STEREOLOGY

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1. THE PROBLEM

The tasks put forward by the recent developments in information systems research, especially those connected with the problems of knowledge representation, made the parallel task of advancing a formal ontology for the common sense world—for the world of everyday human experience—of first rate importance. This is, above all, a task of representing the denizens of the naive physics, of the mesoscopic objects and of the quantitative reasoning in space and time in general [19], pp. 20 f. By way of addressing this problem, many authors placed great hopes on a variety of new approaches of increasing complexity. Here we shall pass in review four of them.

Set Theory. To this purpose the resources of the naive set theory are widely used. Unfortunately, set theories—of any kind—fail to do justice to the difference between natural totalities, such as dog, and *ad hoc* totalities, such as {Brezhnev, the sun, the sea}.

Mereology. This is the discipline investigating the relation between parts and whole. Unfortunately, as it was noted in the literature, in capacity of formal ontology of the mesocosmic objects, traditional mereology has many deficiencies. For example, it neglects the problems of continua and boundaries which are *sine qua non* when the objective is to represent integral objects of the mesocosmos.

Mereotopology. This motivated attempts—made in the recent years mainly by Roberto Casati, Achille Varzi and Barry Smith—to supplement mereology with topology to a mereotopology. Central concepts of mereotopology are boundary, inside/outside, abutting and surrounding. It is based on a simple mereo-topological primitive of *connected parthood*.

Regrettably, mereotopology fails to present the objects in their full integrity as well. This brings some proponents of mereotopology to the idea to supplement it with at least two other disciplines: (1) morphology: theory of qualitative discontinuants; (2) kinematics and dynamics which explain the behavior of its parts (see [23], p. 439, [24], p. 29). They must help to represent the shape and behavior of objects, as well as the interaction between them.

Theory of Granular Partitions. This new discipline (first developed in [25]) tries to come to terms with the task to represent the results of sorting, classification, dividing into units, count-

ing, parceling out, mapping, listing, pigeonholing, cataloguing. Its models apply different types of partitions—that are appropriate for different situations—in which the objects under scrutiny can be put in. Partitions themselves are not objects.

Our Project. In this paper we advance a new type of formal ontology, which suggests more exact models of the experienced reality (or merely treats it in amore exact, full-fledged terms) than set theory, mereology, mereotopology, and the theory of granular partitions. In particular, stereology is clearly different from the theory of granular partitions, since is sees the objects and processes under scrutiny as constructed *exactly* like their modes—it sees no difference but identity between objects and models. Some authors believe that this badly needed discipline is to be sought at the interface of mereology, topology and measure theory. (see [9] p. 181) In the next pages, we shall follow another direction.

2. WHAT IS STEREOLOGY?

To the best of our knowledge, the term *stereology* was used only once in the literature—in one of the latest papers of C. Lejewski (see [5], pp. 193, 196 f.).[1] In his paper "Ontology: What Next?" [4], this author followed S. Leśniewski's catalogue of the disciplines of being which includes *ontology*, *protothetic* and *mereology*. Roughly, ontology was for Leśniewski the theory of what it is, mereology was a general theory of part–whole relations, and protothetic was a theory of propositions. To these three, in 1982 Lejewski added chronology as the theory of objects distributed and extended in time. In 1986 he attached stereology to them, defining it as "a theory of objects as distributed and extended in space" ([5], p. 196).

In the present essay we are going to develop this idea of Lejewski further, albeit in another format. We, more precisely, shall advance stereology as *formal ontology* cum *logic*; i.e. not as something that superstructures mereology, but as a discipline that is more fundamental than it in the sense that mereology (as well as set theory, mereotopology and the theory of granular partitions) can be put in its terms. Our stereology is also more fundamental than any reist ontology. This means that, and we are going to show this in what follows (in § 4.2), a reist ontology can most comfortably be built on the resources provided by stereology. Finally, our stereology is not

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[1] The term was also used in passing in [21], p. 77.

merely logic of spatial reasoning.[2] Indeed, it is formal ontology of objects that are situated in, what we shall call, logical space[3]—not in geometrical space.

