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THE THREE DIMENSIONS IN DESIGN

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SUMMARY

Design studies in our architectural training are mostly limited to examples based on the perpendicular coordinate system. However, full utilization and the appropriate choice of the alternatives of form offered by space necessitates full knowledge and understanding of the topological and geometric principles of three dimensions. Every single object around us has a form which is a combination of tops, edges and segments. The rules pertaining to the systematics of three dimensions can be established through the combined permutation of the features related to points, lines and planes. The three dimensional forms resulting from the intersection of these features divide the space into two areas which are the limited and the unlimited spaces. These two areas are subject to a contrasting tension, from inside out and outside in. The limited areas can be studied under three main titles: Polyhedrons, prisms and curvelinears.

Space can be coordinated within certain principles through linear, surfacial or spatial modular units. Lines radiating with equal angles from a central point divide the space into equitable areas. Radiating lines permit four basic types of coordination of space. These coordinations consist of 3, 4, 6 or 10 lines.

Systems, which in addition to the three dimensions have four or more dimensions, can be studied through topologies. In a way, three dimensional structures constitute a spatial section of topologic systems.

The structural behaviour of a building is directly related to the form and geometric order of its components. Therefore it is not possible to abstract a building and its structural

problems from the geometric and topologic laws of space. The design of space is in fact its organisation through objective features.

Considering its direct relation between structural and spatial matters, it appears to be prerequisite of improving design skills in schools of architecture that students are introduced to and are taught the topologic and geometric rules governing the three dimensions.

INTRODUCTION

Not any formation is unrelated to the geometrical and topological rules of space in which it is located. In environmental design things are organised in a space which is defined by three dimensions. In regard to the mentioned fact, it can be explained that designing is making the organisation of solids and spaces together. Therefore full knowledge and full understanding of topological and geometric rules of space is one of the most important conditions of designing. Whereas, in architectural education the design studies are mostly limited to the examples based on the perpendicular coordinate systems and as a result they fail to develop imaginations and creative power. Another way to develop the creative power in designing is to have the full knowledge of the nature of perception and full knowledge of cosmic nature beyond the limits of perception. In order to understand the essential and objective form of nature and to imagine new possibilities for creations, the designers should leave their limited perceptions. Understanding the essential and objective form of nature beyond the subjective perception of it and imagining any possible universal systems can be done only through the concepts that are beyond the limits of perceptions. The subjects of mathematics, which include the possible shapes in three dimensions and space organisations, are directly related to the designing ability. So, it stands to reason to say that courses about imaginations and designing abilities should not only include objects, but also the geometrical and topological analyses of space which limit the objects' formation.

THE BASIC PRINCIPLES OF THREE DIMENSIONS

Each object around us has a form. From the geometrical point of view forms are a gathering of tops, edges and segments. The tops, edges and segments can be imagined as a kind of intersection of three-dimensional, two-dimensional and single-dimensional objects. These intersections divide the dimensions into closed (limited) and open (unlimited) areas. The closed surfacial areas are polygons and shapes that have arched edges. The closed spatial areas are polyhedrons, prisms, pyramids and the solids that have arched surfaces. The basic elements of closed spatial areas are tops, edges and the segments. The total number of tops and segments of a closed spatial area is equal to the number of its edges plus two, whereas the number of edges of closed surfacial area is equal to the number of its corners [1,2,3].

Both surface and space have spatial systematizations. The rules of these systematizations, which put specific limits to the kinds of the form repertory, can be found out through the permutation of three-dimensional, two-dimensional and single-dimensional modular units. Lines on a surface that are repeated with equal intervals and equal angles form consecutive modular polygons by intersecting at certain points. The straight lines that connect the centre of these polygons form another modular polygon series which are related to the previous straight line organisation. The two contrasting polygon series that are balanced by the tension lines, which direct form inside out and outside in, are the creators of each other. The contrasting creation exists in three-dimensional closed areas as well as in two dimensional closed areas [1].

THE BASIC POLYHEDRONS

To analyse the three-dimensions one can start by researching out the packaging possibilities of modular units in space. Touching each other at a similar position, the modular spheres can form only five kinds of group in space. These are the groups of four spheres, six spheres, eight spheres, twelve spheres and twenty spheres. The straight lines, which connect the centre of the spheres in any group, define the closed spaces which have determined forms. These closed spaces are known as "Basic Polyhedrons" or "Platonic Solids" [3,4].

