Perception of Space in Painting

Slavik Jablan
The Mathematical Institute,
Knez Mihailova 36, P.O. Box 36,11001 Belgrade, Serbia
E-mail: jablans@yahoo.com

Ljiljana Radović
Faculty of Mechanical Engineering, Department for Mathematics,
A.Medvedeva 14,18000 Nis, Serbia
E-mail: ljradovic@gmail.com

Abstract

During the history, perception of space in painting is changed from one- and two-dimensional geometric patterns, that dominate in Paleolithic and Neolithic art, through "hierarchical perspective" and orthogonal axonometry used in Egyptian painting, Byzantine counter-perspective, Renaissance linear perspective, cubistic polycentrism, perceptive perspective, to the non-orientable space of abstract painting. Trying to explain 3D-vision as the reconstruction of 3D-image from its 2D-projection, that is in general not unique, we will consider different extreme forms of perspective (e.g., anamorphoses), or the formation of ambiguous reconstructions of 2D-projections resulting in visual illusions and impossible figures.

Key words: perception, space, perspective, visual illusions, impossible figures

MSC: 01A05, 01A10, 51A03

1. Preliminary notes

In this paper we will try to give brief view on perception of spaces throughout history of art and panting as well as mathematics and design. During the history, perception of space in painting is changed from one- and two-dimensional geometric patterns that dominate in Paleolithic and Neolithic art, through "heirarhical perspective" and orthogonal axonometry used in Egyptian painting, Byzantine counter-perspective, Renaissance linear perspective, cubistic polycentrism, perceptive perspective, to the non-orientable space of abstract painting. Trying to explain 3D-vision as the reconstruction of 3D-image from its 2D-projection, we will consider different extreme forms of perspective or the formation of ambiguous reconstructions of 2D-projections resulting in visual illusions and impossible figures. We will start with idea of symmetry which is in behind all different perceptions of spaces.

2. The Idea of Symmetry

The laws of nature and the objects of human creation are representations of symmetry. The word symmetry originates from Greek science and corresponds to the term "common measure" (ςιμ=

„common“, μετρων= „measure“), directly pointing to one of the two most important problems of the Greek mathematics− the question about the commensurability of two line segments. The other important area of study for Greek mathematics was the theory of regular geometrical figures: regular polygons, polyhedra (Platonic bodies), uniform (Archimedean) polyhedra, inextricably connected to symmetry. The other meaning of the word symmetry originates from Greek philosophy and aesthetics and it is connected to a spectrum of philosophic-aesthetic terms: harmony, proportionality, balance, well-behaved form, etc. Throughout history, the universality of symmetry was reduced to its simplest form− bilateral or mirror-symmetry. In the written form, the word simetria appears for the first time in the Latin text „Tratato I“ by Francesco di Giorgio Martini. At that time, the term „symmetry“ had already lost its universality and was related only to architectural structures and their bilateral symmetry. One of the main Renaissance theoreticians of architecture, Vitruvius, and other Renaissance architects often used this word in their writings.
We find symmetry almost everywhere in nature. Certainly, any symmetry can be followed by a breaking of symmetry, dissymmetry, and some deviation from perfect symmetry which results in variety of forms Symmetry in art reflect symmetry in nature. Since Paleolithic times, the oldest period of human civilization, symmetry has played an important role. After representing a single motif, a deer’s head, the Paleolithic artist continued to repeat this figure by reducing and stylizing it, with the result being a frieze based on translation (parallel motion). In the same way, the series of figures in an Egyptian fresco perfectly illustrates translational symmetry (on the left in Figure 1). Throughout history symmetry has occurred in very different forms as artists tried constructing different symmetric artworks such as rose-windows from the Chartres cathedral, or the Op-art works by Victor Vasarely based on squares(on the right in Figure 1) .

Figure 1: *Symmetry in arts*

Rennaissance scientists and artists were fascinated with regular polyhedra, i.e., ideal geometrical bodies. We all know the famous Leonardo da Vinci’s drawing „Vitruvian man“− the composition of a human figure according to ideal proportions. From ancient times, beginning with Egyptian culture, the theory of proportions was applied to sculpture and architecture, i.e., buildings and sculptures were proportioned according to a canon. To an even greater extent, detailed and precise canons were used in ancient Greece, and in the Renaissance Leonardo tried to use these canons to inscribe the human body in the circle and square, archetypal forms representing Heaven and Earth.

