ARCHITECTONICS - A SYSTEM OF EXPLORING ARCHITECTURAL FORMS IN SPATIAL CATEGORIES

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Abstract

Comparative researches based on visual analyses of different architectural objects enable separation of the small number of basic recurrent units defining spatial aspects of architectural form independently of when and in which cultural circle the object was created. These basic units of spatial structure can be termed spatial universals. Using them in accordance with some basic and universal rules of assembling into larger wholes makes possible creating any spatial objects as well as transforming them into different ones. At the same time words of natural languages contained in dictionaries give us important clues how people think about space. Another important clues are included in some recent theories of perception. All these findings taken together have been the basis to create the system of notions and terms regarding space in architecture. It is founded on basic and universal spatial elements (units) and rules of their composing into larger wholes. The paper is the trial of presenting such a notional system which was termed architectonics (or morphotectonics). Basic notions enabling description and analysis of spatial structure of any architectural object have been introduced. Fundamental spatial units have been also distinguished based on the principle of hierarchical structure – from elementary ones, through more and more complex up to largest ones playing decisive role in defining the whole architectural object. Basic spatial morphological features called also cardinal ones have been differentiated. Primary kinds of articulation have been discussed dealing with the empty space (internal or external), line, surface and volume and their elementary units had been distinguished. Besides morphological features characterizing composing elements the rules of their assembling have been specified, which have been termed syntax or relational features, characterizing spatial wholes composed of elements. Both morphological and syntax features may be treated quantitatively or measured by means of introduced coefficients. The presented system of notions as well as the quantitative approach should enable objective description and analysis of the built environment which is the necessary condition of research dealing with relations between man and his behavior and the environment, if these researches have to fulfill such elementary scientific criteria as repeatability, verifiability, internal and external validity and inter-subjective communication. The presented methodological proposal is addressed in particular to research on perception and cognition of the built environment and people's reactions to it, such as evaluations, associations and emotions. It could be also useful in historical research carried both in comparative and systematic perspective, as well as in environmental aesthetics where comparing the new object with existing surrounding is of crucial importance. For the reason of limited place the paper is restricted only to presenting the system itself, while applications should be the subject of different publications.

Keywords

Architecture; space; system; description; analysis.

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Introduction – Initial Assumptions

The comparative research dealing with the manners of shaping the built environment in different cultural circles and historical periods carried on from different cognitive perspectives and, based on different methodological assumptions, provides sufficient materials to formulate the hypothesis that in theoretically unlimited variety of spatial forms generated anywhere and at any time, there are some common elements of basic character – recurrent and generally employed. It includes, in particular, the spatial systems (layouts and arrangements) of architectural objects, their main composing elements and their features, as well as the manners of gathering these elements into larger wholes. These recurrent basic units, invariable and not dependant on time and place in which they were generated, may be termed spatial universals. This notion is analogical to language universals, being a relevant component of contemporary psycho-linguistic concepts (Wierzbicka, 1996). A similar idea is also present in some recent concepts of architectural theory, mainly based on phenomenological approach (Thiis-Evensen, 1988), separating some basic units called "archetypes" or "primitives". Although these findings have not been proved by empirical methods, nevertheless could be of some value for theoretical considerations. The concept of "primitives" has a long tradition reaching in its roots ancient ideas of Plato and Pythagoras and continued in many later theoretical treatises. Such units are, in some way, meta-historical and meta- cultural. Since all living processes of human beings always proceed with an environment of definite spatial structure, its recognition is one of the basic cognitive activities enabling adaptation and survival. On certain phase of human species evolution the specific human ability to create the space of environment appeared – the production and transformation of artificial spatial systems like buildings, structures, settlements, villages, cities, towns, etc., which, being the products of man, have to be comprehensible for him, reflecting the structure of his cognitive possibilities.

The recurrence of some basic manners of space shaping seems to support the next hypothesis, according to which there exists one universal spatial system common to all people as a sort of universal spatial "language". According to the currently dominating approach to many human competences, such a system would be universal, biologically qualified characteristic of human species, as well as being the component element of our genetic equipment like language qualifications. To put it in a different way – every human being possesses the innate ability to create elementary spatial objects, understanding other already existing ones and availing them as the tools. This ability seems to be the biological basis for natural, unconscious and free assimilation of spatial elements, their features and the rules of their composing into larger wholes by small children, as well as for conscious intentional processes of learning and creating space at the later stage of personal development. Owing to this ability, we are not only able to perceive space, but we are also able to think about it, create its representations, and speak about it. According to some contemporary linguistic theories, spatial notions are more fundamental than other notions expressed in given language (Maciejewski, 1996) which could be the strong premise of the previously presented hypothesis.

Nevertheless the construction of such hypotheses is not the goal of these considerations. They rather show the author's view on space in architecture. Regardless of its truthfulness the possibility of the construction of the spatial notions system in architecture appears to be of great importance to architectural research and theory. It seems also reasonable to find it perceptually and cognitively and exploit the analogies to language systems, which serves as the source of inspiration and pattern. The subject of the present considerations will be first of all investigating spatial objects in architecture, and in particular looking for some cognitive units of universal character. The basis of this search is the supposition that the ways of shaping space by man are determined not only by traditionally acknowledged premises of technology, function and culture having changeable character, but also by perceptual and cognitive abilities of man, which – as being biologically qualified or innate – are, as a rule, stable and universal. For this reason the recognition of the universal rules of shaping space can have important meaning, not only theoretical, but also practical, because it should lead to better fitting of created spatial structures to the structure of man's psyche.

The main goal of researches on morphology of architectural space carried on for many years from that specific perspective (Niezabitowski, 1979, 1995, 2002) was searching for spatial universals and creating fundamentals of the universal spatial system which is common to most architectural objects, while simultaneously being reflected in human languages which in turn reflects human thinking. This approach was mainly inspired by some recent concepts developed in the frames of psycho-linguistics (Kurcz, 2000). The method of research is based on comparative visual analysis of architectural objects created in several of the biggest cultural circles of Europe, Asia and America as well as in the most important historical epochs (of the pre-historical period, ancient times, medieval period, and modern times). The basic research material were photographs of about 500 architectural objects of different historical periods and cultural circles contained in well known basic books on history of world architecture, "Key Monuments of the History of Architecture" (A. Frazer, H. Millon, 1965). This material was subjected to visual analyses and comparisons in order to separate fundamental, recurrent elements defining spatial systems of architectural objects, their characterizing features and relations between composing elements. So the primary method used in this research can be classified as observation, since it is planed, systematic and directed to specific goal. To achieve this objective the special research tool previously termed morphotectonics (Niezabitowski, 1979) enabling description and comparison of spatial systems in architecture was created. The primary premise of creating this system was fulfilling the basic scientific criteria which are well known and widely accepted in many scientific disciplines, like objectivity, inter-subjective communication, internal validity, external validity, generalization, recurrence of results, etc.

Since some basic ideas of the concepts presented in the paper were inspired by linguistics and particularly psycholinguistics, some of the introduced terms and notions were also borrowed form this disciplines (like for example morpheme or formant) (Berko Gleason, Bernstein Ratner, 2005). Others are well known and widely used within the area of architectural theory and practice. However, of special importance are notions and terms taken from the famous "Roget's English Thesaurus". This unique dictionary of English language was constructed not on the usual way of putting words in alphabetical order, but was based on classifying them according to some principal ideas being foundations of thinking about the world. So in the class of space we can find about 130 spatial categories, each of them including from several to tens of words, so that the total amount reaches about 7 thousands terms regarding space and spatial objects. If we assume that there is a connection between language and thinking which is the basic thesis of psycholinguistics (Kurcz, 2000), we can also built the hypothesis that analyzing natural languages gives us important clues as to people's ways of thinking about space in general and architectural space in particular.

Moreover, there is no scientific evidence that people really think about space using strict mathematical notions and definitions. These statements taken together could be the basic premises of building the notional system possible to employ in describing, analyzing, comparing and systematizing spatial objects in architecture. Findings of visual spatial analyses were confronted with notions regarding space taken from the above mentioned dictionary and combined together to form the presented descriptive/ analytical tool. Some of its elements are also supported by recent theories of visual perception, like Marr's computational theory, and Biederman's Recognition by Components theory. The whole proposition should be treated as theoretical concept which needs empirical verification. But this can not be the subject of the small sketch like the presented paper. Finally it has to be noted that some important attempts of systematization of architectural forms were already successfully made by other authors (F.D.K. Ching, 1993, R. H. Clark & M. Pause, 1996, W. J. Mitchell, 1994). Some of them are more oriented at teaching which does not mean that they do not fulfill scientific criteria, while others are more readily implemented in architectural research.

Basic Notions and Definitions of Architectonics

Architectural object as the spatial system

To keep the necessary scientific discipline we will begin with the basic statement that every architectural object can be considered as the spatial system. The method of system analysis proved to be particularly useful for investigating highly complex objects, so its application to architecture should be well founded. The general definition of a system must be descriptive and based on the enumeration of its main elements. So every system:

1) is an ordered and cohesive set of components, creating the whole which is different from components itself,

2) every component is characterized by the set of features,

3) all components are connected by the set of relations, which is called structure of the system,

4) every component remains in specific relation to the whole system, or serves particular function in it; the set of these relations (or functions) is called organization of the system,

5) every system as the whole remains in definite state, defined by the set of features which are constant in the chosen period of time, 6) some system undergo the processes of changes, or modifications, which means (among other things) that one can make different operations on the system components. Some of these notions can be used in description, analysis and comparison of architectural objects.

