Bartłomiej Skowron

The Forms of Extension*

> The nature of corporeal substance is *extension in length, breadth and depth*; and any other property a body has presupposes extension as merely a special case of it. For example, we can't make sense of shape except in an extended thing, or of *motion* except in an extended space. The nature of thinking substance is *thought*; and anything else that is true of a mind is merely a special case of that, a way of thinking.
> *Principles of Philosophy*
> René Descartes

1 The extension as ontological difference

Res extensa is extensive but *res cogitans* is not. The extension as such in *Principia philosophiae* becomes this, what differs thoughts and things. Thus, it is not unimportant whether a particular object is extensive, whether it extends somehow and between something or whether it is not extensive and there is no way of attributing the formal character of "being between" to its entity. For "extending" is the essential diversifying property within bi-categorial ontology of that what extends and what cannot extend; though not only in this ontology it diversifies substantially. The answer to the question, what is the extension itself, is not obvious. In this article, we take up this question and suggest some direction for research on the issue of extension as such. We should add that the extension as such appears in many other philosophical contexts, in the context of part-whole theory, in the issue of perceptual objects, in research on time, and even in problem of stretching of literary work, from its beginning to the end. But in this article we are dealing with *extension as such*, not with a special kind of extension of this or that object.

On the basis of considerations presented in this article, we obtain a sketch of infinitely-categorial formal ontology. We claim that bi-categorial ontology is not adequate. The reality is much more complex. The complexity of reality is based on the various kinds of extensionality.

* This text is a bit changed and extended translation of Skowron (2013).

2 Ontological explanation of extension

There are scarcely any systematic studies on extension. Philosophical tradition had left some, scattered here and there, remarks on it. Even if they are systematic, they are often intertwined with particular metaphysics. Further on we will try to gather the basic ontological intuitions with reference to the formal characteristic of extension, so as to enclose them in some formal frames.

What occupies space is extensive for it extends between the parts of some space. In this meaning, solids in 3-dimensional space, temporal intervals in space of time and colourful blots spreading on sheet of paper are extensive. In each of those meanings the extension differs in some aspects; for solids, 2-dimensional surfaces are limitations for extending objects, for colourful blots there are curves, and for a length of time – spot moments (instants). The problem concerns the differences regarding the dimension of extending objects. Therefore, we suspect that the prerequisite for an object to be able to extend is its having positive dimension. Time modelled linearly can extend from left to right, from the past to the future or from right to left, i.e. from future to past. Yet, regardless of the turn, it extends in one direction, remaining in linear model. In case of extending colourful blots, apart from left-right extension, we have extending upwards and downwards and sets "left top", "right bottom", etc. In case of solids, additional dimension, usually called the depth, appears. Philosophical tradition rather does not single out objects with more dimensions than these mentioned above.[1] It is a kind of limitation, especially as in contemporary scientific-cognitive practice multidimensional objects are successfully considered.

Some complexity, consisting in possibility of division, is associated with extension. What extends between its ends can be, for example, halved or divided in n parts. What the division is depends on structure of divided object. This remark will gain more clarity in further parts of this work, where we will define precisely the notion of space. The possibility of division is often enhanced to infinite possibility of division, that is to claim that we can divide an extending object infinitely. So, let's assume that the extending object can be divided infinitely, not specifying, for the time being, what the division is.

Another characteristic of what is extending is impenetrability or impermeability, that is one extending object cannot penetrate the other. Extending objects

1 In our other work we showed that the notion of possible world is related to infinite dimensionality. Also other notions of combination ontology, such as element (monad), complex or situation, are related to the characteristic of dimensionality. See Skowron (2014).

can at most be similar in some respect, one can be a part of the other, they can touch each other, border each other, they can be separated by such and such space, but they cannot penetrate each other. However, the thoughts that reportedly are not extending can permeate each other. Impermeability is the formal moment of what Ingarden called "closedness".

From etymological point of view, the extension is that, what spreads, *extends* (from Latin *ex-* "out" + *tendere* "to stretch") between one thing and another. The extending is what is "between" this and that, what from its nature must be between some ends. Moreover, being Paderborn between Münster and Göttingen does not prove that Paderborn extends between Münster and Göttingen. Therefore, being between is being from – to, what is from Münster to Göttingen is in proper sense that, what extends from Münster to Göttingen. Thus, being between is being everywhere (or almost everywhere) between. In other case we do not deal with extension *sensu stricto*.

