computer Generated Infinite Patterns from Natural Scene Photographs

Infinite patterns of recognizable objects offer a demonstration equivalent to the "sine-wave" speech or the multiple interpretations of oronyms.

Inspired by the tessellations and periodic works of M.C. Escher, whose unique and fascinating works of art explore and exhibit a wide range of mathematical ideas, such as geometries of structures in plane and space, projective geometry and non-Euclidean, I was thrilled to try to employ tessellation and its play with geometry of space to express luminance and colour relationships and gestalt principles with photography of natural forms in infinite patterns.

It is the experience in making generating images of infinite patterns that has raised my attention to visual vibration and the need to search for counter mechanism to the Gestalt organization processes discussed.

Similar to natural condense packing, "Tessellations" are divisions of a plane, the arrangements of closed shapes that completely cover the plane without overlapping or gaps. Typical shapes of a tessellation are polygons or regular shapes, such as square tiles (there are also irregular shapes). When perceiving a tessellation

the identities of the depicted forms seem to change and interact with each other, like multiple interpretations of strings of sound into oronyms, or figure-ground vibrations, and give a sensation that the forms are breaking free of the plane itself- what Escher called a "metamorphoses", which is an ambiguity in perception, equivalent to sine-wave speech.

8. Procedure

Tiles with interesting patterns were cropped out of photographs of natural scenes. The cropped tile was in the shape of a regular square, to allow easy tessellation as shown in Figure 4.

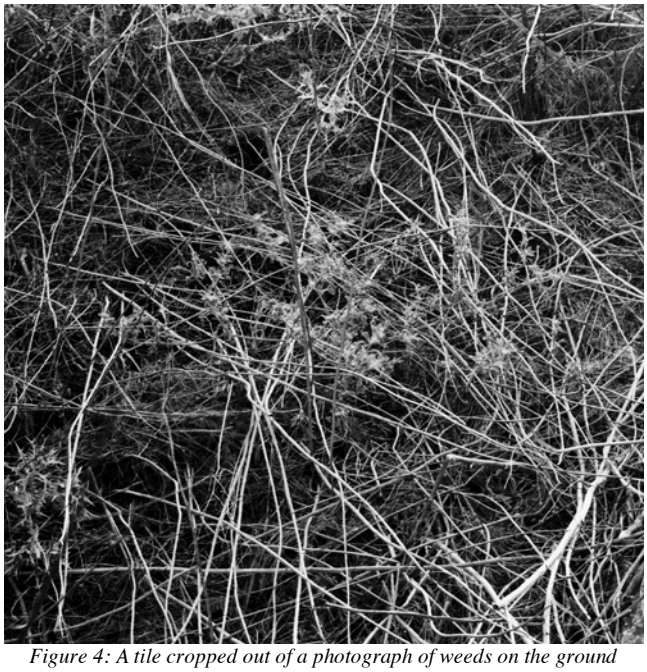

Figure 4: A tile cropped out of a photograph of weeds on the ground

Tessellation, in this demonstration, was achieved by using multiple reflections around a fixed point. One reflection is orientation reversing, resulting in a mirror image. But when one reflection follows another, the second reflection is another mirror image, resulting in orientation preserving. Both vertical and horizontal reflections were applied. The resulting infinite patterns are shown in Figure 5 (black and white from the tile of weeds in figure 4) and Figure 6 (colour).

The qualitative experience of choosing the tile to be cropped out of the photograph, revealed that although tiles with patterns of a unified, closed geometrical form are at first sight more attractive as figures and tempting to use, than formless and open patterns, when tessellation is complete though, patterns of closed shapes yielded a repetition of similar individual forms, that did not interact with one another and their diversity was only numerical. But with formless open shapes, a wide variety of combinations and unifications, lead to many options for element organization and local global relationships and interferences, thus resulted in a stronger visual fluctuation between symmetry and complementary connectivity.