Adapting the system approach to architectural objects one can say that they can be considered as the sets of spatial elements connected with each other in such a way, that the observer can visually perceive them as the orderly and cohesive whole. This requires some additional explanations dealing with the manner of our perception of the surrounding world. Since a considerable part of information coming to our mind from the external environment is transmitted through the sense of vision; we could say that our perception of space is mainly visual. This does not mean that we could neglect the role of other senses, but still their role in the perception of space is only ancillary. Therefore, regardless of the unquestionable importance of such senses as touching, smelling, hearing or kinesthetic stressed especially by phenomenological approach (Thiis Evensen, 1988) we can treat the perception of spatial objects as mainly visual, and could s ay that they are in some way visual objects composed of visual elements and defined first of all by their shape and dimensions. This means deliberate simplification, omitting such important visual features as color and texture. Not considering these visual features was motivated by the tendency to increase clarity and intelligibility of the argument as well as by restricted frames of this paper. The above definition of spatial system complies also with the Gestalt laws of visual perception.

So the proposed architectonics is a system of notions reflecting both our mental skills and common experiences with space and spatial objects, based on acquired knowledge which we gain through perception and cognition. These three elements are also reflected in languages. To return to the analogy with language system we should differentiate between two main components of the architectonics:

1) Morphology - considering spatial elements of the system and its features, 2) syntax – investigating spatial relations between elements themselves, as well as between elements and the whole.

The spatial morphology of architectural object

Every spatial system (or architectural object) contains a definite number of spatial elements and units of different kinds. To explain and define these basic notions we should use the method of reduction and ask the basic question: what are the smallest and already not divisible visually perceived parts of the spatial system, being something like the "particles" of chemical compound, or – using rather the comparison with language which seems much appropriate – the "characters" of visual space? It will be convenient to understand by the elementary spatial unit of architectural object the smallest visually perceived and clearly defined three dimensional part of it being either independent whole or a part of the bigger whole. This unit, being the smallest visually discernible physical component of the object, is not always relevant for the perception of the whole and not necessarily influencing its integrity, will be called voxel (volumetric element) (Mitchell, 1994). It is a kind of spatial point, being physically a very small lump of given building material. They could be compared to characters or phones in language.

We can take the somewhat abstract assumption, that its shape is more or less spherical or cubic, while its dimension is defined by the ability of people's normal eye resolution. So voxel is a material point which we are able to perceive visually. For this reason it may also be named visual point. As abstract as they may appear, voxels are not virtual ideas but concrete material things, exemplified by such real objects like vertexes of the cube or another solid, or small amount of pigment on the surface, etc. For this reason, voxels can assemble with each other in the process of accretion or agglutination, which results in creating bigger parts, being able to divide space into different regions, which can be named morphemes. There are three basic manners of assembling voxels: 1) grouping them one after the other in such a way, that they form a single free line, which we will call the visual line, 2) grouping them in such a way, that they form a single free surface, which can be called visual surface, 3) grouping them in such manner, that they create visual volume, which we can call visual solid. We can give them one common name of basic visual elements or visels. Watching any architectural object we can easily recognize such components like points, lines, surfaces and solids, so we tend (consciously or not) to interpret this object as composed of visels. While voxels and visels still seem to be rather purely theoretical concepts based on visual perception but not very useful in practice of spatial analysis, morphemes are much more concrete three dimensional units of spatial system, able to define its visual character (Niezabitowski, 2004). Morphemes are generated as the products of the process of spatial articulation, which means that, in the most general sense, location the definite portions of building material in particular places. The particular building material will be given the generalized term substance. In that meaning, it must have such physical features, as solid state of aggregation, resistance to forces, hardness, and durability (Gibson, 1979). The result of the featured process is a division of formerly homogenous universal space into substantially differentiated parts: full space and empty space. We can say that architectural space is a set of full and empty places which are always complementary and never exist separately (at least in terrestrial conditions). This also means that space is not substantially continuous – or that it is articulated. Putting all these statements together we could name them the "rule of general articulation", which is the first rule of spatial definition. The division of space means introducing boundaries between parts of a given subject, which separate one part from the other, or separate particular parts from the rest of space. Every morpheme is a defined spatial region limited by the outer line or surface called boundary, which surrounds it from all directions. Putting this in categories of Gestalt theory of perception, one can say that morphemes are the figures, while the whole spatial system plays the role of ground. The space inside the boundary may be called interior. Such an approach is parallel to the Gestalt notion of figure and its contour, which is nothing other than the physical and visual boundary. The interior of the morpheme can be either filled with substance (or full) or remain the empty space. So morphemes are either the portions of substance or the empty spaces between them. Correspondingly we can say that about full morphemes - massives and empty morphemes – vacuons.

In other words, massives are the positive spaces (filed with substance), while vacuons are negative spaces (devoid of substance). For example capitals, shafts or bases of columns are massives (positive spaces), while channels hollowed within the solid shaft are vacuons (negative spaces). Morphemes as the smallest parts being able to divide space could be compared to syllables. Adding morphemes to each other leads to the creation of bigger components of spatial system, which can be considered as independent and self sufficient, relevantly influencing the integrity of the spatial system and its wholeness. Such parts will be called formants. They may be considered as counterparts of words in language. The examples of formants could be windows, portals, cornices, eaves, columns, pilasters, etc. To explain this notion, let's take the example of window, as the complete whole, called formant. Such an element, playing the independent role in the whole building, consists of many smaller, dependent parts, like frames, wings, panes, mullions, glazing bars, window sills etc, which are not reducible to smaller visually and spatially relevant components. Such parts may be called morphemes. In the most general sense, they can be regarded as architectural details, which is a traditional, well known and widely used architectural notion. Since formants consist of morphemes, they may be considered as subsystems of the whole spatial system. Just like morphemes, formants can also be interpreted as figures, while the whole spatial system plays the role of a ground.

Every morpheme or formant can be characterized by the set of spatial features, which can also be called distinctive features. By this notion, we will understand definite physical properties defining the way in which the morpheme or formant spreads in the space, distinguishing it from other elements. The part of architectonics investigating features of the elements of spatial system may be called spatial morphology.

As we have previously noted, in practice, formants are the well known building elements like windows, doors, balconies, oriels, cornices, socles, etc. One can divide formants into: 1) primary formants, which are the main parts, deciding about features of the whole system, and 2) secondary formants, being the subordinated parts, deciding about the features of the primary formants. Whether the given formant is primary or secondary depends on: a) its localization in the system, b) its dimensions, and finally c) its spatial function in the system. Primary formants are components of the system localized in spatially important places, possessing relatively large dimensions and fulfilling the most important spatial functions in the system. The important places within the spatial system are: whole external boundary or its visually perceived parts like contour as the whole, its upper part, its lower part, its sides and vertexes. Other important places of the system are: places within the silhouette, like main vertical or horizontal divisions, primary and secondary axes and visual center. Important spatial functions are: accentuation of the above mentioned important places, filling, separating, and connecting. The function of accentuating means that these places are marked by introducing to them spatial elements attracting our attention. Accentuating of the whole contour may be called framing, upper part of the contour - crowning (or resting), lower part of the contour – underlining (or supporting), sides of the contour – flanking. Correspondingly, the framing elements may be named frames, elements accentuating upper parts - crowns , lower parts – bases and side parts – flanks. The function of filling resolves to contain one object within another and may also be called nesting. Separating is a more complex function since it depends on substantiality. If the given components are vacuons (or empty elements), separating them is possible only by using a full element (or massive), while connection is possible only by using an empty element (or vacuon). On the contrary, if the given formants are massives (or full elements) their separating is possible only by using an empty element (or vacuon), while connecting them is possible by using a full element (or massive). This rule, being one of the most fundamental principals of spatial articulation, may be named the rule of connecting and separating spatial regions, which is the second rule of spatial definition. On the formants we can make some basic system operations. The most relevant of them are: addition, subtracting, division, substituting, replacing. All of them are articulating operations which lead to generation of the spatial systems, representing different degrees of complexity.

So the concept of spatial function leads us to the third level of assembling spatial units - the set of formants (both primary and secondary formants), which could be treated as the counterpart of sentence in linguistics. It will be termed tecton. It is a more complex system than that of formant, containing more elements which are bound by complex relations. The example of this unit may be the façade of the building or another big part of it like inner wall with a complex system of composing elements. This analogy to linguistics would be incomplete if we did not differentiate the highest, fourth level of assembling spatial elements being the counterpart of text. It is the building as a whole, the edifice or volumen, which should be treated as the most complicated spatial system, being the subject of our analysis. Of course, we could continue this way of thinking and take into account also much more complex spatial systems like parts of cities, cities as a whole, etc. But for the clarity of analysis, we will restrict the scope of it only to the above mentioned levels. Summing up, we have introduced five spatial units enabling spatial analysis on five different levels. On the first level such units are voxels and/or visels, on the second - morphemes, on the third – formants, on the fourth – tectons, and finally on the fifth – edifices or volumens (whole buildings). Decomposition of larger wholes into smaller parts seems to be in accordance with some of the recent theories of visual perception like Marr's computational theory (Marr, Nishihara, 1978) and, in particular, with Biederman's Recognition –by – Components theory (Biederman, 1987). The latter describes the way in which this process of decomposition or parsing the visual field into segments is usually performed, founding on edges extracting through detecting differences between luminance, texture and color of surfaces, as well as recognizing regions of acute concavity. Another support of the concept of main components of the visual area is provided by the empirical data and conclusions from recent researches on the activity of human eyes during the visual process (Keul, Hutzler, Frauscher, Voigt, 2005).

Morphology of spatial systems investigates three spatial features regarding both spatial units being parts of the whole structure (morphemes, formants, and tectons) and the whole structure (volumens). The set of these features, which we will call cardinal features, contains: 1) shape, 2) dimension, 3) directivity.