3. Paleolithic and Neolithic ornaments

The first examples are symmetric ornamental patterns and friezes that Paleolithic man drew on the walls of caves or engraved on bone, giving testimony to his ability to recognize, record, and create symmetry. A handprint was probably the oldest symbol in the history of mankind, the first attempt of a man to leave evidence of himself.

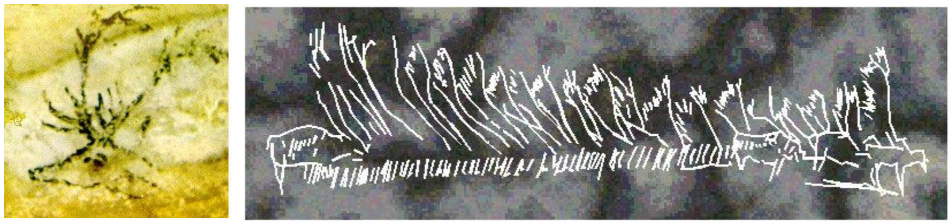
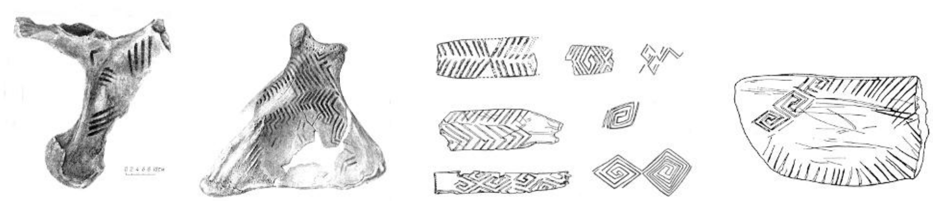


Figure 2: *A prehistorical art*

A prehistorical artist simplified the drawing of a herd of deer by stylizing it and, reducing it to a repetition of pairs of horns, and obtained a symmetrical pattern called a frieze or bordure − a decorative motif based on translational repetition (Figure 2).

We have found that the oldest examples of ornamentation in Paleothic art were from Mezin (Ukraine) dated to 23 000 B.C. Note that 23 000 years is a time period ten times longer than the complete written history of mankind. At first glance, the ornament on the right side of Fig. 3a appears to not be significant, it is an ordinary set of parallel lines. On the right side of Fig. 3b this pattern is transformed into a set of parallel zig-zag lines− an ornament with a symmetry group of type pmg, generated by an axis of reflection perpendicular to another axis of glide reflection (Fig. 3b). Let's see how the creative process for the design of this ornament may have developed. Imagine a modern engineer who begins a construction project. At first he makes a rough sketch, and then he begins to work more seriously to solve the problem. The next series of ornaments from Mezin is more advanced. The previously mentioned sets of parallel lines are arranged in friezes and meander patterns (Fig. 3c, d).



(a) (b) (c) (d)

Figure 3: *Basic patterns from Mezin*.

In Figure 4a we see the final result, the masterpiece of Paleolithic art ─ the Birds of Mezin decorated by meander ornamentation. The man of prehistory has applied the symmetry constructions that he learned, and he has preserved them for posterity. On the mammoth bone, modeled in the form of a bird, he engraved the meander pattern which represents the oldest example of a rectilinear spiral in the form of meander ornamentation.

The next artifact is an engraved bracelet from the same excavation site (Fig. 4b). If we look at this bracelet in developed form, we notice that there is a continuous transition from one ornament to another via a third ornament: on the left corner, reminiscent of the famous print „Metamorphoses" by M.C. Escher. You can see the meander ornamentation, then the set of parallel zigzag lines used as a symbol of water, and again the continuous transition to another meander ornamentation. [2,3].

(a) (b)

Figure 4: *(a) Bird of Mezin; (b) developed bracelet.*

The ornaments on Fig. 5 look very different one from another. Among them are black-white and colored ornaments, and at first glance, it appears that there is no unifying principle. Their common property is that they all consist of a single element (module). Notice the small black-white square in the middle. It consists of a set of parallel diagonal black and white lines (strips). If this square is used as the basic motif, then all of these ornaments can be constructed from it. We call this method of construction the principle of modularity. Our goal is to construct all ornaments or structures by using the smallest number of basic elements (modules) and to obtain, by their recombination, as many different ornaments (structures) as possible. This module, a square or rectangle with a set of parallel diagonal black and white strips, we will call an Op-tile; it is the basis of Mezin meander patterns (Fig. 4).

