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Spatial Models in Thinking and Communication

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Spatial models joint external and internal aspects of human activity, mental schemas of thinking, and spatial structures of things. These models represent objects of knowledge, valuation, and transformation due to similarity with them in various relations, and they participate in inter-subject communication using schemata common for many people. The spatial models can reproduce a modelled object or be productive regarding it. These models are created in cognitive modus of comprehension as images of objects known at various mental levels; in projective modus, they appear as projects of object's transformation and planes of subject's actions; in communicative modus, they are interpreted as spatial texts expressing certain senses. All of them interact in spatial thinking, which deals with the relationship of parts and the whole, unlike logical thinking operating with genus-species relations. Both practical and theoretical thinking use common spatial schemas as means of internal modelling, which are elaborated in collective and individual experience. Due to their simplicity and unification, these schemas can serve also as units of spatial codes mediating the objects representation and inter-subject communication through spatial texts created in the semiotized space.

Keywords: cognitive, projective, and communicative modes, spatial schemas, units of codes and texts

Introduction: *Logos* and *Topos* as Two Aspects of Spatial Modelling

Space and *mind* are traditionally opposed in the history of philosophy as connected with different fields of the world. Meanwhile, there are spatial models serving as means of object's representation and inter-subject communication as far as specific *spatial thinking* can be performed.

The relations between spatial and mental structures, between the *things* and *thinking*, are ambivalent. Studies of things in their spatial organization and thinking about them have been divided during many centuries. This divergence can be seen still in relations of ancient philosophical concepts *logos* and *topos*. Although an ambiguous notion of *logos* by Heraclitus contained a syncretic unity of logical thinking, ordered things, and true speeches expressing both of them (see Cassidy, 1972), the next development of philosophy increased the distance between them rather than their connection. Such distance is clear, for example, in distinctions of *Canon* and *Organon* by Aristotle, where world of things and logic of thinking about them are different domains of researches. Even though the Organon contains the *Topics* using an image of place as a metaphorical device for a description of discussed theses, the research of *topos* as a feature of things themselves is related to field of *Physics* as doctrine of the natural world (see Aristotle, 1981). The opposition of things in the spatial world and of thinking in the subject's mind is saved even two thousand years ago in the dualistic conception by René Descartes, who contrasted space and thinking as the attributes of bodily and spiritual substances, correspondingly (Descartes, 1989, p. 335).

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Immanuel Kant had removed this contraposition of spatial and mental constructions considering space and time as forms of contemplation, which a transcendental subject has *a priori*. According to him, the subject has, together with schematism of abstract categories using by the reason in processes of logical thinking, also a schematism of geometrical figures and other spatial relations, which only can give knowledge about things (see Kant, 1998). Ernst Cassirer has modified Kant's doctrine studying diverse modes of space representation in various "symbolic forms" of culture, which differ between each other by the ways of formation and interpretation of spatial relations (Cassirer, 1923-1929; 1985; cf. also Panofsky, 1927).

The contemporary semiotics of space considers the representative and communicative functions in various spatial bearers of meanings (see, in particular, Lagopoulos, 1993; Lotman, 1992; Pellegrino, 1999-2007; Toporov, 2010). The spatial models belong to the field of its studies, and most clearly demonstrate connections between spatial and mental structures.

Indeed, each spatial model has both these sides. On the one hand, it has always a certain spatial configuration, which could be conventionally linked with the notion *topos*, in a bright sense. On the other hand, each spatial model is regarded to human mind and contains a certain *logos*, understood in not less large sense. Like each sign is, by F. de Saussure, a bilateral unit of signifier and signified (Saussure, 1959, pp. 66-67), so each spatial model is a joining of "topos" in its expression plane as a configuration of meaningful spatial relations and of "logos" as a meaningful content expressed by it. At the same time, logos and topos are connected in the spatial modelling not mechanically and mutually interact with each other.

The presented paper intends to consider a participation of spatial models in thinking of various levels and their connection with communicative means of spatial semiosis.

Spatial Modelling in Human Activity

On Formation and Interpretation of Spatial Relations in Human Activity

Spatial relations in human activity are involved into a system of *subject-object* and *inter-subject connections*. It is, on the on hand, activity of *knowledge*, *valuation*, and *transformation* of objects by subjects, and on the other hand—processes of *communication* between subjects themselves, who can discuss all aspects of this activity (see Kagan, 2006).

The interaction between subject and spatial object of his activity occurs in two opposite directions. One of them is an external expansion of human into various loci of the spatial surrounding and the formation spatial relations there in accordance with his purposes and plans. Another direction is an internal activity intended to comprehension of spatial relations and their senses for the human, who is able to imprint signals coming from external world. Unlike the changing of physical space, his perception and comprehension are ideal processes, in which not the external bodies, but their internal images are formed and changed. Both directions interact: external relations of objects are transformed according to subject's ideas and spatial schemas; on the other hand, the internal representations of existing or transforming spatial relations are coordinated somehow with external world.

The mental activity of the subject is not limited by the cognition of objects, but contains their ideal transformation in processes of imagination and planning of actions. The internal activity includes also valuation of both object's situations and results of its transformations by the subject. This valuation can be ground for the new acts of knowledge of objects, of their ideal and real transformations in the next cycles of interaction between these modes of the subject-object relations.