Ad 1) The shape of the component (or the whole set) may be described by six specific aspects of this cardinal feature: 1.1) dimensionality, 1.2) geometrical quality, 1.3) curvature, 1.4) flexure, 1.5) convexity, 1.6) articulation.

Ad 1.1. Dimensionality of the component or the whole system is the aspect of shape, being the particular case of proportions of its basic dimensions (length, width, height). When one, two or all three dimensions are so small that they do not play a relevant perceptual role and for that reason may be omitted, we will differentiate the following modalities of dimensionality: punctual, linear, superficial, solid. It is obvious that these notions cannot be treated literally according to geometrical definitions. They are based on the common perceptual interpretations of visual data flowing in from the environment. These data are compared with our knowledge about geometrical objects like points, lines, surfaces and solids stored in our mind, and then categorized correspondingly on the basis of resemblance. So when all three dimensions of a single object (width, length and height) are so small that they could be omitted, we can interpret it as point and can talk about punctual articulation (Plate I, Fig.1, 2). The example could be the handle or another very small detail, only faintly noticeable so that it can be easily interpreted as a point. When two dimensions of a single object (for example length and width) are very small, while the third is so big and clearly noticeable that it can be regarded as dominating, we can interpret it as line and talk about linearity (Plate I, Fig. 4). The example could be the mast, very slender column, bar, stick, rod, rope, string, etc. When one dimension (for example width) of the object is very small, while the remaining two (length and height) are so big, that can be treated as dominating – we can interpret it as surface and talk about superficiality (Plate I, Fig.5). The example could be the single free standing wall, screen, curtain etc. Finally, when all three dimensions of the object are big and clearly noticeable, though none of them is clearly dominating – we can interpret it as solid and say about solidity (Plate I, Fig. 6). The example could be the building of any type. It is difficult to measure dimensionality because it involves the question of the visual perception of proportions. Practical measures could be established either by arbitrary assumptions, what seems to be an inappropriate solution, or by empirical study, which has not been done yet.

Ad 1.2. Geometrical quality is the aspect of shape based on the possibility of describing it by means of the basic notions and figures of Euclidean geometry. This should not be confused with regularity, although in some cases it seems to be convenient since it gives some possibility of simplification of the form, which is close to the Gestalt notion of Pragnantz, or a good form. (Plate II, Fig. 1-4). The opposite of this feature is non- geometric quality. This concepts should be implied in terms of empirical research in visual perception rather than in mathematical notions of structural information theory (van der Helm, Leeuwenberg, 1996) since the results of the former are not always in accordance with the latter (Olivers, Chater, Watson, 2004). The measure of geometrical quality is the coefficient of geometrical quality, which could be defined as the ratio of the number of geometrically shaped components (Gp) to the total number of parts composing the system (Ap), Cgeom = Gp/Ap (it may also be expressed in percentage). A more detailed description should investigate the number of different geometrical types of figures (like triangles, semicircles, rectangles, etc.) applied in particular morphemes or their parts. Of course, also the notion of geometry (like the previously discussed notion of dimensionality) should not be treated literally, but rather intuitively. There is a great variety of very complex shapes which are geometrical in the strict sense of the word, but perceptually they are not recognized as such since this interpretation is too difficult for our mind. In terms of the Gestalt theory of perception they are not good Gestalts, since they contain too much information to process. So in using the term "geometrical quality," we will understand it rather in the manner pointed out by Irving Biederman's theory of Recognition by Components (Biederman, 1987). According to this theory, people perceive all spatial objects reducing them to different combinations of 36 simple geometric volumes (geons), so it is also possible to interpret all architectural objects and their parts in this way. It seems to be especially promising in regards to the most important of the previously differentiated spatial units, like formants and tectons which decide on spatial definition of any architectural object.

Ad 1.3. Curvature is the aspect of the object's shape which needs to consist of at least one curved line or surface (it refers to contour, silhouette or solid). The opposite of this feature is non curvature (Plate III, Fig. 1-4). The measure of curvature is the coefficient of curvature being the ratio of the number of curved lines or surfaces (Cp) appearing in particular formants to the total number of lines or surfaces (Ap) employed in the system, Ccur = Cp/Ap (may be also expressed in percents). It is also possible to measure the total length of curved and straight lines, and count the ratio of the first ones to the second ones, or measure the total area of curved and flat surfaces, calculating their ratio.

Ad 1.4. Break or flexure is the aspect of shape referring to the fact that the outer surface of the object possesses at least one sharp edge or its contour possesses at least one vertex. The opposite of this feature is oval quality (Plate IV, Fig. 1-4). The measure of flexure is the coefficient of flexure, which could be defined as the number of sharp edges and/ or vertexes. Break is often one of the possibilities to mark the border between adjoining spatial components.

Ad.1.5. Convexity is the aspect of shape pertaining to the fact that it is impossible to find such a tangent to the contour (or outer surface) which could cut this contour (or outer surface). The opposite of convexity is concavity. To define these features in perceptual terms we can say, that convexity is the case in which projecting parts appear, while concavity means employing recessed parts (Plate V, Fig.). Of course, we can encounter also mixed cases, in which both convex (projecting) and concave (recessed) parts appear in the same object. The measure of convexity is the coefficient of convexity, defined as the ratio of the area of outer surface covered by projections (Aproj) to the area of the whole outer surface of the object (Asurf), Cconv = Aproj/ Asurf. Correspondingly, the measure of concavity is the coefficient of concavity, defined as the ratio of the outer surface area covered by recessions (Arec) to the whole area of the outer surface Asurf, Crec = Arec/Asurf. Both may also be expressed in percentage of total outer surface. In practice, normal visual perception of the outer surface means usually the perceived silhouette of the object. The notion of convexity with its counterpart concavity seems to be the key morphological concept since it is based on the ideas of emptiness and fullness, or – to put it in a different way – on the idea of spatial articulation. In the strict sense concavity is the lack of material (substance) in a given part or region of the object. Thanks to the presence of such regions it is possible to distinguish between different morphemes or formants, or to define where the one morpheme finishes and the next begins. The border between different adjoining parts often puts on the form of concave or convex region (Stamps, 2000). As previously noted, another kind of border is break (edge). These remarks lead us to another important notion of morphology, which is the articulation of space.

Ad 1.6 Articulation is the aspect of the shape related to the division of the space by disposing definite portions of material in it. We can differentiate four basic kinds (or aspects) of spatial articulation: 1.6.1) articulation of empty space (or free articulation), 1.6.2) articulation of line, 1.6.3) articulation of the surface (planar, superficial or tied articulation), 1.6.4) articulation of full (solid) space (or tectonics) (Plate VI, Fig. 1-6).

Ad 1.6.1) We can differentiate five main modalities of the empty space articulation, which are strictly connected with dimensionality: 1.6.1.1) punctual articulation (Plate VII, Fig.1 D), when empty space is divided by punctual components (which is rather purely theoretical case in three dimensional space, but may be real on two dimensional plain; example – lumps of material on the wall surface) , 1.6.1.2) linear articulation, when empty space is divided by linear components (example – the structure made of rods, like in geodetic domes) (Plate VII, Fig. 1C, Fig.4) 1.6.1.3) superficial articulation, when empty space is divided by superficial components (example – structure made of slabs, like in most usual buildings of different type) (Plate VII, Fig.1B, Fig.4), 1.6.1.4) solid articulation, when empty space is divided by solid components (example – the structure made of very thick, massive columns, like in the Egyptian temples or different massive blocks like in Sydney Opera) (Plate VII, Fig.1A, Fig.2) 1.6.1.5) mixed articulation, when empty space is divided by components of different dimensionality (Plate VII, Fig.5). In the last case we can count the number of all main components and the number of particular parts of different dimensionality (punctual, linear, superficial or solid) and express their participation in the whole in percents, using correspondingly the coefficients of punctual articulation (Cpunct = x % of punctual components), linearity (Clin = x % of linear components), superficiality (Csuperfic = x % of superficial components) and solidity (Csolid = X % of solid components).

Ad 1.6.2. Articulation of line is based on dividing it into different segments. There are two basic kinds of line articulation: 1) continuous (without intervals), 2) discontinuous (with intervals). In the first case, the line is divided by vertexes or points of bending and segments can have different shapes, lengths and directions. In the second case, when the intervals appear, the segments can also be differentiated on the basis of shape, length and direction, but additional parameter has to be taken into account – namely the length of the interval. There are many possibilities of classification of different kinds of articulated lines, but it is not possible to present them here, so we will restrict ourselves only to the above mentioned two-fold division.

Ad 1.6.3) We can distinguish seven basic units of superficial (or tied) articulation: folds, offsets, ridges, furrows, pockets, pinnacles, openings (Plate VIII a and b). Folds and offsets are both concave and convex formations, and the main difference between them is that folds are curved, while offsets – not curved. There are a lot of examples presenting folds like undulating walls of many baroque architectural objects, wavy ceilings and vaults, etc. (Plate VIII a, Fig.1, 2). Also, offsets are a very popular way of shaping building surfaces, both walls and roofs (for example shed roofs) (Plate VIII a, Fig.3, 4). Ridges are elongated convex formations (e.g. pilasters, attached columns) (Plate VIII a, Fig.5, 6), while furrows are their opposite - elongated but convex (Plate VIII a, Fig. 7, 8). Pinnacles are convex formations of punctual character (fleuron, crocket, tenon) (Plate VIII b, Fig.3, 4) while pockets, being their reverse, are punctual but concave (e.g. niches, conches, cavities, recesses) (Plate VIII b, Fig.1, 2) Openings are the two dimensional perforations in the continuous surface, and their different types depend on shapes and dimensions. There are numerous examples of this unit all over the world like windows, doors, gates, door-ways, portals, etc. (Plate VIII b, Fig.5, 6). In all cases of articulation discussed above, we can measure them by counting the percentage of total surface covered by the specific units.