The first basic polyhedron, which is formed out through the grouping of four touched spheres is called "tetrahedron". The others are "octahedron", formed out by six spheres, "hexahedron" or "cube" formed out by eight spheres, "icosahedron" formed out by twelve spheres and the "dodecahedron" formed out by twenty spheres. Every top and every edge have their own similar organisations in basic polyhedrons. The basic polyhedrons, which are formed through the uniting of equilateral triangles, have only three possibilities to form out the closed space. Uniting three by three at a top the squares form out cubes. Squares surfaces cannot close any part of space by uniting four by four at the top of a polyhedron. Uniting three by three at a top, regular pentagonal plains can only form out dodecahedrons. No matter how many they are, it is impossible for regular hexagons, which unite at their top points, to determine a closed area within three dimensions. Therefore, within three dimensions there is the possibility of a total of five basic polyhedrons consisting of plains in the form of three equilateral triangles, one square and one regular pentagon [3,4].

COMPLEX POLYHEDRONS

Touching each other at a similar position only twelve spheres can surround a sphere which has the same diameter with the others. This group of spheres form out a complex polyhedron which has fourteen surfaces. Six of these surfaces are equal sides triangles and the others are squares. This polyhedron is called "cuboctahedron". Because of the fact that its radius and its edges have the same size, cuboctahedron has a spatial importance among the group of complex polyhedrons. If the sphere at the centre fails to resist surrounded by it the cuboctahedron will transform into icosahedron which consists of twenty equilateral triangle surfaces.

Transformation of the tops, edges or surfaces of polyhedrons to each others forms out the group of complex polyhedrons that are known as "Archimedean solids". Although the basic polyhedrons consist of only one kind of surfaces, the complex polyhedrons consist of two kinds of surfaces or more which are triangular, square, penthagonal, hexagonal etc. At the same time, every polyhedron has a dual one.

PRISMS AND THE SPHERICAL SOLIDS

The prisms are formed out through the transformation of the polygons throughout a straight line. The smallest base of prisms is triangular and the biggest is circular plain. The variations of prisms between the triangular prism and cylinder are unlimited. Prisms have also duals as polyhedrons have.

The top points of all polyhedrons are on the surface of sphere. In the case that the edges get their places on the surface of spheres, other kinds of polyhedrons are formed out which consist of curved edges and spherical surfaces. The spherical surfaces can be divided into smaller parts by the curved lines. Thus spherical polyhedrons can be obtained whose edges consist of curved lines. Dividing the surface of sphere into modular parts is based on some rules. The basic polyhedrons can also be used in this process. Buckminister Fuller who is a structure designer has a lot of study on this subject. If the basic polyhedrons are supposed as spheres, it can be concluded that all the spherical solids are based on five kinds of groups. But the number of these groups can increase to six by adding the sphere which has two poles and which is based on prisms. The curves of the edges of these polyhedrons are in the same directions. Whereas, the other kinds of the closed areas have the opposite curves. One of the most important of these solids is the "torus". The hyperbolic paraboloid surfaces can be considered as a part of a torus. The solids which have opposite curves can be obtained by transferring the straight line through a determined turning [3].

MODULATION IN THREE-DIMENSIONAL SPACE

The three-dimensions can be coordinated by straight lines which radiate with equal angles from a starting point. These coordinations divide the space into equal and similar areas. The space, which we live in, has only four kinds of possible coordinations of straight lines. These coordinations are formed through the intersection of three, four, six and ten radiational straight lines. The three straight lines which intersect each other at right angles divide the space into eight equivalent areas. Being based on the quantity of the lines in this coordination, our space is known as "three-dimensions". The four straight lines which intersect each other at $70^0\ 32^I$ divide the space into six equivalent areas. This coordination is the dual one of the former coordination. The six straight lines which intersect each other at $63^0\ 27^I$ divide the space into twenty equivalent areas. The dual of this coordination consist of ten straight lines which intersect each other at $41^0\ 49^I$. This coordination divides the space into six equivalent areas. The four basic spatial coordinations which are explained above prepare the forms for the repertory of automorfique formations of the natural structures. The five basic polyhedrons can be used while researching these coordinations systems. The coordinations of lines in space coordinate the surfaces and the spatial areas at the same time. The coordinations which consist of three and four straight lines coordinate the tetrahedral, hexahedral and octahedral modular areas. The coordinations which consist of six and ten straight lines coordinate the dodecahedral and icosahedral modular areas. There is a rate of (1+ 5)/2, known as the "golden section", between consecutive segments that are formed through the intersection of the mentioned coordinations [4,5].