All of these ways of the subject-object activity and object's comprehension can be represented also in the acts of the inter-subject communication. Like a deep internal connection exists between external verbal communication and internal processes of verbal thinking as results of its interiorization (see Vygotsky, 1982), there is an interaction between external object transformations and spatial thinking in its various aspects. In the same way that internal planning processes guide the design of a human's external environment, so do the internal images created in the processes of cognition of objects are based on the subject's actions with them. Just as architectural buildings are created in the exteriorization and embodiment of subject's projects, so the creation of various mental constructions contains internal methods, which are structurally similar to ways of external transformations of objects.

On External and Internal Spatial Modelling

An activity of the subject in space is connected with choosing of some spatial relations that are important in pertinent cases and not actual in some others. Thereby, the spatial surrounding of the acting human is opened for him not as a mathematically unified and homogeneous continuum of points without any qualities, but as a ground for a highlighting of spatial relations, which are relevant for certain purposes. They have different qualities for various ways of subject's activity and different valuation for them. So, the subject creates diverse *mental models of space* for solving of various practical or theoretical tasks. Space is given to subject always in form of such models built with a system of means available for him.

The polysemantic *concept of model* is understood here as means of representing an object by virtue of structural similarity with it in some relations. The binary and symmetrical relation of similarity between model and its object is combined here with the ternary and asymmetrical relation of representation of an object to the interpreting subject by the model. The *spatial model* represents its objects due to structural similarity of its spatial relations with something else. Various ideal images, schemas, cognitive carts, and so on can be considered in this quality. Moreover, this internal modelling is a condition of purposeful using of external spatial models, because they can represent something only for an interpreter, who is able to construct such internal models.

The modelled object can contain configurations structured in a similar way—as a territory is represented by a geographic map with similar configurations. However, spatial models can represent also non-spatial structures, if some semblance between orders of their elements remains. For example, spatial relations between parts of a "genealogical tree" remain a structural similarity with blood relationship between members of a family and therefore can serve as a spatial model of cause-and-effect relationships developed in time.

On Productive and Reproductive Functions of Models

The modelling in general and spatial modelling in particular can perform two reciprocal functions in the subject-object relations. The *reproductive models* repeat some structural features of an original, whereas the *productive models* serve themselves as originals of other objects, which should be created as something similar to them. Both of them perform the representative function in virtue of their structural similarity with a modelled object, however, this object participates in the relation of modelling as an original in the first case, and as a copy—in another one. Both these functions do not exclude each other and can be performed by one the same thing, because they have a common ground in a structural similarity of the modelling and the modelled. Their difference is, therefore, not structural, but only functional. For example, the form taken from a sculpture is a

reproductive spatial model in relation to the original statue, but itself becomes a productive model for the copy to be cast using this mould.

In a similar way, the internal spatial models can perform *productive* and *reproductive functions* as well. Their distinction in this internal activity has the form of differences between the *cognitive* and *projective* ways of the object's representation. Whereas the mental models created in scientific theories are intended on the objects of knowledge and perform therefore the reproductive function, the internal and external models created in architectural planning serve as patterns of forthcoming buildings and are productive models in relation to them. However, like the external mould can combine the functions of productive and reproductive models in relations to different objects, so the internal schemas can participate in both these functions.

Modes of Comprehension and Mental Models of Space

Variety of Understanding Forms and Ways of Space Modeling

As already mentioned, the comprehension of the spatial environment by the subject of activity includes cognition, evaluation, and mental transformation of the object, which can be the content of messages involved in inter-subject communication. These *modes of comprehension* correspond with types of various ideal *models of space* formed in these processes (cf. Cassirer, 1923, pp. 30-31).

A comprehension of space in *cognitive* modus creates *images* of spatial objects modelled at diverse levels of sensorial and rational cognition. Its *projective* modus is intended at the representation of space as a field, where the individual or collective subject performs certain purposeful actions with objects. The models of space created in this modus naturally take forms of *projects* that represent desirable conditions of transforming objects and *planes* structuring actions of the subject himself. The cognitive and projective ways of subject-object relations are connected also with *communicative* modus of the space modelling, in which spatial formations are constructed and reconstructed as meaningful *texts* involved in the processes of inter-subject communication.

All these modes of comprehension can be accompanied by the *evaluative*, particularly, *affective* modus, which relates the knowledges of objects, planes of their transformation, and texts used in inter-subject communication with some images of perfect conditions and actions. Comprehension of the surrounding space as more or less favorable for the subject usually does not lead to the creation of any specific models of it, but is aimed at capturing and expressing some marks of anxiety, calm, and similar emotional reactions to certain spatial conditions (for example, claustrophobia, agoraphobia, etc.).

Spatial models of different comprehension modes are interacting with each other. Indeed, any ideal model contains some *knowledge* on an object, because it is similar to it. It is also always a result of mental activity choosing some available "materials" and of their *transformation* in a conceivable construction. Because these materials are selected and structured for a certain purpose, their model supposes a *valuation* of different conditions as more or less preferred in relation to the chosen target. As far, as each such model can be transmitted from subject to subject, it is included in the *communicative* aspect of the activity. Nevertheless, there is a specialization of mental models of space by different functions, dominant in the cognitive, evaluative, projective or communicative mode of subject's activity.