Ad 1.6.4) We will differentiate three basic kinds of the full space (solid) articulation, also referred to as tectonic articulation: 1.6.4.1. positive articulation ("convex solid" or "block"), 1.6.4.2. negative articulation ("concave solid" or "syncline"), 1.6.4.3) internal articulation ("inner solid" or "cave") (Plate IX). Positive articulation of the solid ("convex solid") is based on the units (tectons) which we will call blocks. Depending on their dimensionality and directivity we can differentiate the following kinds of blocks: punctual block (relatively small mass with all three dimensions close to each other, e.g. small house, kiosk, etc.), linear standing block (large mass whose height is clearly bigger than the remaining two dimensions, e.g. post, column, tower, etc.), linear lying block (large mass, which length is distinctly bigger, than the remaining two dimensions, e.g. beam, elongated block of flats, etc.), superficial standing block (large mass, whose height and length are big, while thickness is relatively small, e.g. screen, thin wall standing alone, etc.), superficial lying block (large mass whose length and width are big, while height is relatively small, e.g. lying slab or plateau, etc.), and massive block (large mass, whose all three dimensions are big and similar, e.g. massive volume, big cubic edifice, etc). Negative articulation of the solid ("concave solid") is based on the units (tectons), which we will call synclines. Perceptually, they can be interpreted as empty spaces (vacuons) engraved in full mass and opened from above. Depending on their dimensions and directivity, we can differentiate the following kinds of synclines: punctual syncline, linear standing syncline, linear lying syncline, superficial standing syncline, superficial lying syncline, and solid syncline. Internal articulation of the solid is based on units (tectons) which we will call caves. Depending on their dimensionality and directivity we can differentiate the following kinds of caves: punctual cave (room), linear standing cave (shaft), linear lying cave, superficial standing cave, superficial lying cave, and solid cave.

Ad 2) Dimension is the cardinal feature denominated in several different ways or possessing different aspects. Its first aspect is linear, defined as the interval measured on the straight line between two most distant points of contour or outer surface. It may pertain to particular dimensions in vertical direction (height) or in horizontal dimensions (width, length). The second aspect is related to the surface and defined as an area, while the third aspect pertains to the volume of the solid. Another aspect of dimension is its ratio to the dimensions of its surroundings, which may be described as relative dimension or scale. Finally, we can say about the ratio of the one of three basic dimensions (for example height) to another (let's say width), which is usually called proportion.

Ad 3) Directivity is the cardinal feature which defines dominating directions of spreading the component (or the whole system) in space. Within the frame of reference appointed by the earth's environment we can differentiate the following aspects of directivity:

3.1. verticality, 3.2. horizontality, 3.3. obliquity, 3.4. no- directivity (Plate X). We should differentiate between the directivity of the whole system and directivity of particular components. So the whole object can be vertical, while its composing elements are horizontal and reversed. We can also encounter two other cases: horizontal objects consisting of horizontal parts and vertical objects composed of vertical parts. In each case we can define the auxiliary coefficients like the ratio of the number of vertical/ horizontal morphemes/ formants to the number of all morphemes/ formants. Each of four main aspects of directivity of the whole object can be measured by specific coefficients. Correspondingly, we can measure the verticality/ horizontality of the whole using coefficient being the ratio of the greatest height to the greatest horizontal dimension (width or length), and obliquity by defining the angle of inclination to the horizontal direction. When none of the main directions is dominating, we can speak of no-directivity. Another way of measuring this feature is, for example in case of verticality, counting the ratio of the number of vertical elements (morphemes, formants, tectons) to the number of all elements, or ratio of the total length of vertical elements to the total length of all elements. The same pertains to the remaining modalities of directivity.

The spatial syntax of architectural object

Beside cardinal features spatial objects composed of formants (or formants composed of morphemes, if they are considered as sub-systems) are characterized also by syntax features of two main kinds: 1) constitutive features and 2) topographical features. Constitutive features define the general quantitative properties related to the distribution of components, while topographical features define detailed spatial relations between formants or the way of its spreading in space.

Ad 1) Constitutive features include two main aspects: 1.1) complexity, and 1.2) differentiation (Plate XI, Fig.1, 2). Complexity is the constitutive feature which defines the number of main components. One can differentiate three levels of complexity (or modalities of this feature): small, average and high (Plate XI, Fig.1,3,4). Differentiation is the constitutive feature defining the number of different kinds or classes of main components. One may distinguish three levels of differentiation (or modalities of this feature): small, average and high (Plate XI, Fig.2, 5, 6).

Ad 2) The set of topographical features contains: 2.1. orderliness, 2.2. inclusiveness, 2.3. substantiality, 2.4. configuration, 2.5. zoning.

Ad 2.1) Orderliness is the topographical feature of the system which defines the rules of arrangement of main components. The number of these rules determines the level of orderliness. When no clear rule of arrangement is possible to detect we can talk about state of chaos (Plate XII, Fig.1 A). This concept seems to be very close or even analogical to the notion of regularity, so the previous remarks on this subject relate to it (see the discussion on geometrical quality). One can differentiate three levels of orderliness: small, average and high (Plate XII, Fig.1, 2, 3) Orderliness of the system may be based on: grouping of main components possessing equal cardinal features (shape, dimension, directivity) which may be called cardinal orderliness (Plate XII, Fig.2) or arrangement of the main components according to the definite relations, which may be called relational orderliness. This kind of orderliness takes into account the following spatial relations between main parts: distance, direction, angle and sequence. When both cardinal and relational orderliness occur in the object, we may talk about complete orderliness (Plate XII, Fig.3, 4).

Ad 2.2) Inclusiveness is the topographical feature defining the outside-inside relations between morphemes/ formants. Depending on this relationship, one can differentiate the following modalities of inclusiveness: separation, penetration and containing (Plate XIII, Fig.1). Separation takes place when neighboring spatial regions have no fragment in common (Plate XIII, Fig.2). Penetration, on the contrary, means that regions have some common spatial fragments, or one of them is at least partly surrounded by the other (Plate XIII, Fig.3). Finally, containing is the state in which one region is nested in another, being surrounded by it from all sides (Plate XIII, Fig.4).

Ad 2.3) Substantiality is the topographical feature defining the presence or absence of material in particular fragment of space. One can distinguish two reciprocally bound features being different aspects of substantiality: 2.3.1 consistency (or density), 2.3.2. continuity (or closure).

Ad 2.3.1) Consistency (or density) is the topographical feature defining relative intervals between formant (Plate XIV). Depending on this, we can distinguish three levels or different states of consistency: distance, proximity and adhesion. This concept corresponds with the notion of spatial contiguity which is well known in research on perception of visual patterns although interpreted in different ways (Olivers N.L, Chater D, Watson D. G, 2004). When the interval between two components is equal or bigger than the sum of their biggest dimensions (which ranges), one can say that they are distant. When the interval between them is smaller than this sum but bigger than 0 one can refer to their proximity, and when the distance is equal 0 one can refer to adhesion. One can measure the level of this feature using the coefficient of consistency icons, which is the ratio of the mean distance between morphemes (formants, tectons) to the mean of their dimensions. A good example of this feature could be the interior of an Egyptian temple with its thick pillars and relatively narrow spaces between them, or the interior of the Taj Mahal shrine in Agra demonstrating the same phenomenon. Adhesion may depend on the number of points in which the adjoining morphemes (or formants) meet with each other and on the total area of the common surface.

Ad 2.3.2) Continuity (or closure) is the topographical feature, defining the substantial character of borders, or the presence of full or empty fragments in them (Plate XV). We can distinguish three levels of continuity: small, average and high. The measure of this feature is the coefficient of continuity Ccont being the ratio of the sum of the length, area or volume of empty spaces in the border to the total length to the area or volume of the whole border (depending on its dimensionality). The illustration of three levels of continuity may be as follows: the frame (small continuity, low degree of closure), the raster or the perforated wall (average continuity, average degree of closure) and the full wall without openings (high level of continuity and high degree of closure).

Ad 2.4) Configuration is the topographical feature of the system defining the spatial arrangement of its main parts in the whole and the relations between them. We should underline that configuration has two different, though sometimes bound aspects. The first one is connected with the outer spatial structure of the whole mass, regarded as the full solid and investigated from outside, the second one – with the inner structure of the same mass, regarded as the hollow, empty solid and perceived from inside. The first one consists mainly of massives or at least they are perceived as massives, no matter if their inside is hollowed or not. The second, on the contrary, consists mainly of vacuons or is perceived as mainly empty space, or a set of reciprocally bound empty spaces, regardless of the presence of some massive elements.

To make a clear distinction between these aspects, we have to discuss the previously introduced notion of tectons and tectonics. So the first aspect of this notion means the massive (or perceived as massive) primary formants, decisively influencing the spatial structure of the whole system investigated from outside. The second aspect of tectons means the biggest interior empty spaces defining the inner structure of the hollowed mass. So examples of massive tectons are wing pavilions, cupolas, towers, wings, roofs, or other big projected and massive parts of the building, while the examples of empty tectons are big halls, saloons, lobbies, interiors of stair cases or other interior vast rooms of buildings. As tectons are the biggest macro-formants (primary formants) defining the shape of the whole mass from outside or inside, to be able to denominate the reciprocal spatial relations between them we have to introduce the tool for coordinating them. This tool will be called the spatial skeleton. This is the set of inner lines located in such a way that in each section they are in equal distance from the outer boundary.