The diagonals of the surfaces of hexahedral areas which are formed by the perpendicular coordination bring to view another coordination which consists of six lines. Different from the basic coordination systems, this one has two kinds of radial angles (60^0 and 90^0). As a result, this coordination packages two kinds of polyhedrons consisting of tetrahedral and octahedral spaces. At the same time this coordination can be obtained through the intersection process of the spatial diagonals of cuboctahedrons.

THE STRUCTURAL CONTENTS OF THREE-DIMENSIONAL SPACE

Structure is the group of elements which have determined relations with each other. The integrations in any subject such as function, form, aesthetics, statics, etc. are not unrelated with their outside factors. It can be said that structure is the equivalence of inside and outside components. Structural formation is defended and transformed by the coordinations between its components. So, forms and geometrical coordination of the components are directly related to the structural performance. For instance, structural performances of a triangle and a square are not the same. A square frame which is under a loading can be deformed only by changing its angles.

Whereas, a triangular frame is not deformed only by changing its angles. This geometrical principle which affects structural performance is not valid for only two dimensional forms, but also for three dimensionals. Structural formation has two basic components which are space (emptiness) and material (fullness). The modular materials which have cohesion make new entegrations through spatial organisations. The cohesion between the components creates the tension of pulling and pushing in any part of structural groups. The tension of all components is the inertia of that structure. The structural units divide the space into two contrasting areas which are finitive and infinitive spaces. These two areas have dual tensions from outside to inside and from inside to outside. In the space, structures are formed by obeying the rules of these tensions [7,8].

Every kind of structure can be formed only in three-dimensional space. It is impossible to imagine the hyper structures of imaginary spaces which have more than three dimensions, even though mathematical operations give knowledge about them. Their projections can be obtained in three dimensional space through topological operations.

The momentum of the constructive elements which resist the vertical load increases in rate with the square of the length of the interval. Therefore, the thickness of the constructive elements should also be increased. Finally the structure becomes heavy and cannot support itself. Whereas, this problem can be solved by coordinating the elements which have only the tension of pulling and pushing. Loading the elements in the directions of their axis's, one can do away with the momentum [7,9].

THE ORGANISATION OF THREE-DIMENSION

Every objective design is related to the three-dimensional space. Therefore, the three-dimensional space also becomes one of the elements of designing as well as the objects. In environmental designing by the help of the objects, the three-dimension itself is also directly organised. Therefore, it is very important to have full knowledge and full understanding about space in the architectural studies. In these studies it is not possible to use all possibilities of spatial coordinations by basing the studies only on perpendicular coordinations. Full knowledge and full understanding about the geometrical and topological rules of space is the first step to develop the method of creation and designing [10].

Day by day the structures are being more light, more strong and more flexible. Therefore, the organisational cohesion which is supplied by the entegration of the structure is taking the place of the statics that are based on the weight of the components of the structure. The first aim of the modern designing is to use the materials as less as possible in order to organise the space. To realise this, mankind must make the synthesis of the knowledge and discoveries about mathematics and the applicable sciences that have been obtained since his being. So looking from this point of view many engineers want to apply the universal principles of formations to architecture [10,11].

Physiological, psychological and sociological necessities of human beings are changing because of the development of science and technology. Using the traditional methods to solve the problems of future adds new problems to the previous ones. Although improving the highways seems as a solution for futural communication, specialists put forward that before competence of the highways mankind will get rid of grazing on the ground and will catch three dimensions in motion. This motion does not only include communication, but also all the structural systems.

A structure consists of many different components which have different functions. The result of these functions are the main function of the structure. Every structure has a statical system which forms it and keeps it standing. The system of the structures not only include the statics, but also the systems which supply their lives. Therefore spatial networks which are based on universal rules should be adopted as a basic principle instead of traditional system in order to obtain more prevalent solution [11].

During the year 1994-1995, I tried to give knowledge about the geometrical and the topological rules of space in the course of "Basic Design". The program of this course was prepared by me at the Faculty of Architecture in the Erciyes University located in Kayseri.

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