Cognitive Models of Space

The *cognitive images* of space are formed in the processes of knowledge acquisition as *reproductive models* of the knowing objects. Resemblance and approximation to them are traditionally considered their merit.

The cognitive models are created at diverse levels of knowledge—not only in the logical concepts, but also on "infralogical" levels of psyche (in terms: Piaget & Inhelder, 1963). There are among them the sensorial, perceptual, and apperceptual levels of vision described in psychology (see Ananiev, 1977, p. 127). Although various levels interact in cognitive processes, several of them can dominate depending on a task: the detailed perception of a visible object, its quick recognition, or a logical reasoning about it.

The mental models of space constructed on these levels differ between each other by types of their elements and structural invariants. In particular, the images forming on *sensorial level in visual field* represent space as a world of changeable optical phenomena. Their elements are colour spots with different sizes and properties. An invariant of itis space is formed by a constant structure of the visual field inserted in the general internal schema of subject's body with its constant anthropological axes "top-bottom", "left-right", and "front-back".

The visual images of the *perceptual level* of vision form spatial relations in another way and have other elements and structural invariants. Unlike the egocentric treatment of phenomena in the visual field, the visible world of the perceived objects is eccentric in relation to the viewing subject (see Gibson, 1950). The elements forming this space are the perceptual images of external objects that have constant forms relatively independent on distance, lightening, angle of vision, and other changeable elements of the visible world. In the same time, the metric relations of objects can be most adequately represented at the perceptual level (see Vecker, 1974, p. 206). The anthropological axes are exteriorized, taken outside in space as invariants of the human environment. The inequivalence of these axes and corresponding anisotropy of the perceptual space is also its invariant property.

The structural invariants of spatial models forming on the *apperceptual level* are related already to the functions of spatial objects. On this level, not so much the metrical relations (sizes, distances, etc.) are relevant, but the topological properties of the modelled objects: whether they are wholly or holey, open, or closed, etc. The schemas of their recognition and cognitive cards used for subject's movements contain first of all the connections between their details, which are important for a certain function of a tool or destination of a target. On this apperceptual level of modelling, the autonomous spaces are formed with various elements and structural invariants—for example, the mental models of two-dimensional and discrete space of the chess board or tree-dimensional and continual space of the football field.

At the *conceptual level,* various practical and theoretical models of space are formed. Only several of them are also spatial models (which have space not only as the represented object, but also as the means of representation). These are, for example, the coordinate systems described theoretically in mathematics and used practically in cartography. Theories of space that model it with verbal descriptions or mathematical calculus are no longer spatial models themselves, because they no longer use spatial relationships as means of modelling.

Projective Models of Space

Unlike cognitive models, which represent space as an object of knowledge, *projective models* represent it as an object of transformation and as an environment in which the subject carries out practical actions. These mental models create for the subject not the "space of contemplation", but the "space of action". Projective models of space can be exteriorised, embodied in external object forms and constructions. They include the spatial relations between objects to be organized ("projects" in the narrow sense) and the schemas of actions to be taken by the subject to implement them ("plans"). Both differ from cognitive models of the future, because

the former represent what must be done for certain objects or subject action to occur, whereas the latter construct representations of the expected future regardless of the subject's preferences. Prognosis as knowledge on possible future does not coincident with its projecting as formation of ways for an achievement of desirable conditions in result of subject's activity.

Like cognitive activity, the processes of mental organization of movements and planning of spatial actions can be built up on different levels. The hierarchy of these levels is described by the theory of N. Bernstein (1967), who showed their connection with different neurophysiological substrata and their belonging to different stages of development in phylogeny and ontogeny. These levels of movements planning can contain only patterns of changing relations between parts of own body without connections with external objects (the B-level), to be correlated with forms and sizes of these objects in manipulations or in locomotions around them (the C-level), to be plans of a purposeful action with tools (the D-level), or to be schemas of meaningful behaviour among them and other persons using various ways of spatial communication (the E-level). Projective models of space referring to the organization of movements at different levels give rise to distinct in spaces of movement, the *spaces of locomotions*, *of object actions*, and *of social behaviour* (see more details on spatial modelling and formation of autonomous spaces with distinct functions in: Tchertov, 2015; 2022; 2023).

Communicative Comprehension of Spatial Models

The results of the different types of comprehension are interrelated and, under certain conditions, translatable into each other. The images of space created in cognitive processes can be included in the subject's behavior plans, which, in turn, can themselves be represented as images of certain situations. A mutual connection of *images* and *planes* (cf. Miller, Galanter, & Pribram, 1960) is performed in both directions. At the same time, both the images of spatial objects and the subjects' plans of behavior can be expressed in various *texts* (in wide semiotic sense, as in: Ivanov et al., 1998, p. 38) carrying these meanings from subject to subject.