Division of the whole object to components corresponds with Marr's concept of extracting parts of the visual form. His proposal contains several steps: extracting contour, finding regions of deep concavity and label both convex and concave sections, finding segmentation points, dividing contour by segmentation points, finding component axis, and finally relating axes. (Marr, Nishihara, 1978). Such a set of lines as a kind of spatial axis, may be considered as the substitute of the real shape so it may be easily analyzed, described and compared. We can differentiate two component elements of a spatial skeleton (or axis), trunks and branches, though some systems have only trunks, while others, only branches. We can also find systems without a skeleton, in which it is reduced only to one point. The elements of skeletons may be of closed or open character. On this basis, we can build the complete taxonomy of spatial arrangements presented in Plate XVI a. (some examples of it are presented in Plate XVI b).

Despite the aspects of syntax discussed above, we should also take into account that spatial syntax is the process of assembling spatial units in spatial groups of different kinds. Thus, we can distinguish three basic kinds of grouping: assembling in rows, assembling in layers, and piling up. Assembling units in rows means grouping them along a particular line spreading in one direction, and at the same time putting them in proximity. As the result the group spreads only in one direction. Assembling in layers is based on grouping units along lines multiplied several times so that each line adheres closely to the neighboring one. As a result, the group spreads in two directions. Piling up means putting one layer on another one in the third dimension – height.

Ad 2.5) Zoning is the topographical feature defining the location (or position) of the formants in the whole system. One can differentiate the following positions: front, back, left, center, right, upper, lower. Describing and analyzing the system in this respect, we should enumerate the number of macro-formants (primary formants) located in particular zones.

It seems convenient to gather all the differentiated features in Spatial Features Inventory, which forms a kind of taxonomy (Niezabitowski, 2004). It consists of three main parts containing three main kinds of features: cardinal (morphological), constitutive and topographical (syntactic) (respectively Tables 1 – 3), which are set together from the most general to the most detailed ones starting from descriptive categories, through their aspects and ending on modalities (or sub-modalities) of aspects.

General Comments on the Procedure of Spatial Analysis

The complete and detailed description and analysis of spatial architectural system based on notions and terms introduced in the above deliberations is the process containing several stages, which should follow in the strict succession. The first question we have to answer deals with what is to be our main subject of interest: whether the analysis should deal only with chosen parts of the object or the object as the whole. If the answer to the second question is affirmative, we have to decide whether we want to describe the object's exterior or interior, which implies a completely different descriptive and analytical situation. Suppose we decided to examine the whole object from outside. In such case, we should take into account that what we usually see from one fixed point of view is only the part of the whole outer surface of the object, which could be named its shell. To gain the complete outlook of the whole, we should either walk around the building and above it (which is usually impossible in practice), or examine its photos (drawings) taken from different perspectives and points of view.

Regardless of what is the source of our information, we should notice that the shell is usually divided into three relatively independent but still bounded parts: walls, roof and floor. The latter is observable only from inside, so in this case we can omit it, and focus attention only on outer walls and roof. Next, since we decided to describe and analyze the object from outside, we have to examine the articulation of the outer surfaces and then the articulation of the solid. Analysis of articulation of the surfaces is the process in which we differentiate the biggest components of the outer surface of the walls localized in important places of it, or macro-formants (like cornices, eaves, socles, pilasters, bounded columns, windows, portals, balconies, porticos, loggias etc.). Correspondingly, analysis of the articulation of solid is the process of differentiation of the biggest components of it or tectons, like breaks, projections, wings, towers, turrets, roofs, cupolas, etc. To summarize this first stadium, we can say that its essence is the recognition and enumeration of the main components of the system, which means establishing its contents and defining the degree of its complexity.

The second stadium of description and analysis deals with shapes, dimensions, directivity, position and articulation of the main formative components enumerated in the first stadium. In describing them, we use all of the previously introduced notions as well as measures, which allow us to express the features of components in a quantitative manner.

Conclusions

Every scientific discipline begins its development from description, measuring, analysis, comparison and systematization of basic phenomena. The science of architecture, which unlike architecture itself is a rather young discipline, should work the same. If we accept this position, the attempt to create the new sub-discipline within the range of positive architectural theory (Lang, 1987), exploring spatial aspects of architectural form and laws of its shaping will be well-founded. It can help us to understand better not only architecture as such, but also comprehend man, who creates and uses it. The above deliberations are the trial of the notional system creation, enabling exploration of spatial phenomena in architecture in a way which fulfils the basic criteria of science. Such a system of notions, as well as the possibility of quantification of spatial phenomena, is the prerequisite of scientific exploration of architectural form which is not only the matter of aesthetics but also the matter of spatial morphology. This system could be implemented in research of architectural psychology, especially the perception and cognition of the built environment, as well as environmental aesthetics. On this basis, we can expect possibilities of prediction of human reactions and appraisals of it which should be of crucial importance for shaping the built environment of high quality.

Plate I. Shape of the morphemes. Aspect: dimensionality

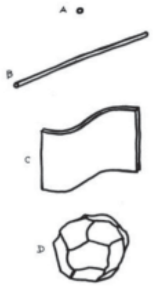


Fig.1. Dimensionality (punctual, linear, superficial, solid)

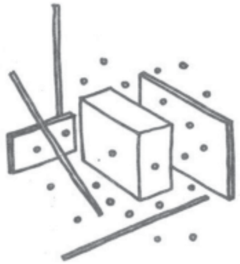


Fig. 2. Dimensionality (mixed)

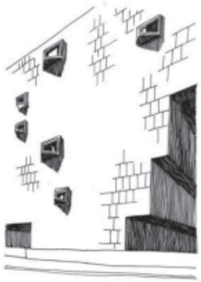


Fig.3. Punctual dimensionality

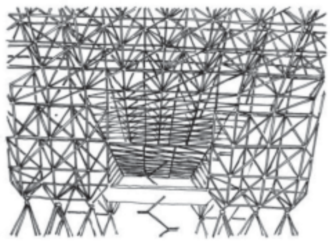


Fig.4. Linear dimensionality

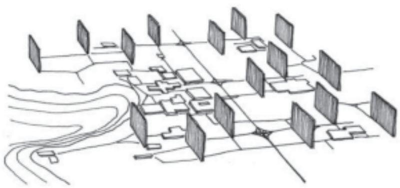


Fig.5. Superficial dimensionality

Fig.6. Solid dimensionality

Plate II. Shape of the morphemes. Aspect: geometrical quality

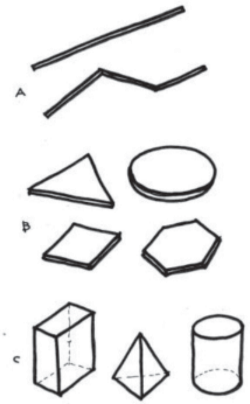


Fig.1. Geometrical quality (scheme)

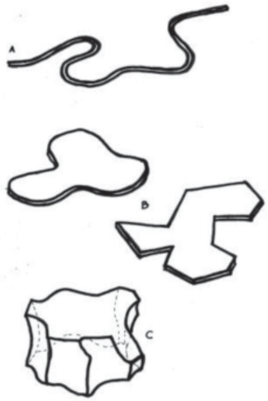


Fig.2. Non-geometrical quality (scheme)

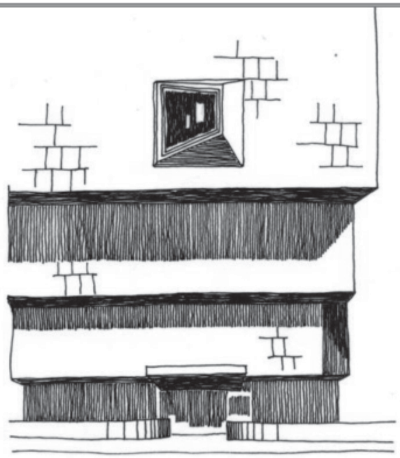


Fig.3. Geometrical quality

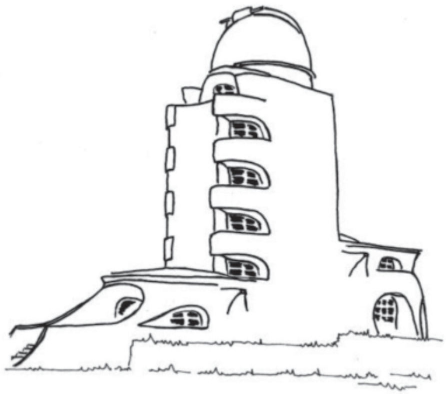


Fig.4. Non-geometrical quality

Plate III. Shape of the morphemes. Aspect: curvature

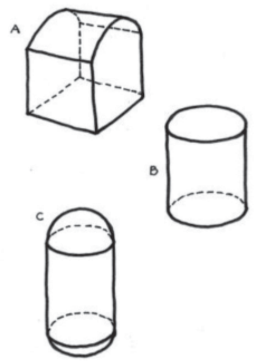


Fig.1. Curvature (scheme)

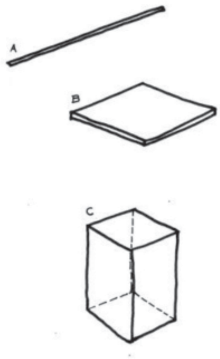


Fig.2. Non curvature (scheme)