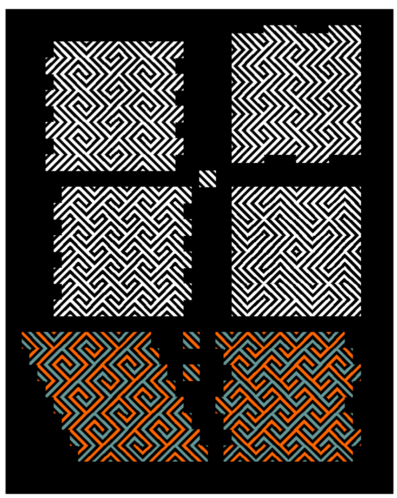


Figure 5: *Modular key-patterns.*

The whole of Neolithic art is characterized by the use of spiral ornaments, dating from the period from 6 000 to 2 000 B.C., where the most important ornaments are those from the Tripolian culture, coming from the excavation sites of Butmir, Lepenski vir, and from other cultures such as the Aegean cultures. The Neolithic period is the time when ornamental art (especially the construction of „black-white" patterns) greatly flourished and most of the ceramic ornaments originate from Neolithic times.

Figure 6 shows a series of ornaments from Titsa culture (Hungary) and Vincha (Serbia), dating to 3 000-4 000 B.C. Notice that ornaments from Vinca (Fig. 6b) are all based on meanders, continuing the tradition of Paleolithic ornaments from Mezin and Scheila Cladovei They are painted on ceramic and can be found in similar Neolithic settlements. By observing the numerous examples of Neolithic „black-white" ornaments, with the black part („figure") congruent to the white part („ground"), we conclude that all of them originated from basketry, matting, plaiting, weaving, or textiles and then were copied to the stronger media of stone, bone and ceramic. Many of these ornaments are obtained from interlaced patterns. Antisymmetry is the symmetry of positive and negative, light and shadow, black and white, „over-under". Therefore, antisymmetry can be used for so-called dimensional transition.

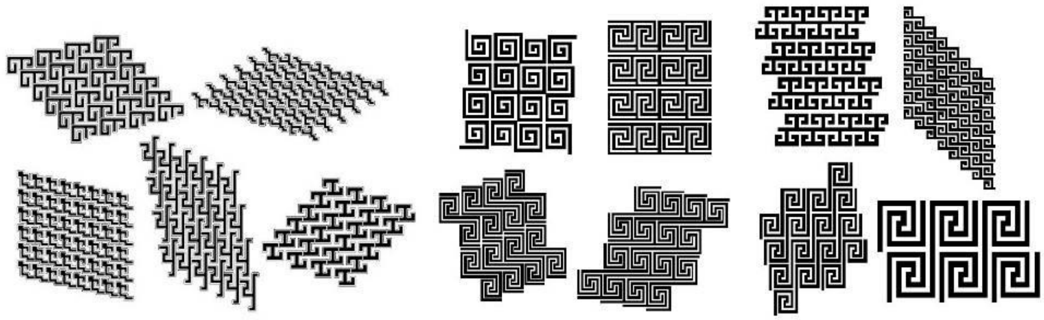


Figure 6: *Neolithic ornaments from Titsa and Vincha culture.*

The best textile patterns were copied to ceramic vessels which requires great skill since the surface of the ceramic vessels are curved. We can find similar examples all over the world (e.g., in Neolithic Lapita ceramics from Fiji (Fig. 7a), or Anasazi ceramics, (Fig. 7b).

(a) (b)

Figure 7: *(a) Lapita ceramics (Fiji); Anasazi ceramics.*

4. The development of perspective

Now, we will put attention on Ancient civilizations. The first is Egyptian civilization and how did they represented the space. They have been using so coaled low of frontality, i.e. orthogonal representation where all the shapes are on 90 degres. They didn't know about perspective, but they used "hierarchical perspective" the most important persons were the biggest, as figures of pharaohs, while the figures of slaves are very small. Also, they used "the principle of superposition: the figures on the bottom are the closest one and so on. Minor scenes at the bottom of a painted image are shown at a far smaller scale than the main figures higher up. They also used to put the plane of projection down in frontal plane, and did have canons for ideal proportions.