Both cognitive and projective models of space constructed in the mind of the subject are included in the semiosphere of culture (see Lotman, 2000) and in various networks of inter-subject communication. Each creator of a spatial message—be it a written text, a drawing, or an architectural structure—previously forms in his mind a productive model of this meaning bearer. Each recipient of this message forms its own internal reproductive model, which can turn out as productive again, if it becomes a pattern for new embodiments. Therefore, the spatial text (in the broad semiotic sense) is created as a reproductive model of author's idea and a productive model for the receivers of this spatial message.

The *images* and *plans* participating in this communicative activity become the *meanings* of the semiotic means involved in these spatial models. They organise the collective experience of cognition, of external and internal transformation, as well as of objects evaluation by the subjects of communication. Like the meanings of words emerge, according to Vygotsky (1982, p. 19), as a "unity of communication and generalisation", so the images and plans are elaborated in the joint collective activity.

Interactions of Spatial Models in Thinking

On Interactions of Cognitive and Projective Models

Cognitive and projective tasks are solved by spatial thinking with the help of spatial models, which can perform both cognitive and projective functions. The *re*-productive internal models created by subject on diverse mental levels in processes of knowing are *produced* using operations with spatial images. They are

similar to purposeful actions made by a craftsman with objects of his transformations. There is a similarity of external operations with spatial objects to internal mental operations, and such similarity is a ground for spatial modelling.

In particular, a simple addition of units in the process of arithmetical calculation can be compared to combination of bricks, which a mason performs in process of house building. In a similar way, a subtraction of the arithmetical units has its correlation with activity of a carpenter, who removes superfluous parts from a plank prepared for an inclusion into a worked construction. In the same key, the arithmetic operations of division can be compared to the activities of a draftsman dividing a sheet of paper into several parts, or an architect laying out a plot of land. Similarly, a serial multiplication of produced artefacts can be considered as an analogy with the operations of multiplication in thinking.

On Features of Spatial Thinking

All mental models of space built in the acts of cognition and transformation of objects and in the acts of intersubjective communication are created as a result of intra-subjective activity of thinking.

Thinking in broad sense—from Descartes to Piaget—includes not only operations with logical forms, but also ideal operations with infralogical images. In particular, the *spatial thinking* is an operating mainly with visual images created at the apperceptual level of internal modelling (cf. Arnheim, 1969). It is the purposeful formation and transformation of the spatial images associated with the organization of subject's relations with the objects of activity and with other subjects. Therefore, the spatial thinking is a process, where the subject constructs spatial models of an object with certain features, whether it is a plan for a trip to a location or the identification of the orbit of an Earth satellite.

The spatial thinking differs from verbalized logical thinking by its *genesis*, *structure*, and *functions*. They have different *genesis*, because the spatial thinking has still natural roots in intellect of higher primates, whereas the verbalized thinking is developed only in culture on the basis of a human language (see Vygotsky, 1983). Unlike the verbal thinking interiorized from external communicative actions between people, the spatial thinking is developed primarily in practice of subject-object relations. Only secondarily, it can be involved in communication acts in reverse processes of exteriorization. This does not prevent the individual's spatial thinking from being shaped by culture and dependent on its patterns of behaviour (cf. Cole & Scribner, 1974).

As the spatial thinking operates not with logical concepts, but with schemas of objects and of subject's movements, its *structural organization* also differs from processes of deduction or induction. Instead of operations with *logical classes* connected by relationships of *genus* and *species*, the spatial thinking deals with relationships between *images* of a *whole* and its *parts* (cf. Piaget, 1994, p. 202).

This structural particularity of spatial thinking gives to it possibilities to perform special *functions* of modelling different objects in visible images, which can represent a multitude of relations between parts in a simultaneous picture of the whole. Due to these features of spatial thinking, it can serve for expression in a visible spatial form of diverse non-spatial and non-visible content from various areas of culture—language, myth, art, science, etc. (see Cassirer, 1923-1925).

On the Parallels Between Logical and Spatial Thinking

At the same time, there is a natural parallelism between the structures of logical and spatial thinking. Both of them contain acts of analysis and synthesis, even though they are performed by another way. An analysis in spatial thinking of various levels is not deduction of logical consequents from prerequisites, but a separation of

parts from the whole—as the detailing of the simultaneous image when looking at a picture. Synthesis in it is a composition of spatial parts into a single whole. The internal spatial combinatorics of these parts in thinking differs from free imagination, because spatial thinking is goal-oriented; like logical thinking, it is aimed at solving certain tasks that arise in the processes of cognition or transformation of objects.

There are also the parallels between the logical laws and some principles of spatial organization. In particular, the logical law of identity, which requires an unchanging of the content and volume of concepts in mental operations with them, has an intuitive ground in internal operations performing with constant forms of objects unchanged by transpositions in the space. The logical law of contradiction, which does not allow the simultaneous truth of a judgement and its negation, has its correspondence in the notions that the same body at the same moment cannot both be and not be in the same place. In a similar way, the logical law of the excluded third corresponds to the notion that the body at each moment must be only in one place in space—either "here" or "there"—and cannot be simultaneously in different places. It is no accident that Hegel's negation of the laws of identity, contradiction, and excluded third in his logic is paired with his way of resolving the paradoxes by Zeno of Elea: asserting that a moving body is and not is in the same place of space, and even that it is in two different places at once (see: Hegel, 1993, p. 282).