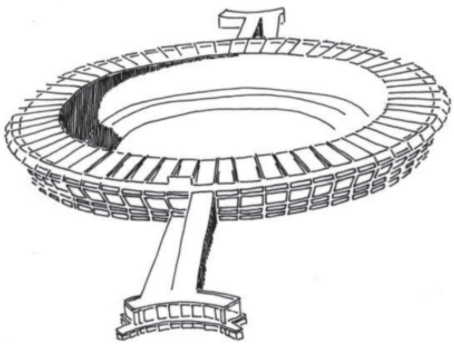


Fig.3. Curvature

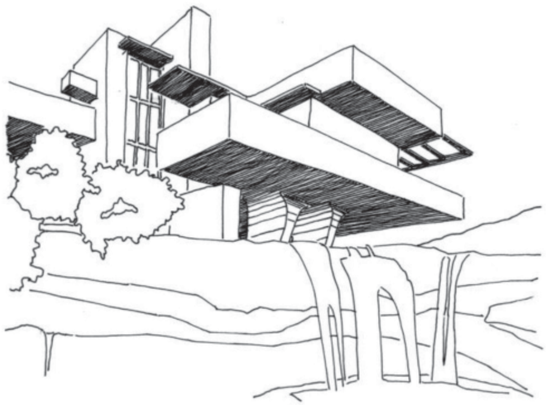


Fig. 4. Non curvature

Plate IV. Shape of the morphemes. Aspect: flexure

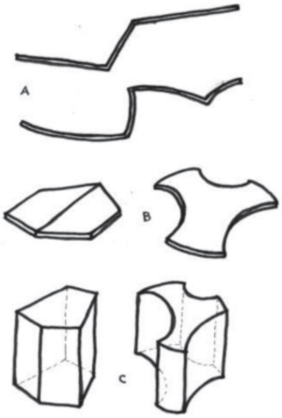


Fig.1. Flexure (scheme)

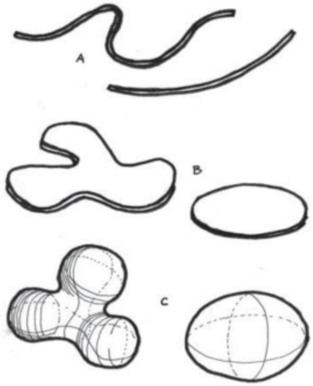


Fig.2. Oval quality (scheme)

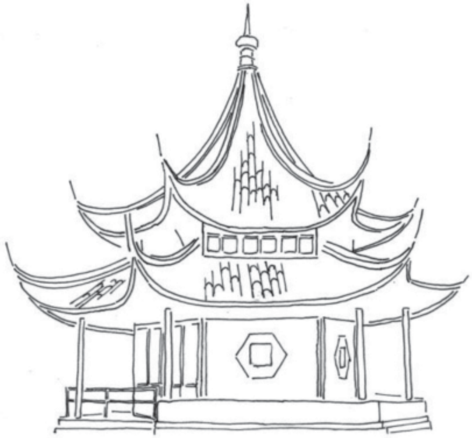


Fig.3. Flexure

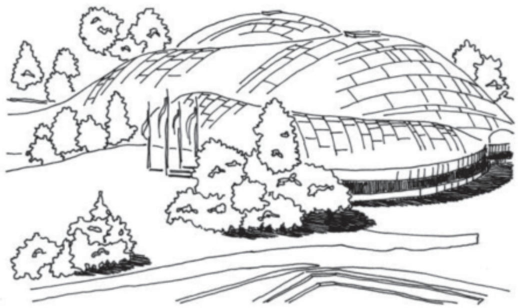


Fig.4. Oval quality

Plate V. Shape. Aspect: convexity

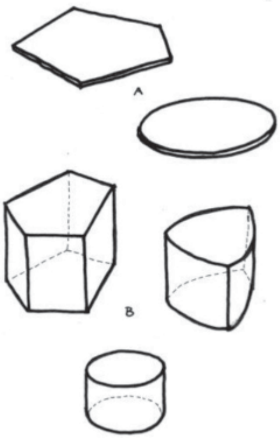


Fig.1. Convexity (scheme)

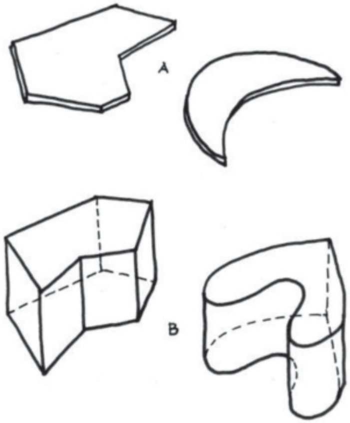


Fig.2. Concavity (scheme)

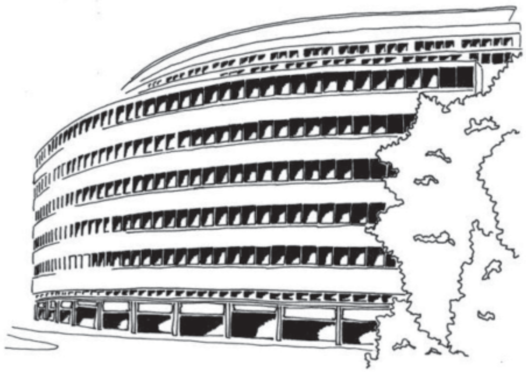


Fig.3. Convexity

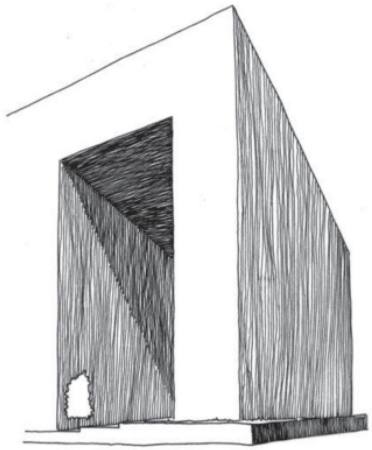


Fig.4. Concavity

Plate VI. Shape. Aspect: articulation

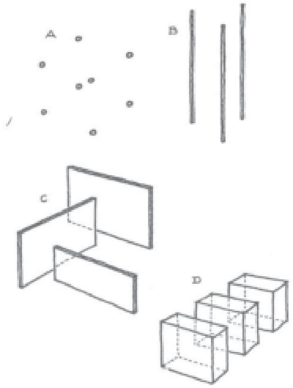


Fig.1. Articulation of empty space

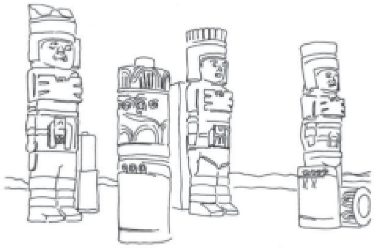


Fig.2. Articulation of empty space

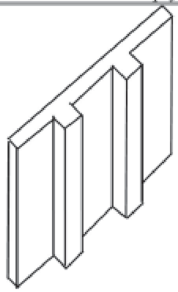


Fig.3. Articulation of surface

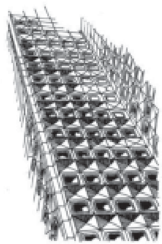


Fig.4. Articulation of surface

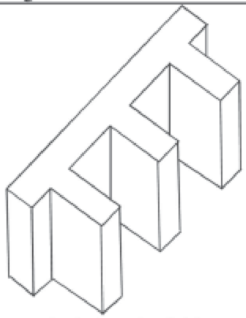


Fig.5. Articulation of solid (tectonics)

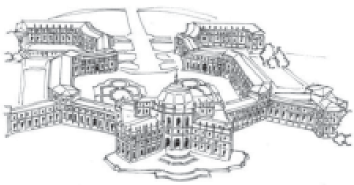


Fig.6. Articulation of solid (tectonics)

Plate VII. Articulation of empty space. Four basic modalities

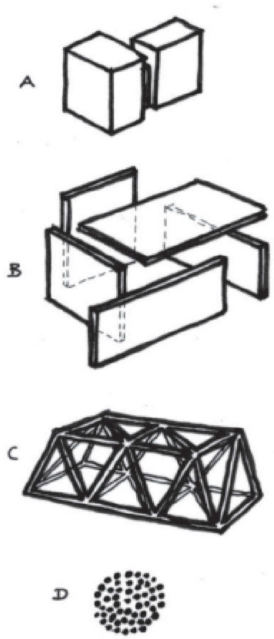


Fig.1. Modalities of space articulation
A. Solid articulation
B. Superficial articulation
C. Linear articulation
D. Punctual articulation

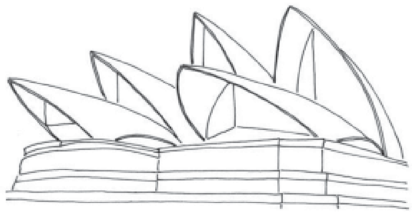


Fig.2. Space articulated by solid elements

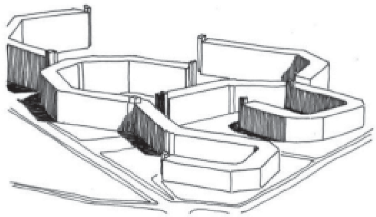


Fig.3. Space articulated by surface elements

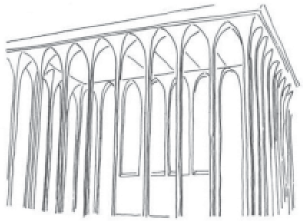


Fig.4. Space articulated by linear elements

Fig.5. Space articulated by mixed elements

Plate VIII. (a) Articulation of surface. Basic units.