2.1. Stereology as a Formal Ontology of Bulky Individuals

Stereology can be further defined as a formal ontology of substances[4]—or of objects, of integers, in a word, of bulky individuals. Of course, formal ontologies of integral wholes were already advanced in the past (see e.g. [14], pp. 324 ff.). Stereology as theory of integral wholes, however, introduces radically new moments. Above all, it rejects things other than bulky individuals such like relations, etc. It, however, do not reject processes, events and other occurrences, as the reist ontology does.

In order to further elucidate stereology,   we should like to note that it is inspired by some ideas of Wittgenstein's theory of objects as developed in his *Tractatus*. In what measure his theory of objects follows the theory of objects of Franz Brentano, or that of Alexius Meinong, we shall not discuss here.

2.2. Stereology as Modal Formal Ontology

I particular, stereology is a kind of modal formal ontology that discriminates between the *world*, in the meaning of possible worlds, and *reality*:

- the *reality* is the sum total of all objects and constructs that exist now[5] (i.e. states of affairs, complexes, totalities, etc.; from the point of view of stereology, these are one and the same[6]);
- the *world* is the sum total of objects and so of all possible constructs.

Four remarks on this. (1) Constructs are made out of objects (see on this § 3.4). If the objects are the atoms of the world, constructs are its molecules. (2) It is obvious that the sum-total of all constructs of the world are much more in number than the sum total of all constructs in reality. Indeed, the world comprises all constructs of reality and adds to them all possible constructs as well. (3) An important point of stereology is that it considers both objects and constructs as granular objects. As a matter of fact, here we make free use of the theory of granular partitions,

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[2] Such logic is developed in [9a].
[3] A concept first developed in full by Russell and Wittgenstein (see [12], pp. 224 ff.).
[4] Compare with a similar project in [29].
[5] Here we use the terminology of [3], p. 265.
[6] For alternative understanding see, for example, [17].

with the already cited (in § 1) remark that for us, there is no difference between the partitions and the objects that fill them: these are identical. (4) Every object—both simple and complex (e.g. a construct)—has its specific face-boundaries that keep it separate from all other objects. These boundaries are rather like thin layers, not like strings or wire. In other words, the objects can be seen as granular structures or cells.

2.3. Interrelations Between World and Reality

In regard to the world, the following is to be said: (1) Objects build up the world, in the same way in which the building blocks make up the wall. (2) Every possible object contains in itself all properties, tropes, appearances (faces, forms) in (with) which it *can* occur in different constructs (see [25], 2.012). (3) The construct (state of affairs or other occurrent) is identical with the objects that constitute it; more precisely, it is one of their possible transformation (see § 3.6). This means that objects have priority over constructs. (4) An object enters a construct with one of its faces, but as the whole object; this means that the object appears in constructs with this or that particular property of its. The consequence is that in different constructs it appears (participates) differently.

In order to make this understanding of the world clearer, we should remind the reader an old story. Aristotle saw reality as composed of substances which are bearers, or carriers, of accidents (see [19], p. 22). Now, stereology sees the world as composed of bulky, granular objects, which can be interpreted as Aristotelian substances, the faces of which are all their possible accidents—that means, all their possible appearances in different constructs. It, however, does not see accidents as merely *dependent* on substances (as stated ibidem). The accidents are appearances which are substantial ones. Indeed, they present the objects *as* substances. Example: The redness of this apple is substantial to it. If it is green, it will be another apple.

2.4. Picture of Logical Possibilities

We can also see the objects, already defined as granular, and with many (possible) faces (appearances) as implicit, folded up polyhedra (not as spheres, or toruses). The whole world (the space as such), which comprises all the possibilities, can be then seen as having the structure of an implicit honeycomb (see [2]), its cells being the objects (and constructs) with all different faces of theirs. Of course, they cannot be set out in the conventional, three-dimensional space in their explicit form, in which all their faces and possible connections are presented. In the three-dimensional space we can only present reality, which means, all that is the case in

this actual moment. The honeycomb structure of the *world* is only logically possible and thus non-existent. Only the structure of *reality* has the form of a real honeycomb.