This parallelism between logical thinking and operations with visible spatial relations is clear, for example, in a capability of spatial models to represent logical relations between classes—in Euler's circles, Venn's diagrams, various graphs, schemas, and other visible constructions. Each such model is projected and produced as means of cognition and can serve as example of mutual interactions between the projective models created in the planning processes and cognitive models formed in the processes of knowledge. In their turn, spatial structures can be represented by logical relations: intersection (conjunction), division (disjunction), complements (logical closure), etc.

The parallels between logical and spatial structures have also a psychological aspect revealing in connections between logical and infralogical operations (see Piaget, 1994, p. 102). Such parallels give possibilities to consider thinking as a psychological process, where verbalized logical actions are transformed constantly in forms of visual-spatial images, and return, these images are expressed with help of logically organized speech (Vecker, 1976, pp. 134-136). Such mutual interaction of spatial and logical thinking is clear in description by Albert Einstein of his thinking process, where mental operations with movements of objects in space preceded their formulation into rigorous theoretical constructions (see Hadamard, 1945, pp. 142-143).

Spatial Schemas in Internal Modelling

Mental Schemas and Spatial Models

Ideal spatial models constructed in the mind of subject and transmitted in acts of intersubjective communication contain common *schemata* participating in formation of objects' images and action plans of subjects. Each spatial *schema* is a brief way to create more or less detailed images of represented objects. According to Kant, for example, "The schema of the triangle can never exist anywhere except in thought, and signifies a rule of the synthesis of the imagination with regard to pure shapes in space" (Kant, 1998, p. 273).

To the extent that a schema represents a mental object through a resemblance between them, it can be regarded as its *model*. Simple schemas such as triangle, circle, and other geometric figures can serve as productive and reproductive models or be included in more complex spatial models as their parts. Although both the concepts are in some ways mutually reciprocal, there is a difference between them. Not any model

serves as a scheme, because there are models containing except for the schematic forms also more or less detailing representation. They can contain not only essential, but also accidental features of spatial objects. For example, a detailed picture of a tree in the botanical atlas contains a more particular its model than a pictogram. Unlike the detail drawing, a pictographic representation contains only essential features of its object, which are necessary and enough for its schematic (re)cognition or (re)production. The schemas will be, correspondingly, the reproductive models ("images") attracted in processes of knowledge and productive models ("plans") used for creation of new objects.

Spatial Schemas in Practical Thinking

The simplest ways of subject's mental actions have similarities with the main types of object formation in the activities of craftsmen. These types were described in theory of technical arts by architect and art researcher Gottfried Semper (1863), who linked them with the ways, in which different materials were processed. In particular, *tectonics* deals with addition of parts, as in works of a mason; *stereotomy* is related to a reciprocal operation of subtraction, as in work of a stonecutter; *weaving* characterizes a work with ready threads, which can intertwine in different way, and *pottery* is, by Semper, a conditional term for any operations of transformations made with soft materials by potter, glassblower, caster, and so on.

A general description of these ways was given by Aristotle, who stated that the objects

> arise either by rearrangement, as a statue of copper, or by addition, as growing (bodies), or by taking away, as the figure of Hermes of stone, or by composition, as houses, or by qualitative change, as things that change in relation to their matter. (Aristotle, 1981, p. 76)

Thus, there is a system of relationships between the parts and the whole: transitions from parts to the whole in their jointing and from the whole to the parts in its dismemberment, combinatory permutation of discrete parts in a whole composition (as in weaving), and continuous transformation of the whole into another whole in a result of changing of relations between its parts (as in "pottery" or "casting"). The fifth type, noted by Aristotle, can also be exemplified by such a process as firing, which transforms the clay product into a solid ceramic object.

Such structures are developed and applied primarily in practical activity and in artistic thinking. For example, the distinction between "tectonic" and "atectonic" forms of vision in classical and baroque architecture (according to Wölfflin, 1921) may well be interpreted also as a difference already in their artistic conception between tectonic and plastic ways of creating spatial constructions.

Basic Spatial Schemas as Units of Collective Consciousness

The spatial schemas and mental models composed of them are developed not only in the individual experience of persons researched in the psychologist's studies. The results of this experience are preserved also in culture, first of all—in practice of external transformations of human environment—and they are established in collective mind as units of spatial thinking. For instance, an object form of a cup can be reproduced in various times together with its ideal models. In all these changes of both ideal schemas of the object and of their material embodiments, a certain structural invariant is preserved—a spatial form, which can be internalized in acts of objects perception, be externalized in acts of their (re)production, and be remained as a recognized and reproduced unit of collective consciousness.

Similarly, regular geometrical figures—circle, square, cylinder, etc.—were used as schemas of construction and (trans)formation of an object in practical activities of craftsmen, architects, or land surveyors

since ancient times, long before the science of "geo-metry" separated them from this practice. Their dissemination in various fields of human activity is due to the fact that they are constructed according to simple and clear rules as models of spatial objects, both projected and cognizable.