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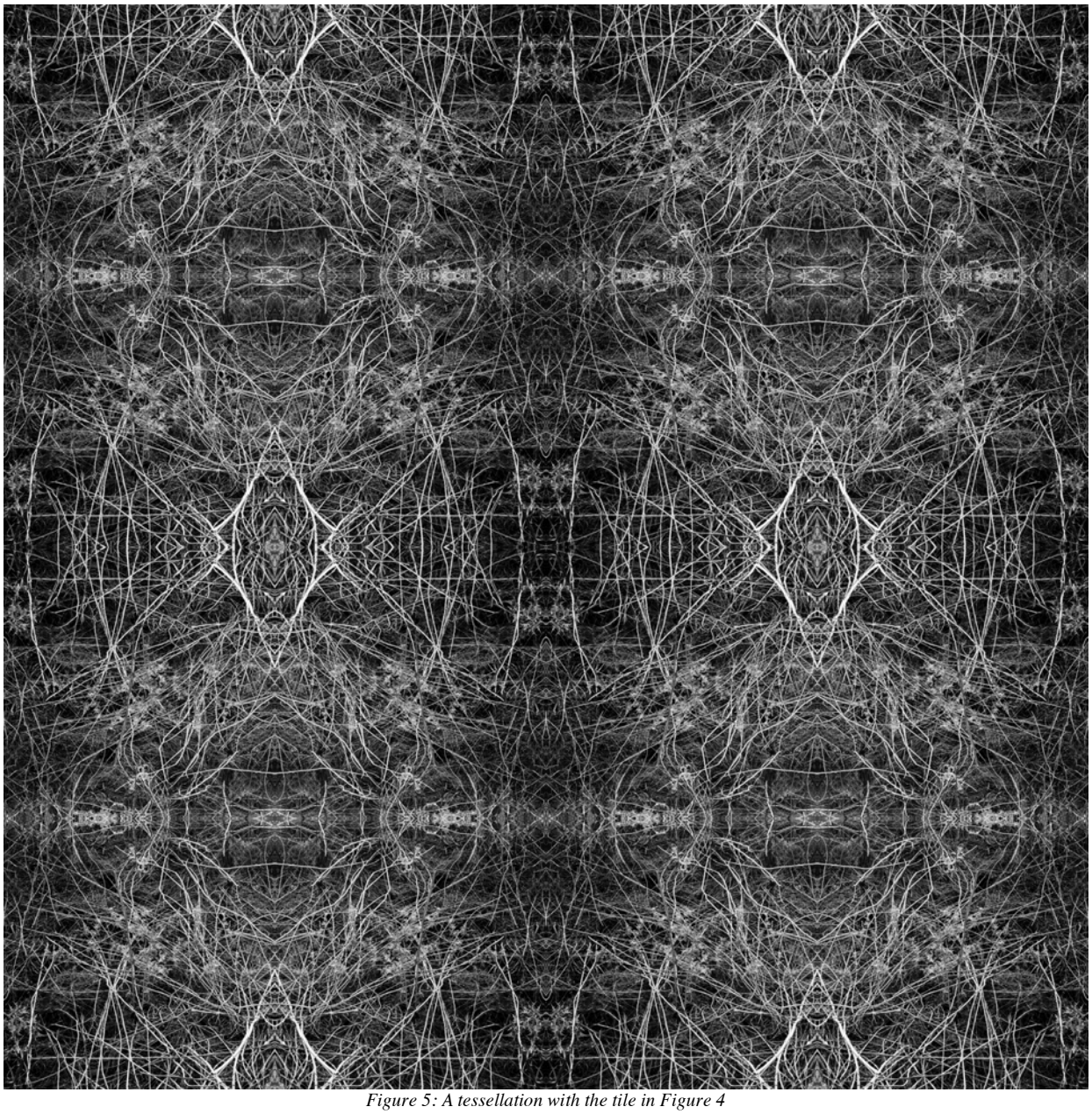

Figure 5: A tessellation with the tile in Figure 4