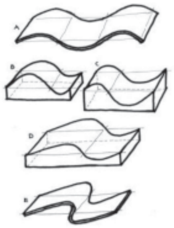


Fig.1. Folds (scheme)

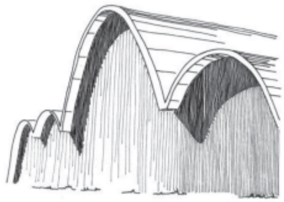


Fig.2.Folds

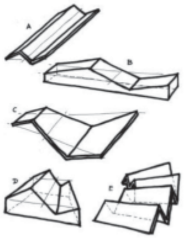


Fig.3.Offsets (scheme)

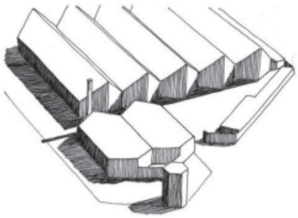


Fig.4.Offsets

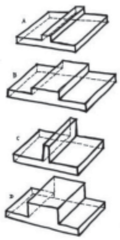


Fig.5.Ridges

Fig.6. Ridges

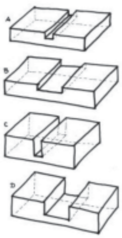


Fig.7. Furrows (scheme)

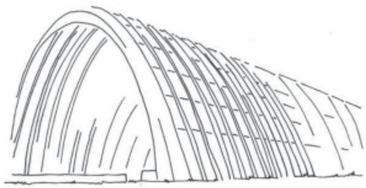


Fig.8. Furrows

Plate VIII (b) . Articulation of surface. Basic units (cont'd)

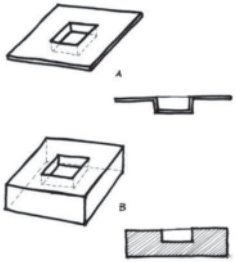


Fig.1.Pockets (scheme)

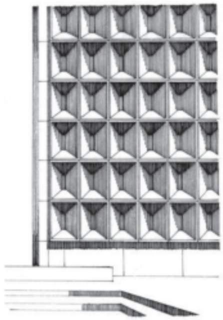


Fig.2. Pockets

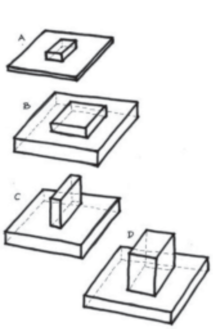


Fig.3. Pinnacles (scheme)

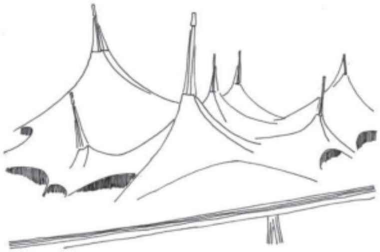


Fig.4. Pinnacles

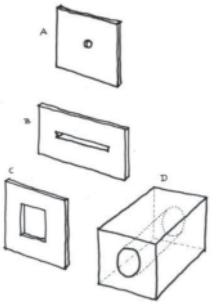
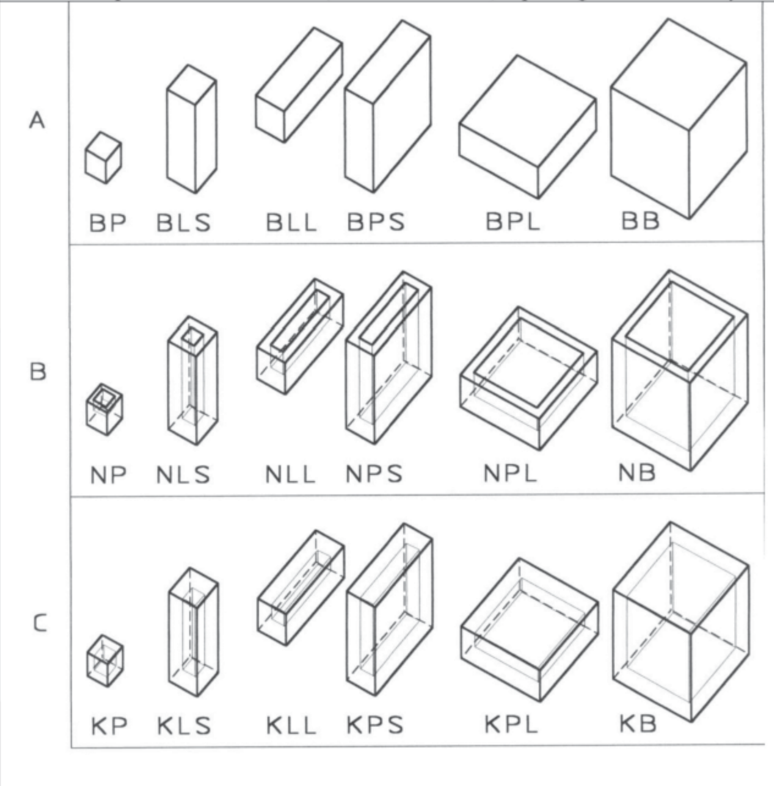


Fig.5. Openings (scheme)

Fig.6. Openings

Plate IX. Shape. Articulation of solids (tectonic articulation) depending on dimensionality



A – positive articulation („convex solid" or „block")
BP – punctual block, BLS – linear standing block, BLL – linear lying block,
BPS – superficial standing block, BPL – superficial lying block, BB – massive block

B – negative articulation ("concave solid" or "syncline"
NP – punctual syncline, NLS – linear standing syncline, NLL – linear lying syncline,
NPS – superficial standing syncline, NPL – superficial lying syncline, NB – solid syncline

C - internal articulation ("inner solid" or "cave")
KP – punctual cave, KLS – linear standing cave, KLL – linear lying cave,
KPS – Superficial standing cave, KPL – superficial lying cave, KB – solid cave

Plate X. Directivity.

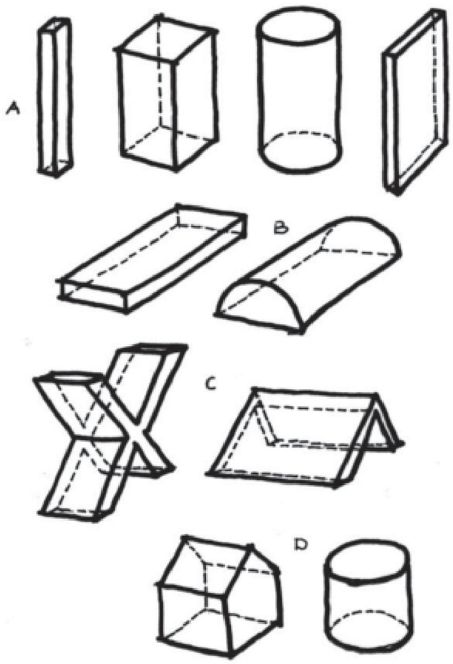


Fig.1. Different types of directivity

A. Verticality
B. Horizontality
C. Obliquity
D. No-directivity

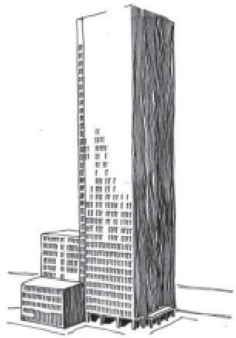


Fig.2. Verticality

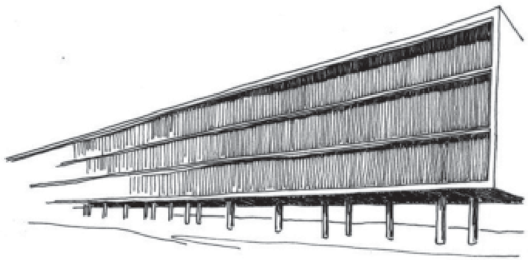


Fig.3. Horizontality

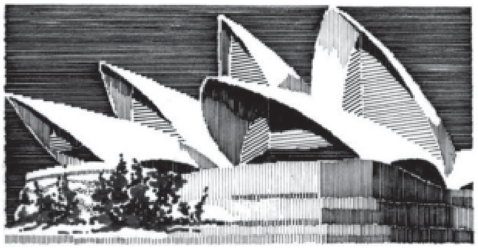


Fig.4. Obliquity

Plate XI. Syntax features. Aspect: constitutive features (complexity and differentiation)

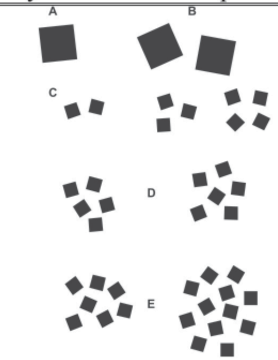


Fig.1. Different levels of complexity

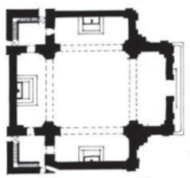


Fig.3. Small level of complexity

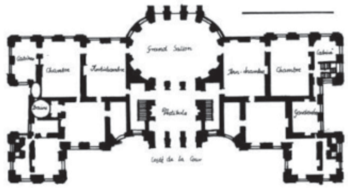


Fig.4. High level of complexity

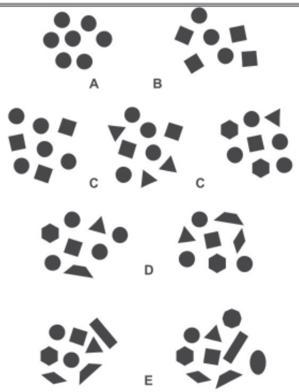


Fig.2. Different levels of differentiation

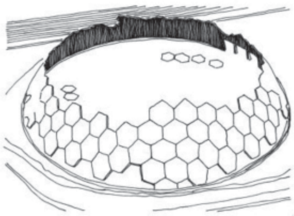


Fig.5. Low level of differentiation

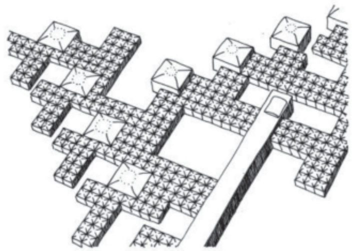


Fig.6. Average level f differentiation

Plate XII. Topographical features. Orderliness.