Still in the mythological thinking, the simplest elements of the future geometry (straight lines, circles, spheres, etc.) gave a possibility to represent the manifold of things with the help of unified spatial schemas forming "an alphabet of the geometrical signs" (Toporov, 2010, p. 47). All the more, the natural philosophy and proto-science used the elementary spatial schemas of regular geometrical figures. In particular, the Pythagorean view on the nature as on cosmos of geometrical and arithmetical figures, its Plato's image as a construction of natural elements-stoicheias are based on these schemas of spatial thinking.

Spatial Schemas in Abstract Thinking

These figures also turn out to be suitable for theoretical models of nature, whose "great book" sometimes even seemed to be written "in the language of numbers and geometrical figures"—as Galileo thought (cf. Foucault, 1994, p. 71). However, it is more correct to speak about units of culture elaborated as spatial schemas for both cognitive and projective models. The emergence of alternative systems of geometry contributed to the realization that only theoretical models of physical objects, a kind of "projects" of physical reality that could be "validated" or conversely "rejected" by experience and theoretical analysis, could be built in its language.

Manifestations of spatial schemas similar to the Semper's shaping types can be found both in the formation of spatial models of cognized objects and in the structural organization of the theoretical thinking itself. In the first case, the schemas of spatial thinking developed in practical and artistic activity guide the construction of mental models of the world structure. This is clearly visible in natural philosophical concepts of the cosmos structure, which have a technomorphic character—when the cosmos is likened to a product or structure artificially created by some demiurge (cf. Losev, 1974, p. 173). Such mental constructions of the universe partially reproduce spatial schemas developed in the practice of object activity, which may even correspond to some or other Semper's types of shaping. So, the idea that the cosmos is constructed of undivided atoms (Democritus, Epicure, and other) uses the mental schemas of tectonic type. Using in theoretical thinking of "Occam's razor" or of Spinoza's principle "*Determinatio negatio est*" can be considered as an application of stereotomic operations related to those that apply barbers or carpenters. A theorizer can think also about "a net of concepts", which he drafts on a researching object or on "weave of being", which he investigates. He reproduces in this relation mythological images of the world as "the result of superimposing on a flat, wide, open space some network of weaving, texture" (Toporov, 2010, p. 355), a *text* in an ancient sense. There is in the same row, the representation of the world as created in joining of the amorphous hora-matter with formed eidos-patterns in Plato's *Thymeos* that is clearly linked with images of clay transformations under hands of a potter or a metal casting.

Spatial Schemas and Styles of Thinking

Not only construction of various spatial images of the world, but also the theoretical thinking as an activity itself can be connected with preference of certain spatial schemas and modelling ways using them. According to Yuri Lotman: "The very construction of the world order is inevitably thought on the basis of some spatial structure organizing all its other levels" (Lotman, 1992, p. 389). The spatial structures serve in this case as patterns for construction of other ideas, and a choice of their basic schemas influences the *styles of thinking*.

A theorist using various spatial schemas may resemble diverse craftsmen approaching the formation of a

thing in different ways. Creating his spatial or quasi-spatial models, he builds mental constructions (out of words, concepts, or spatial images) like a builder or carpenter who assembles the parts of the future construction into a new whole organized from discrete units.

This kind of thinking has a pronounced structural character. The very notion of "structure" dates back to the construction activity and only later spreads to the natural fields, and then to the humanities. As Roland Barthes had formulated, structuralism is an activity in any sphere, whether it be science or art, which has in its ground "two specific operations—division and mounting" and is connected with singling out and combining distinguishable units (Barthes, 1989, pp. 256-257). However, there are even in frame of structural way of modelling, in this sense, two approaches—from parts to whole and from whole to parts. They could be titled, very conventional, "atomism" and "holism".

Different versions of "*atomism*" are intended on construction of theoretical models built from elementary units that can be added to each other in various combinations. This strategy of thinking includes not only natural-philosophy, as by Democritus, or physics, as by E. Rutherford. The "logical atomism" by B. Russel falls into the same category as well intending to consider "atomic facts" existed independent of the whole (see Russel, 2010).

Unlike it, "*holism*" is such way of mental modelling, which originates from a whole as something initially given and considers its parts as a product of decomposition. In such cases, the theorist's course of thought is similar to work of an engraver or a draftsman, who introduces a certain structure into yet undivided surface of a "clean sheet" delimiting its parts and separating out "figures" from the "background" and from each other. This style of thinking is inherent to structural linguistics, since F. de Saussure gave priority to a whole of the language, from which partial units are derived, and without which cannot have a sense (cf. Saussure, 1959, p. 120). In a similar way, the Gestalt psychology finds the whole more important than parts—in contrast to associative psychology intending to use atomistic way of modelling (see Koffka, 1935).

Even in mathematics, there are two approaches: the atomistic one, which makes the whole out of the parts—from arithmetic of natural numbers to Cantor's theory of infinite sets—and the topological one, which allows continuous transformations of a ready continuum—like soft clay in the hands of a potter. According to H. Weyl, topology and algebra are two opposite and hardly compatible approaches. If the first moves from continuity to discrete structures, the second goes in the opposite direction of thought. Therefore, "it is not surprising that they are poorly compatible. What is easily achieved with one approach requires the greatest effort with the other." (Weyl, 1989, p. 34).