All mentioned moments of extension, i.e. spatial dimension (immersing in space), divisibility, impenetrability, being everywhere "between" in specific sets, determine various kinds of extension but do not consist of its definitional perspective, for we do not know yet, what is the very extension. M. Rosiak described it as the possibility of co-existence of a multitude of objects, abundance of differences between places.[2] Extension is, so to speak, medium which enables to diversify the location. This statement is very general, and it has to be general. We should notice that this characterization is given in spatial stylization, i.e. when defining the space as a set of places and their differences it is said that the possibility of co-existing of a multitude of objects in this space is exactly its extension. As we suspect, every extending object is just the part (e.g. subspace) of such extending space. Further on we will act similarly, but not identically. We will propose a general notion of space, while extending objects will be the spaces having certain special properties. The way of extending, and we assume there are many, depends on kind of objects being extended or extending, and on the forms of their connections.

The general question appears: whether we attribute the extension to the objects immersed in some space or to the spaces itself. N. Hartmann[3] claims that what is in space is extending, the space enables appearing of extension, it is the plasma of extension, though it itself is not extending. In this sense the space as such is a principle. Our understanding of space differs from Hartmann's under-

2 Cf. Rosiak (2013), 382.

3 See Poli (2013). Hartmann probably would say that our study on extension is based on categorical error, but we would respond that his ontology and our ontology are fundamentally different.

standing, it is more general and in our approach space is not just a principle. Our understanding allows us to distinguish many (many more than Hartmann could) kinds of space, however, it does not distinct one, precisely indicated – and thereby to distinguish many of its parts as well as the entities consisting of it. Still, such an approach enables us to speak almost interchangeably both about space and the objects of that space, that is about the extension of objects in space and of spaces themselves.

Not all formal moments of extension described here were attributed to it. Ingarden attributed some extension to the primary individual object, though it was impenetrable, that is, in a way indivisible.[4] Another problem is, whether one can show the example of extension having the property of being between but not having the property of spatiality; or not having the property of divisibility but having the property of impermeability; similarly in other cases. One can claim that those properties are mutually definable or co-definable in a specific way; one can say that they are, in a sense, independent from each other. It is impossible to resolve this question here, for we do not know yet what we precisely mean by space, divisibility, being "between", etc. Below, we will define some of these notions with mathematical preciseness – and only on that basis one can try to settle anything.

3 A new direction for discussion on extension

We should note that appearing characteristics of extension often concerned pure geometrical notions, such as space, distance, solid (and its shape). In a natural way, when we want to give an example of extending structure, we quote *continuum*, 3-dimensional Euclidean space or plane. It makes sense, because in philosophy space was conceptualized by geometrical notions. But, on the other hand, Bergson and Ingarden warn against geometrization of philosophical issues, and especially against geometrization of extension of time. In this context, it seems that geometry lost its explanatory power in philosophy, and especially in metaphysics. And it is so, indeed. Nowadays, however, geometry, being after all *ancilla philosophiae*, is replaced by another mathematical science – topology.[5] It is a far-reaching generalization of geometry, and thus it is suitable for conceptualization of generally understood spaces and various types of extension. Topology is also called – and it is extremely meaningful in the context of definition of extension

4 Cf. Rosiak (2003), 89.
5 See Mormann (2013).

assumed in this article – *Analysis Situs*. Topology is the analysis of situating and forms of location of specific objects in specific spaces. Incompletely and imprecisely speaking, length of line segment, size of angle or area of the plane play an important role in geometry. In general topology, however, those characteristics are not substantial. From a topological point of view, the triangle is identical to square, straight line to line segment without ends, and plane to sphere without one point. Thanks to its generality, topology can study abstract spaces, exceeding highly Euclidean/non-Euclidean paradigm, used often in philosophical argumentation.

The topological space will be then the medium in which we will discuss the extension. It is a set of points together with a certain structure called topology. In this context, a point means the final building material of specific space. The points can be geometrical ones as well as sequences, functions, thoughts, desires, cognitive subjects, Wittgenstein's objects (then, states of affairs could be open sets, and topology could be the form of states of affairs, i.e. the possibility of structure of states of affairs), etc. Over the points we build the structure in which those points show and reveal. It is also possible, and maybe even better in some ontological cases, to express some fields a bit differently, for example with the use of pointless topology.[6] However, we will not discuss this matter here.