In art of Assyria and Babylonia, "hierarchical perspective" is also used. This period of arts is famous on relief with time dimension: they represent the series of persons in few different levels.The art of Ancient Greek is very famous. During the geometric period, people and animals depicted geometrically in a dark glossy color, while the remaining vessel is covered by strict zones of meanders, crooked lines, circles, swastikas, in the same graphical concept. They learned to use local perspective in form of local dilatation, but there is no some general principle.

In the middle age we can find the inverse perspective in the Byzantine art. Inverse perspective, also called reverse perspective, inverted perspective or Byzantine perspective, is a convention of perspective drawing where the further the objects are, the larger they are drawn. The lines diverge against the horizon, rather than converge as in linear perspective. Technically, the vanishing points are placed outside the painting with the illusion that they are "in front of" the painting. The name Byzantine perspective comes from the use of this perspective in Byzantine and Russian Orthodox icons; it is also found in East Asian art, and was sometimes used in Cubism and other movements of modern art.

The first attempt of linear perspective can be found in the period of early Renaissance. The earliest surviving use of linear perspective in art is attributed to Donato di Niccolò and Masaccio. Finaly, we came to Leon Battista Alberti (1404-1474).

Figure 8*: Battista Alberti's set for perspective drawing*

He was humanist scholar, natural scientist, mathematician, cryptographer and architect. Alberti was the first who put the theory of perspective into writing, in his treatise on painting, Della pittura (1435). Alberti described how an artist could get a correct view of a scene by observing it through a thin veil, or velo. The idea is that we can get a correct image of some object seen through such a veil or a window by tracing the outline of the object on the window glass.

Here we have to mention gret Leonardo da Vinci (1452-1519). Leonardo describes another kind of perspective, which we now called atmospheric perspective, which anticipate the doctrines of impressionism. Distant objects appear smaller, less distinct, paler, and bluer.

From the moment when painters solved the construction problems, accepted the exact rules of the linear perspective, and become able to consequently represent more sophisticated 3D objects, sceneries of cities or mass-scenes, they started experimentation and search for the new possibilities how to use the extreme forms of perspective: unusual, non-conventional viewing points or angles. For Example, in Dali's panting Christ of Saint John of the cross, 1951, dominates the traditional motif of the cross, emphasized by using such limiting, extreme perspective, and the combination of two perspective views in the same painting: the simultaneous use of two centers of perspective. Cubism also used a new way to represent space object from several different point of view on the same picture in the same time, so instead monocentism as in linear perspective, now we have polycentrism.

5. Immpossible figures

The basic building block of impossible objects is the Kofka cube: a regular hexagon divided into three congruent rhombs. All three sides of the Kofka cube are identical, so we cannot tell from which of three equally possible points of view it is being viewed, whether it is convex or concave, or even if it represents a 3D-object, or is it a regular hexagon consisting of three rhombuses, which, acted upon by plane isometries, results in a rhombic tessellation.

Impossible figures are figures that contradict our sense of visual 3-dimensional perception. But, are impossible figure possible? At first glance the two cubes on the left side of the slide represent an impossible object. However, you can take an ordinary cube, add to it a part in the form of an open book, join it to the cube, and obtain a real 3D-object which gives an impossible figure in retinal projection. The Penrose tribar can also be modelled by a real 3D-object.

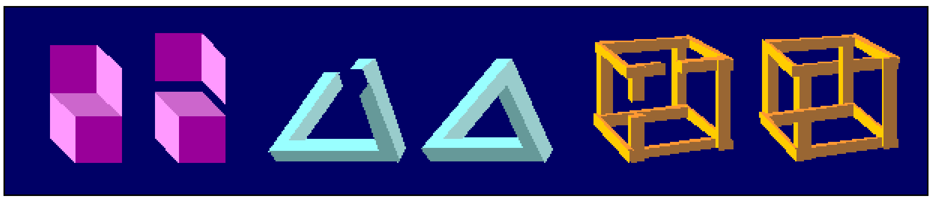


Figure 9: *Impossible figures*

In the process of visual perception our eye and brain makes a choice and accepts the simplest solution even if it contradicts our perception of 3D-objects and represents an impossible object.

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