This point shows that the world is unfolded in the logical space. The geometrical space and the objects in it can always be thought of as situated in logical space. The reverse, however, is not always the case. We can thought of logical space as purely geometrical; but there are cases (for example, propositional attitudes) in which we can not do this.

Extravagant as it appears *prima facie*, similar conceptions are not without precedents in the history of philosophy. For example, such is the view advanced by Bertrand Russell in his book *Our Knowledge of the External World* [11]. According to this author, there is one physical space–time, with many three dimensional points; the latter, however, are defined as "*assemblage* of data of sensation", i.e. they are not points in the conventional sense of the word. To the latter are related the space–times: (1) of our different senses—which are different from one another; (2) of different persons.

If we paraphrase this understanding of Russell's in terms of our understanding of the relation world–reality, we shall say that there is a one–many relation between the objects in the reality, and these in the (logical) world. To every object of reality, with its three dimensions, there correspond many three dimensional constructs in the world, which, by the way, have the form of granular objects.

3. OBJECTS AND CONSTRUCTS: FURTHER ELUCIDATIONS

After this rather rough picture of stereology was drawn, now we shall try to explicate it in more detail.

3.1. Constructs

Facts, processes, and other constructs in *reality* are nothing but parts of the tip of the iceberg of the so defined (logical) *world* which changes every moment.

We can compare the relation between the world (the "iceberg" of possibilities) and reality (or the iceberg's ever changing tip) or, more precisely, realities, which succeed each other every moment, to the relations in a Rubik's cube which consists of elements that have ever changing surface-configurations[7] (of course, the latter is infinitely more simple than the world/reality rela-

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[7] In truth, the elements of the true Rubic's cube have only two/three of their six sides in play.

tion). This quasi Rubik's cube of the world has its face-side—it corresponds to the reality of this moment; as well as its many implicit sides—these correspond to the world (the possible worlds) which unfold(s) in a series of realities.

Our main point is that the truth-makers, or the occurrents, are not tropes (as claimed in [14a]) but what we have called constructs instead: events, facts, states of affairs. Further, as already noted, constructs are transfigurations and concatenations of groups of objects. So the truth-maker of this smile is not a trope located on this face; rather, it is a construct made out of an appearance of this face, and an appearance of the universal-individual smile.

3.2. Changes and Occurrents

It is clear from the preceding sub-section that stereology sees the change from one reality to another as a new click of a cub of (possible) objects to a new configuration of theirs. In this way, it unites the categories of continuants and occurents into one. To be sure, occurrents (events, facts, processes) are nothing but constructs made out of many (faces of) objects which are continuants par excellence; changes are transformations of one configuration of objects into another.

We can see here how different stereology and reism are. Stereology accepts that there are events, whereas reism denies this. Stereology is not reductionistic, whereas reism is. Stereology does not reject sets or classes; it just claims that for certain purposes—such like knowledge representation—it is more comfortable than set theory. Etc.

3.3. Stereology as Part of the "Modal Turn"[8] in Philosophy

Recently, theories of this type were called "combinatorial theories of possibility". According to such interpretations, "possibility just consists in rearrangement of atomic individuals, properties, and relations [objects, with their accidents, in our terminology,] that have been abstracted from atomic facts [constructs, in our terminology]" [15], pp. 227–8. This conception was also called "modal atomism" (see [1], pp. 12 f.).

3.4. Objects Again

In order to make the stereology project clearer, we shall say some additional words about the objects and the ways in which they are connected.

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[8] See on this conception [3], pp. 268 ff.

An object enters a construct (a complex, a state of affairs, a fact, an event) with one of its (logical) faces; a given (singular) construct connects together only some particular (logical, or possible) faces (properties, appearances) of its objects. The objects that participate into this construct can build another construct with different faces of theirs. This means that in the different constructs in which they take part, the objects are connected in different *ways*, or form different *configurations* (we shall speak on "ways" and "configurations" in § 4.6).