Space Semiotization and Means of Communication with Spatial Codes

Semiotization of Space and Creating of Spatial Texts

The results of thinking are not limited by internal activity of mind and can be embodied in various artefacts. Due to this, the mental models can preserve their internal structures in their external transformations and can participate not only in processes of objects knowledge and transformation, but also serve as means of inter-subject communication. The latter is carried out through the semiotization of space and the formation of specific spatial texts in it.

Semiotization of space is a selection and organization of meaningful spatial relations, which are structured and interpreted according to norms of one or several semiotic systems. Therefore, a "semiotic form" is introduced in a spatial "substance", where the "expression plane" is formed, and its connections with meanings

of the "content plane" are established (cf. Hjelmslev, 1961, § 13). Both these planes take place also in *spatial texts* created in result of the space semiotization and capable represent various objects as the means of inter-subject communication. An introduction of the semiotic form in the spatial relations organizes both their "substance of expression" and "substance of content" in the text.

Thus, the space semiotization and the texts formation have external and internal sides. The organization of meaningful relations between external spatial objects is correlated with their internal models in subject's mind. The first has to do with more or less significant transformations of bodily objects, giving them the form of meaning-bearers and transforming them into spatial texts. The second is the preparation of the subjects' consciousness for the selection of meaningful elements and structures.

Using the ancient notions, one can say that both reciprocal processes occur there: an expansion of *logos in topos* at creation of spatial texts is correspondent with a penetration of *topos in logos* at various forms of spatial thinking with help of certain semiotic means.

In a particular case, the written texts contain logos in topos or, in other words, they are organized as bearers of senses in their spatial forms. However, the logos in space is not just a spatialized word, as well as the rational formed space is not just letters. The architect who lays out the site for a building and draws its design, the craftsman who cuts the cloth or gives the right shape to the work, land surveyor who determines the boundaries of land parcels—they all bring a sensibly arranged correct form into the "amorphous" space and therefore—the logos in the topos. Like Plato's demiurge, who introduces form-idea into chora-matter, they use geometrical units described by Euclid as "stoicheia" connected both with letters of the alphabet and with "the letters of the universe", how Plato interpreted the four elements (Plato, 1971, p. 489).

Any artificial organization of the human environment according to productive models of architects, designers, and other creators of meaningful artefacts in it also can be considered as text creation in a large semiotic sense. These are already not the L-text subordinated to rules of verbal languages, but the S-text regulated by some spatial codes. Unlike the written text, these types of space semiotization and texts formation do not subordinate to principles of speech formation—linearity and non-reversibility (see Saussure, 1959, p. 70). The spatial texts can be developed in two or three dimensions of a semiotized space, which can have also other semio-topological qualities—to be reversible, anisotropic, open or closed etc. (see more details: Tchertov, 2019, pp. 234-242).

Spatial Codes as Systematic Connections Between Schemas of Formation and Interpretation

The participants of communication creating and interpreting any texts should use similar mental models. They are productive models of created texts in planning of their authors and reproductive models in mind of recipients. A mutual understanding of communicating subjects is possible due to common norms of texts formation and interpretation, which are regulated by *spatial codes*.

Similar to verbal languages, many spatial codes can perform three main functions: to represent various objects and subject's actions, to serve as means of inter-subject communication through the spatial texts, and to be at the same time the means of intra-subject processes of spatial thinking. However, these codes have their structural specifics, which relates to their planes of expression and content.

Like each language connects the "forms of expression" and "forms of content", in Hjelmslev's terms, the spatial codes organize systematic connections between ways of formation and interpretation of the texts regulated by them. Both of these planes involve spatial modelling and schematics. The extension in culture of

visual-spatial codes is the introduction of certain schemata into collective consciousness. A schema belongs to the code, not to the text; it is a unit of "language", not "speech", in Saussure's terms. The interpretation of a spatial text is the superimposition on it of schemas given by a code.

Semiotic means of spatial codes contain at least unified *schemas* that define units and structures in their *expression planes*. The function of such schemas in a number of spatial codes (architectonic, object-functional, demarcation, etc.) is performed, in particular, by *regular geometrical figures* mentioned above. As it was said, their uniformity allows them to be easily reproduced in thinking of different subjects and to be a convenient means of communication between them. However, the geometrical elements acquire their semiotic functions only insofar as they become components of the "form of expression" in the system of spatial codes. Depending on this semiotic form, the regular geometric figures can perform in various spatial codes different functions participating in both: their morphology dealing with meaningful forms and their syntax regulating meaningful placements of the morphological units. Accordingly, these figures can be differently correlated with the "form of content" in various spatial codes.

On Infralogical Semantics and Schemas in Content Plane of Spatial Codes

Not less important these schemas are in semantics of the codes involving in spatial thinking and communication of ideas produced in it. Whereas the verbal language gives the semiotic means for organization in its content plane of relations between logical concepts, many spatial codes give the means for formation and expression of ideas belonging to infralogical levels of mental activity. This does not exclude that words can express infralogical ideas or that content of spatial codes can be interpreted at the logical level. It is only a question of the fact that spatial codes have particular semiotic means for infralogical mental constructions modelling spatial objects and subject's actions with them.