Topology consists of families of sets of points. However, not all families of those sets are topologies. We call the family of subsets of a set X closed under finite intersections and arbitrary unions, also including X and the empty set, a topology on the set X. Sets belonging to the topology are called open sets, and their complements – closed sets. Topology may also be introduced through other notions, not only the open sets. One can insert topology by providing its basis or by giving the basis of points' neighborhood (e.g. the topology of thought of any subject can be inserted by giving the set of thoughts being "in the vicinity" to every thought of that subject; that set is, so to say, the neighborhood of initial thought), or by axiomatic approach to closure and giving the sets equal to their closure (then, the complements of closed sets are the open sets), or in any other way. We can define many topologies on the set X, though not all of them are of the same importance. In the sense of inclusion, the biggest topology is the family of all subsets of X, and the smallest one is the family consisting of X and the empty set. Let's take the following example: the set of real numbers together with the family consisting of any unions and finite intersections of open intervals (the interval is open in this case if it does not include its end points) is the topological space.

6 See Picardo and Pultr (2012).

This topology is Euclidean topology. However, there are other topologies, far from Euclidean, that give various structures to the set of real numbers.

In the context of our goal, we speak not about formalization but about conceptualization of some philosophical issues. The aim of formalization is to build the closed deductive system (or theory) and to examine it appropriately; and it was practiced – often ineffectively – in philosophy. Mathematical conceptualization or just mathematical modelling does not lead in the first place to building the theory but to building some *analogies* between conceptualized structure and certain mathematical structure. Such efforts are often used in natural sciences. We are dealing not only with theories; we are dealing with the structures of objects and essential properties of these structures.

4 An attempt at clarification of extension

We propose to discuss the extension in topological spaces. Below we will present an attempt to convey formal-ontological characteristics of extension mentioned earlier in topological disguise.

We listed occupy space or being the part of some space as the first condition for extension of the object. The easiest solution would be that the object taking some part of topological space is extending just because it takes part of that space. Such a resolution cannot last, because 3-element set with the biggest topology is the topological space, and its randomly chosen point is, in a sense, its part. However, this point is not extending. We would also rather not call certain open set, consisting of two points, the extending one. Therefore, one should lay on initial space some conditions excluding absurdities – at least the blatant ones. Then, the space should consist of endless and at best uncountable number of points – then we can reasonably examine the extension of objects existing in it. The condition of an endless number of points must be supplemented by some conditions regarding the properties of the space itself. Cantor set – to give another bad example – is an uncountable set. It is hard to talk about extension within its range, mainly because it is a nowhere dense subset of line segment. The Cantor set is a 0-dimensional set. It means that it has no non-empty and not-single point connected subsets. The mentioned properties rather show the critical point of lack of extension than having some extension. This point is not unambiguous since adding one point to the Cantor set so that so-called Kuratowski-Knaster fan came into being leads to connected space and connectedness is one of the desired formal-ontological properties of extension. Maybe the structure of the Cantor set allows us to model some – certainly weak – kind of extension. After all, the Cantor set is compact, there is its continuous transformation to unit interval (moreover, every compact metric space is its continuous image), and it has additional interesting property of invariance on Cartesian product. Strictly speaking, the Cantor set is in topological sense identical (homeomorphic) with any countable Cartesian product of itself.

Therefore, to examine the extension, we should assume some form of connectedness of space, even such that the given space contains random connected non-trivial subspaces. However, since the connectedness can take on undesired forms in topology, we should impose stronger limitations on it, such as containing path-connected subspaces or simple conectedness.[7]

Being between is, as we wrote, being everywhere between. Elaborating on this characteristic of formal extension can assume various forms. One of them is such a possibility that the object extending in a given space is a dense subset of certain, selected suitably subspace of that space. Being the subspace of any given topological space is being its part with topology remained. In this sense, the set of irrational numbers from the line segment (0, 1) extends between 0 and 1, since it is the dense subset of (0, 1). And this range is the subspace of the real line. Yet, as we can easily spot, being between in this case is not being everywhere between in the meaning of quantity; there are no other rational numbers there. But the density of irrational numbers within this range should suffice. All points are not necessary, the density of those points is enough. Being dense is formal-ontological characteristic of the way of location as well as the way of extending between.

Mereological relations in topological spaces can be modelled in many different ways, not only in the sense of being subspace, e.g. as being the compact subspace of entity or connected components, or else. If we did not speak about the density of subspace but about density of initial space, the extending would be limited to extreme cases where extending objects (and to be precise, their closure) occupy the whole space.