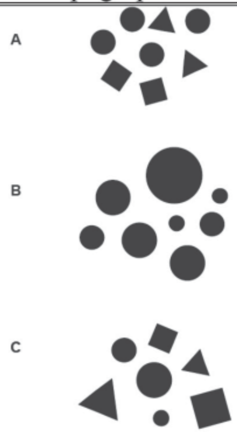


Fig.1.Different types of orderliness

Fig.2. Cardinal orderliness

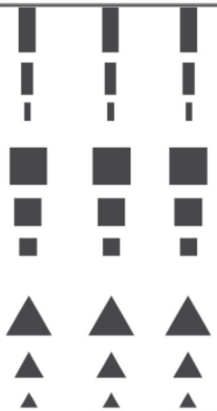


Fig.3. Complete orderliness: cardinal and relational

Fig.4. Complete orderliness: cardinal and relational

Plate XII. Orderliness (cont'd)

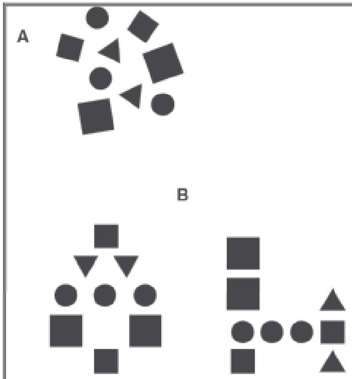


Fig.1.Different states of orderliness
A – lack of orderliness (chaos)
B – state of orderliness

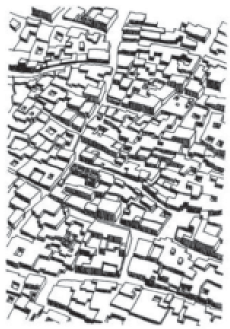


Fig.2. Small level of oredrliness

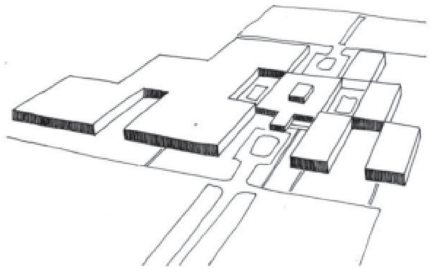


Fig.3. Average level of orderliness

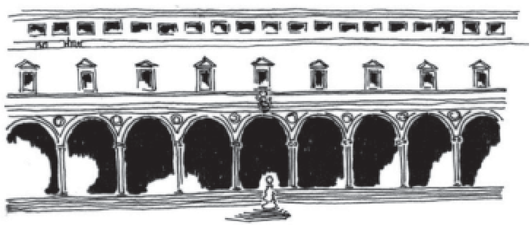


Fig.4. High level of orderliness

Plate XIII. Topographical features. Inclusiveness

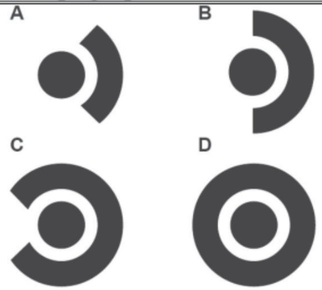


Fig.1. A,B – separation, C – penetration, D – containing (nesting)

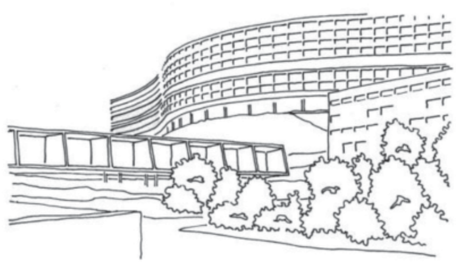


Fig.2. Separation

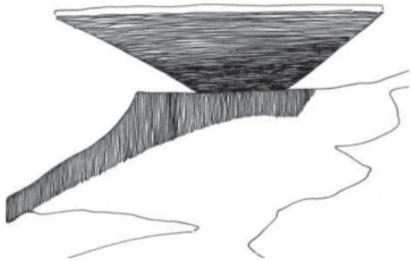


Fig.3. Penetration


Fig.4. Containing (nesting)

Plate XIV. Topographical features. Aspect: Substantiality. Modality: consistency (density)

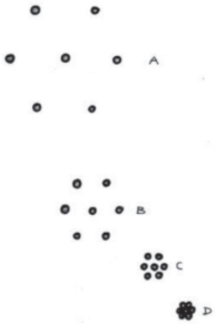


Fig.1.
A – distance
B,C – proximity
D - adhesion

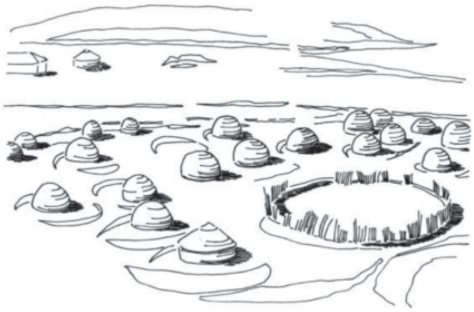


Fig.2. Distance

Fig.3. Proximity

Fig.4. Adhesion

Plate XV. Continuity (closure/openness)

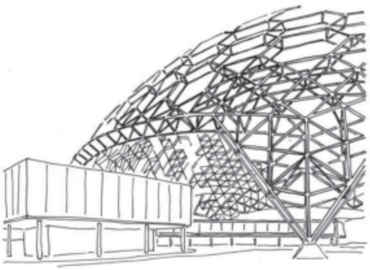


Fig.1. Low level of continuity

Fig.2. Average level of continuity

Fig.3. High level of continuity

Fig.4. Average level of continuity

Fig.5. High level of continuity

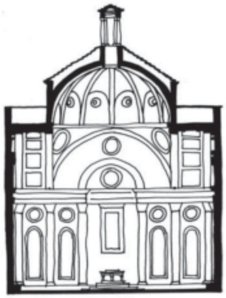


Fig.6. High level of continuity

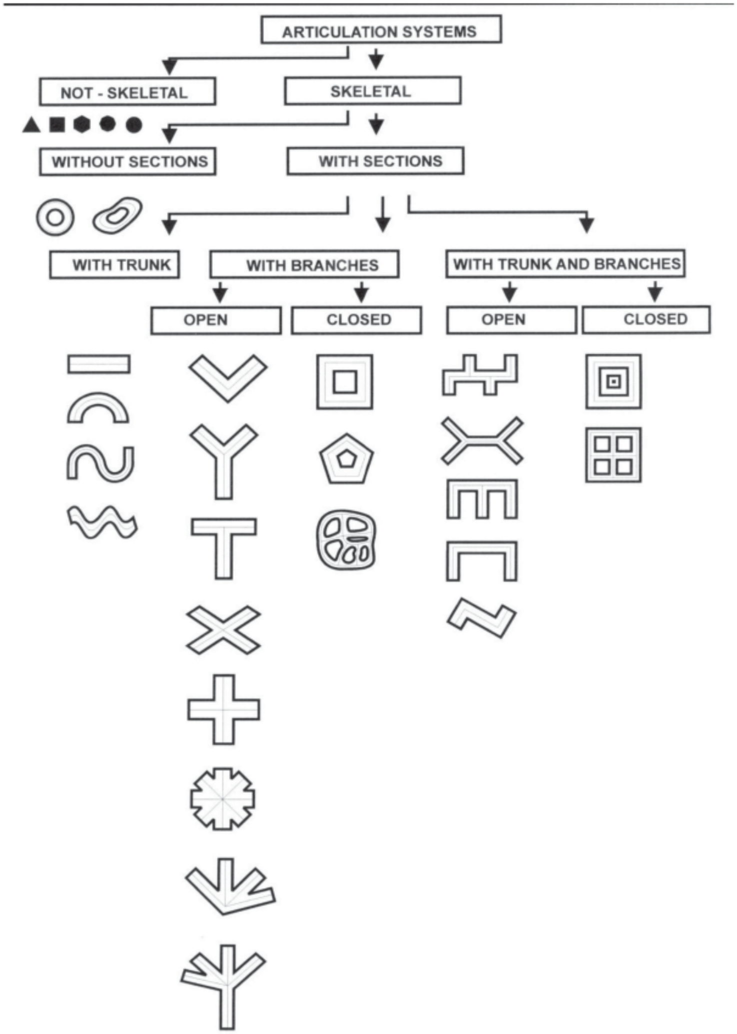


Plate XVI. (a) Configuration – syntactic taxonomy based on visual skeleton

Plate XVI (b). Configuration. Different types.

Fig.1. Trunk and branches

Fig.2. Trunk and branches

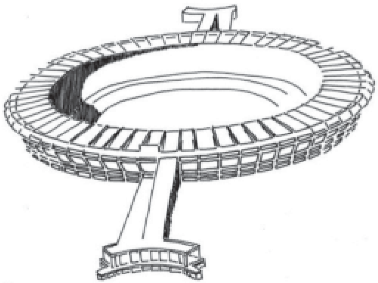


Fig.3. Ring skeleton

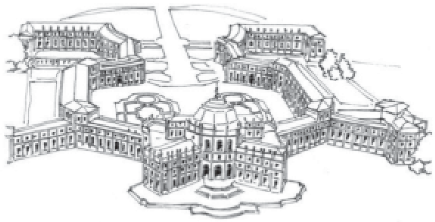


Fig.4. Skeleton consisted only with branches

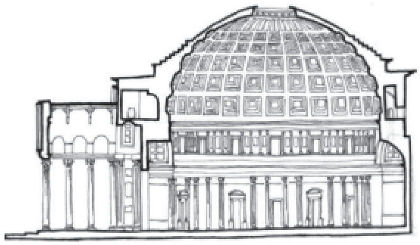


Fig.5. Configuration without skeleton

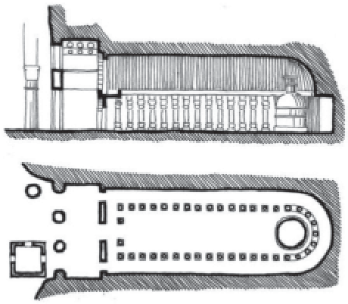


Fig.6. Skeleton consisted only with trunk

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