Unlike logical semantics, the infralogical semantics of many spatial codes deals with meanings formed at lower levels of psyche—not always cognitive, but also projective or affective. Its semiotic research differs also from psychology of thinking, because this infralogical semantics, using Hjelmslev's terms, has as subject matter not the "psychological substratum" and "substance of the content", but its semiotic "form"—the norms of semantic formation fixed by the code. The forms of ideas structured by these spatial codes are in this case not logical concepts, but schemas of objects' recognition and subjects' actions. These schemas become units of thinking with help of the visual-spatial codes and participate not only in the practice of architects, designers, and craftsmen of various specialties, but also in creating of theoretical models in the activities of philosophers and scholars.

All thinking is carried out within the framework of some system of knowledge organized with help of certain semiotic means. While logical operations are based on a system of concepts ordered by a network of genus-species relations, the spatial thinking operates with relations between spatial parts and the whole. A mental field, where these operations are performed, is not the perceptual space of directly perceived objects and, at the same time, it is not the conceptual space created in theoretical models (cp. Russell, 1948). It is a transitional type of subjective space between these two—an *apperceptual space.* On the one hand, it can remain unconscious, and, on the other hand, it contains a generalizing system of ideas that retains only invariant schemas for constructing more developed spatial images. The structure of the apperceptual space conditions the structures of spatial thinking dealing with the relationships of parts and whole just like the logical forms guide

conceptual thinking, which operates with genus-species relations.

The content plane of each spatial code constructs its own specific semantic field, in which the apperceptual space is structured by its own way. In particular, the *architectonic code* organizes in its content plane an apperceptual space, where the forces of attraction and repulsion, gravity, and elasticity are modelled, accompanied by experiences of their balance or disequilibrium, conflict or coherence, etc. The meanings of the *demarcation code* are schemas of locomotion in the labyrinth of obstacles and openings in frames of spatial models formed by a moving subject. The content plan of the *object-functional code* is connected with the functional meanings of artefacts interpreted as tools of objects' transformations in the apperceptual space of subject's purposeful actions. The content plan of the *social-symbolic* code has apperceptual models of social space with its value-significant oppositions of centre and periphery, top and bottom, right and left, "own" and "alien", etc. In the *proxemic code*, the same social space is represented by other elements: not the forms of objects and their places, but the relations between the bodies of people differently situated in this space.

In each of these cases, apperceptual space is structured in its own way becoming an autonomous space with its own specific laws. The "force field" in autonomous space created by means of the architectonic code is structurally different from the "field of object actions" constructed by schemas of the object-functional code, and from the space of social behaviour modeled differently by means of the social-symbolic and proxemic codes.

Owing to the inherent organization of its content plane, each of the spatial codes is an indispensable means of thinking in its own sphere and becomes untranslatable by the means of other codes. Different schemas and structures of semantic fields in various codes with their particular types of apperceptual space differently determine ways of infralogical thinking. Due to this, the "tecto-logic" in mental constructions of architect's thinking by the means of the architectonic code differs from the "techno-logic" in projective thinking of an engineer, who uses the means of the object-functional code, or from the "socio-logic" used by a politician, who projects his meaningful behaviour in space using means of demarcation, proxemic or social-symbolic codes.

Like the verbal languages, the spatial codes can be used in various modes of human activity and participate in diverse discourses as means for knowledge, evaluation, and transformations of objects (cf. Morris, 1971). Not all of them specialize on the infralogical semantics of apperceptual spaces in their content planes. For example, the mathematical calculations are the spatial codes having in their content plane semantics at logical level of thinking, and the musical notation is a spatial code with the infralogical meanings of pieces developing not in space, but in time. At the same time, all spatial codes regulate formation of spatial relations in the expression plane and many of them organize spatial thinking with help of infralogical meanings from the content plane (see more details on the space semiotization, spatial texts, and codes regulating their formation in: Tchertov, 2019).

Conclusion

The philosophical discourse offers a field for comparing research carried out in different fields of scientific knowledge. Like the general philosophical concept of space, the notion of spatial modelling can serve as the basis for various interpretations in the natural sciences and humanities, as well as in technical activities and the arts. In particular, spatial structuring of things and thinking about them, "topos" and "logos" are joined in the spatial modelling as in the activity, which is equally important in cognitive, projective, and communicative processes. Such modelling connects both sites of any mental activity described by Yuri Lotman

(1992, pp. 53-54), who suggested that each complex system—where it is the hemispheres of brain or the semiosphere of culture—necessary includes interaction of semiotic systems of two different types. One of them, as the verbal language, regulates successions of discrete signs and logical thinking; whereas others build simultaneous models, where many parts are connected in unite visible whole. The spatial codes mediate processes of such internal modelling by their own semiotic means providing infralogical levels of thinking. Their schemas extend not only to conventional sign systems, but also to the interpretation of iconic models and systems of indexes used in science, technique, arts, and other fields of creative human activity.

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