As we mentioned above, the possibility of endless division of object is a part (in Husserl's sense) of its extension. The problem of division can be also modelled in many ways. One of them is imposing stronger and stronger separation axiom on space. We present two of such axioms as example: axiom T2 (the space fulfilling this condition is called Hausdorff space), according to which every two points of space can be divided/separated from one another by open sets. Strictly speaking, for every two points there are such two disjoint open sets that one point belongs to one open set and the second – to the other one. If every two disjoint closed sets can be divided/separated by disjoint open sets, we say that the space is normal or

7 It was Dr. Roland Zarzycki who directed our attention to simply connected spaces in context of extension.

that it is T4 space. When modelling division by separation axioms, we discuss the problem of division not in light of cutting or slicing but rather paying attention to carrying out possible differences in the found structure. If any two open objects in space can be separated by closed objects with the use of T4 axiom, it means that every two structural and not coinciding parts of space can be distinguished from each other by two other (being parts in other way) elements of space. In this case closed sets are the diversifying objects or just the differences. Let's notice that in this meaning our proposition harmonizes with M. Rosiak's perspective, in which the extension is the possibility of the co-occurrence of multitude of objects, the multitude of differences of places – the structure, that is topology, constitutes this possibility. And successive separation axioms determine the strength of possible co-occurrence of objects and possible differences of objects' places.

Other ways by which division of space can be carried out are division into connected components of space, division into subspaces or division into subobjects in the meaning of category theory.

The next formal-ontological characteristic of extension is mutual impermeability or impenetrability of extending objects. Topological characteristic of this moment is difficult. The impermeability consists of the following moments: (a) impossibility of taking the same place (in chosen space) in the same time by two objects extending in the same way, (b) having the limit or boundary or restriction, (c) having separate sets of properties, individual difference of extending objects.[8] The conditions (a) and (b) are easy to fulfill, while condition (c) falls outside purely formal tools. In the case of (a) it is enough to say that in topological spaces we generally do not allow points to overlap, though, especially in algebraic topology, identifying of points is often used. In the case of point (b) – while narrowing attention only to the property of being bounded – it is sufficient when e.g. we add on extending object the condition of limitation, i.e. the condition of being included in some ball in given metric; at the same time we must assume that the space is metrizable. Condition (c) cannot be expressed in full generality with help of hitherto used tools, though, after right preparation, some fragments can be expressed.[9]

It is possibile that impermeability is a material moment and in general should be studied in material ontology. It is worth noting that this moment is studied in many areas in contemporary physics and mathematics. One of the examples of that research is *percolation theory*.[10]

8 Cf. Rosiak (2003), 89.

9 See Mormann (1996) and Smith (1996).

10 Cf. Śniady (2013).

When Descartes considered extending substance, he had in mind extension in length, breadth and depth. We mentioned that those characteristics involve having positive dimension. However, speaking about those dimensions (or in those dimensions) one uses a coordinate system – actually the Cartesian one – which is just a tool for describing Euclidean spaces. In topology, metrics play a similar role to the role played by coordinate systems in Euclidean spaces. We can think of metrics as consisting of distance functions. A topological space X is called metrizable if there exists such a metric on it that the topology induced by this metric coincides with the original topology on X. Metrizable spaces, metaphorically speaking, are spaces in which distance function coincides with original topological structure. In metrizable spaces we can examine "distances" (those coincident with structure) between objects, but we are also able to measure the objects themselves. One of those measures is the diameter of the considered object, i.e. the least upper bound of the set of all distances of this object's points. In this context, object is extending if it surely has non-zero diameter, though not every object having non-zero diameter is extending. Thus, having non-zero diameter is one of prerequisites of extending. However, to speak about objects' diameter we should have a metric, and at best metrizable space – then it is possible to take the object's diameter "in accordance" with structure. The category of metrizable spaces is probably the category of immense significance for our main issue. In this context, the theorem of universality of Hilbert's cube for metrizable, separable and compact separable metric spaces acquires metaphysical significance.

5 Toward topological categorial ontology

Ontology which appears here is a topological ontology. Topology becomes a formal ontology. If one chooses an appropriate class of properties of extension, then one will receive the extension types. Types of extension simply are categories of formal ontology. In other words, different topological spaces create different categories of formal ontology.

We are interested in all categories. However, for the fully-fledged ontology, we should additionally consider relationships between them, that is preferably continuous transformation between the spaces. Then we would obtain a category (in the sense of category theory) of all topological spaces. Perhaps the category of all topological spaces is the formal structure of what there is and what is possible.