3.5. Connections of Objects: Cheek-to-Cheek

From what we have said so far it is clear that stereology makes it possible to apprehend reality as a constructed formation which has a quasi crystalline character. This formation is reistic in the sense that it is build around bulky, granular (polyhedric) objects that touch one another so that their faces cover one another exactly. There is no void space between its atoms; "no such entities as properties and relations" [16], p. 245 (see also ([10], pp. 71 f.). Further, we accept Wittgenstein's Tractarian view that not only substances but also individual relations and properties are objects (see [27], p. 61; [28], p. 120).

Here we shall add that objects are connected in constructs only through mere contact to one another; in Wittgenstein's words, no "mortar" is needed for this purpose (see [26], p. 23). Objects in the construct keep to one another through their mere touch—neither through some chemical fusion between them (as Frege believed), nor (as Russell believed) because they are build up "like a good-truck which has a hook in front and an eye behind" ([13], p. 86), so that the hook of an object couples on the eye of the next object (as Russell believed). Objects have smooth surfaces—otherwise, they cannot be cohesive to one another.

Further,

- The faces of objects touch one another in such a way that the edges of one face fit exactly its counterpart face;
- There is no vacuum between objects; no relations that connect them, etc.

These two points do at least two things: (1) they explain the already discussed moment that objects' accidents determine all the possible constructs in which can occur objects *per se*; (2) they explain why bulky objects were defined as polyhedra, and not as spheres and toruses—indeed, they have many different faces with which they contact faces of exactly as much different objects.

3.6. Configurations and Ways

The objects in a construct form a *configuration* with other objects: so that every object enters a construct as a part of the configuration of the latter.

This also means that objects enter the construct in a certain *way*. We see the matter here as follows. Since objects are bulky polyhedrons, they are spatial—logically spatial. Besides, objects' definition as substances also indicates that they are qualitatively determined. Now our interpretation is that exactly like the geometrical figures in topology, when entering a particular construct, objects retain their qualitative properties and integrity. In the same time, however, they *transform* (see [15], p. 24) their actual (Aristotelian) accidents (their 'topological spatial properties' (Barry Smith)) to other ones, setting out in this way a new configuration with a new set of objects.

We can also express this point with in words that in different configurations which it forms, an object appears in different ways—i.e. it appears with different accidents (appearances) of its.

4. TWO KINDS OF USE OF STEREOLOGY

Stereology has two different kinds of use. On the one hand, it can be used as a method of seeing and describing (articulating) the objects and events of the world—so as they really are. On the other hand, it can be used in a reductive sense: as supplying *models* for describing (articulating) parts of reality. In this second sense, the importance of the objects–atoms arises from the fact that they are, as Russell used to put this, the "nomenclature of the world". All other things and facts can be presented as composed out of some of these atoms. This means that everything in the world / reality can be viewed in terms of such elements. And exactly the fact that these are qualitatively determined and integral is the advantage of stereology as model-supplier for knowledge representing over the models of set theory, mereology, mereotopology and the theory of granular partitions.

4.1. Stereology as Theory of Concrete Objects

Here is a preliminary example of how stereology can be used as a theory of concrete objects. The horse "Throne", which takes part in this horse-racing, can be grasped as: 3-years old, as the

N. Prize Winner for 2002, of Arab race, etc. These appearances (accidents) can be combined with the appearances (accidents) of all other objects, compatible with this one.

Here are two further examples of how stereology works in this first sense as a theory of concrete objects.

In Language Processing. An example of how the theoretical apparatus of stereology is to be used in the language-processing related problems is given in our paper [8]. First of all, we must chose a particular approach to language which is congruent with stereology, for example, this one. The backbone of language are the collocations: the recurrent combinations of certain words with other words. Further we accept that every natural language can be seen as a sum of its possible collocations. In stereological terms, this means that words are objects (polyhedrons), which have different faces (they are collocable with different words) that come in direct contact with the faces (particular meanings) of other objects (words). Every face corresponds to one of its meanings. Every word can be activated (can take part in the stream of speech) with one of its faces only. One particular collocation is an actualization out of this pool of possible faces of two or more different objects (words).

All of our natural language can be seen as sum of such collocations. Indeed, (1) the free combinations of words can be also seen as collocations. (2) Grammatical connections (colligations) can be seen as collocations too; (3) Even sentences can be seen as collocations—more precisely, as collocations (colligations) of collocations.