One may ask: why topology? There are many areas of mathematics. Perhaps some of these areas are also suitable for ontology. Topology is probably not the only one. Topology, however, is the closest (or very close to) the phenomena of ontology. Being a whole or a part, being a boundary of some objects, being connected – these are the basic topological properties (in broad sense, not in the strict sense). Topological properties in the strict sense are the invariants under some transformations, under homeomorphisms, which are bicontinuous one-to-one functions. These transformations are good tools to describe the objects' natural change over time (but not only over time) while preserving the identity of these objects.

It is often thought that mathematics is the science of quantities (length, number, etc.). Contemporary research in mathematics, however, considers also quality. Topology is an example of quality thinking in mathematics. Angles and lengths are not very important, qualities such as connectedness or denseness are only important. In the first half of the twentieth century, Polish philosopher Benedykt Bornstein[11] noticed that and as a result has built a mathematical metaphysics. He relied, inter alia, on Plato and Leibniz. He used projective geometry in his system. But the truth is that he had in mind what we today call topological spaces. Our proposal of topological ontology is more general than Bornstein's metaphysics, but it remains in the same spirit.

More recently Thomas Mormann in many of his papers[12] develops ontological issues with topology. For example, in his *Topological Aspects of Combinatorial Possibility*[13] T. Mormann considered combinatorial worlds as mappings from individuals to properties. He draws a line between possible and impossible combinations by imposing structural constraints on the relation between a set of individuals and a set of properties, namely he forced on that relation to be a function. He also proposed to treat the complex individuals and complex properties as open sets. On that basis he could define possible worlds as continuous functions. Our discussion about the extension is applicable to T. Mormann's approach to possibility. More precisely speaking, our considerations concern the features of imposed topology on the set of individuals and the set of properties. In the concluding remarks of the above mentioned paper, T. Mormann writes as follows:

> A world is, so to speak, a *topologically structured* totality of states of affairs, or, to express somewhat more generally, it is a structural gestalt.

This quotation could also be the motto of our paper.

11 See Bornstein (1948). In the footnotes listed at the end of the book are references to other works (also in English) of Bornstein.

12 See e.g. Mormann (1995) or Mormann (2000).

13 Mormann (1997).

Summary

The extension as such is an important ontological property. However, its precise description is not obvious. We proposed to carry out the formal research on extension in the context of topological considerations and to model extending objects with help of topological spaces.[14] There are some properties of various formal types of objects' extension: uncountably infinite number of elements, density, connectedness, compactness, metrizability, having positive diameter and fulfilling suitable separation axioms. We repeat Descartes words as a motto of this work:

> The nature of corporeal substance is *extension in length, breadth and depth*; and any other property a body has presupposes extension as merely a special case of it. For example, we can't make sense of shape except in an extended thing, or of *motion* except in an extended space. The nature of thinking substance is *thought*; and anything else that is true of a mind is merely a special case of that, a way of thinking.

Corporeal substance is extending, and all other attributes of it are in a way immersed in extension; hence the extension is constitutive for corporeality. From our perspective, one should then clarify the type of corporeal substance extension and answer the question whether the thought is non-extending in same way in which the corporeal substance is. Then the mind-body issue becomes a bit more subtle, at least from a formal point of view. Let's experiment on such a case: the extension of corporeal substance is the one type of 3-dimensional open ball, with suitable dents and bumps, but without holes through. It is actually highly probable that Descartes meant just such a structure. To simplify the problem, let's assume that the space of thought[15] is the whole 3-dimensional Euclidean space. The scope of thought is unlimited; therefore this space should be unlimited (of course, this is a big simplification). *Prima facie* both these structures are fundamentally different, even because the first is bounded and the latter is not. One can also claim that the first is a small part of the latter, and this exceeds the first in its size. What are other relations between those two structures? As it turns out, both are identical in topological sense. Despite differences found, there is a strong resemblance between them. In this case, it will be the identity of extension types, what would surely be

14 One should add that quite a big part of present ontological and formal-ontological studies uses topological tools. Moreover, the new subfield of ontological research appeared – mereotopology (also called spatial logic) – joining philosophical and formal part-whole theories with topological tools. To learn more about it, see Pratt-Hartmann (2007), Smith (1996) and Fine (1995).

15 Space of thought could be interpreted as a subspace of life space in the sense of topological psychology of K. Lewin. Cf. Lewin (1936).

undesirable for Descartes. This example – though not the best one and chosen *ad hoc* – shows that the extension is not what diversifies thoughts and bodies.

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