The ultimate practical task of this type of stereology is to compose a comprehensive dictionary of collocations/colligations based on corpus-driven linguistics. The achievement of this task will help to offer a full machine coverage of all words, in all their meanings and meaningful combinations.

In Human Anatomy. In recent paper of his (see [13a]), Rainer Schubert interprets parts of Spatial Anatomy in the common-sense language of objects exactly in the sense of our stereology. For this purpose, this author makes use of, among other things, these two operations: "Ontological Zooming" and "Ontological Shifting" (called so by Barry Smith).

4.2. Stereology as Giving Models

Stereology can be also interpreted as similar to Newton's mechanics, as understood by Wittgenstein in his *Tractatus*, which sees the world trough a net with sufficiently small meshes; the latter are of contingent form. As we are going to see in what follows, however, stereology's models have not the form of nets, neither are they with a form of a lattice, nor of a grid,

nor of graphs. They are complex configurations which have the form of solid objects that are piled one over the other, similarly to the cells of a honeycomb, these cells constantly changing their positions and neighbors, at that.

In short, stereology suggests three-dimensional models of the objects, processes, scenes, etc. of reality. Indeed, the same does set theory. Unfortunately, its models are too abstract. As already noted in § 1, something better does mereology (for a paradigm statement of its point see [10]), and even better mereotopology (for best statement of its point see [18], [23], and [24]) and the theory of granular partitions. My motive to develop the new formal ontology of stereology is that it suggests most adequate models of the objects and processes of reality.

The advantage of stereology as giving models consists in that it analyses the objects, scenes and processes of reality to elementary objects, every one of which of three dimensions. Out of this pool of possibilities, and without to introduce new elements in it, ever different models can be constructed—the type of the models depends solely on our cognitive interests. These models avoid some crucial disadvantages of the models suggested by set theory, mereology, mereotopology and the theory of granular partitions—they represent the objects in their integrity, shape, behavior and interchange.

In this sense stereology is a discipline that sees all situations, events, processes in terms of figurative individuals with three dimensions,[9] and nothing beyond them. The use of this approach is demonstrated by the new developments in the applied sciences. In medicine, for example, the employ of three dimensional screening led to revolutionary changes. The same with the geographical representing: The old two-dimensional maps give place to three-dimensional exact models of parts of reality.

4.3. Two Types of Modeling Stereology

We can imagine two types of modeling stereology which we can call, relating them to formal and material implication, material and formal stereology.

Formal Stereology. This type of formal ontology can help to present (to model) any situation, or process, of the micro-, meso-, and macro-world in three dimensions. As a matter of fact, this approach is applied for a long time in cases where processes and scenes—e.g., a music performance—are represented with the help of a diagram of three dimensions.

Operations of this type are possible because every occurrent (process or scene) can be transformed in terms of material bodies, which have three dimensions. The point is that, as Peter

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[9] In the idiom of Roderick Chisholm, in terms of "spatial individuals" which are "filled by qualities" [14], p. 536.

Strawson has shown this long ago (see [22], 38 ff.), material bodies are the basic individuals in the sense that any identifiable individual can be put in a unique relation to (not reduced to) such items. This explains why processes and scenes, of most different level, have three dimensions with necessity. So sounds have timbre, pitch and laudness (see, ibid., p. 75), colors have brightness, saturation and hue. Etc.

Material Stereology. We can also see the reality of here and now, i.e. the world of the meso-cosmic objects (but also of the macro-cosmic and micro-cosmic objects), as composed of elementary objects which touch one another, and nothing beyond them. In this way, we should present every occurrent or continuant as constructed similarly to a model of stereology.

The task here is to see all situations that we need to represent in three dimensions. Apparently, this task points in reverse to a tendency in mathematics of the nineteenth century (Bolzano, Cauchy, Weierstrass, Dedekind and Cantor) which had one objective: to ban the intuition from mathematics and logic (see [2a]). In contrast, material Stereology has this motto: "Whenever possible, make use of intuitive models in order to see how the matters that are to be represented really run."

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