Framing ontology

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Ouverture

In the past seven or eight years, a considerable interest in ontology has developed. Some data (up to 1997) may be of help in understandind the phenomenon.

Conferences:

- *Linguistic instruments in knowledge engineering*, Tilburg 1991;
- *Knowledge sharing and reuse*, ECAI'92, Vienna 1992;
- *International workshop on formal ontology in conceptual analysis and knowledge representation*, Padua 1993;
- *Knowledge sharing and information interchange*, IJCAI'93, Chambery 1993;
- *Parts and wholes: conceptual part-whole relations and formal mereology*, ECAI'94, Amsterdam 1994;
- *Comparing implemented ontologies*, ECAI'94, Amsterdam 1994;
- *Planning ontology kickoff meeting*, Washington 1994,
- *Cognitive and ontological foundations of knowledge engineering*, Buffalo 1994;
- *ARPA ontology workshop*, San Diego 1994;
- *Building and sharing very large knowledge bases*, 1995;
- *Workshop on basic ontological issues in knowledge sharing*, IJCAI-95, Montreal 1995;
- *Banff conference on knowledge acquisition*, 1995;
- *KAW96 Track on shareable and reusable ontologies*, Banff 1996;
- *ECAI96 Workshop ontological engineering*, Budapest 1996;
- *AAAI Spring symposium on ontological engineering*, Stanford 1997;
- *IJCAI'97 Workshop – Ontologoy and multilingual NLP*, Nagoja 1997;
- *Categories: Ontological perspectives in knowledge representation* (*Bisca*-97), Bolzano 1997.

Internet sites:

- http://mnemosyne.itc.it:1024/ontology.html
- http://saussure.irmkant.rm.cnr.it/web_on
- http://www.cs.utexas.edu/users/mfbk/related.html
- http://ksl.stanford.edu/knowledge-sharing/ontolingua/ontolingua.html
- http://www.medg.lcs.mit.edu/top/
- http://wings.buffalo.edu/academic/department/philosophy/ontology/
- http://wave.eecs.wsu.edu/WAVE/Ontologies/ontologies.html
- http://www.cyc.com/
- http://www.cs.adelaide.edu.au:80/~peirce/
- http://dc.isx.com/I3/
- http://www.darmstadt.qmd.de/publish/komet/gen-um/newUM.html
- http://crl.nmsu.edu/users/mahesh/onto-intro-page.html

Special issues of journals:
International Journal of Human-Computer Studies:

- Guarino and Poli (1995), *The role of formal ontology in the information technology*
- Schreiber and Birmingham (1996), *The Sisyphus-VT initiative*
- Gaines (1997), *Using explicit ontologies in knowledge-based system development*

Ontology is explicitly declared to be helpful in:

- General issues in knowledge representation (Hobbs 1985, Hirst 1989, Skuce and Monarch 1989, Guarino and Boldrin 1992b, Clancey 1993, Guarino, Carrara and Giaretta 1994, Cocchiarella 1995, Guarino 1994, Wielinga *et al.* 1994, Gangemi, Poli and Steve 1995, Guarino 1995, Guarino and Giaretta 1995, Hobbs 1995, Lehmann 1995, Schreiber, Wielinga and Jansweijer 1995, Sowa 1995, Poli 1996, Guarino 1997).
- Knowledge acquisition (Alexander *et al*. 1986, Monarch and Nirenburg 1987, Paton *et al*. 1991, Wimmer and Wimmer 1992, Anjewierden, Shadbolt and Wielinga 1992, Eriksson, Puerta and Musen 1994, van Heijst and Schreiber 1994, Mahes and Wilson 1995).
- Knowledge sharing and integration (Neches *et al.* 1991, Neches, Fiches and Finin 1991, Allen and Lehrer 1992, Genesereth 1992, Gruber, Tenenbaum and Weber 1992, Musen 1992, Patil et al. 1992, Walther, Eriksson and Musen 1992, Guarino and Boldrin 1992a, Gruber 1993, Cutkosky et al. 1993, Pirlein and Studer 1995, Mizoguchi 1994, Goldstein and Esterline 1995, Gruber 1995, Lenat 1995, Gangemi, Steve and Rossi Mori 1995, Gangemi, Steve and Giacomelli 1996, Steve, Gangemi and Rossi Mori 1996).
- Knowledge reuse (Wielinga and Schreiber 1993, Dowell, Stephens and Bonnell 1995, Pirlein and Studer 1995, Gruber and Olsen 1996, Rothenfluh *et al.* 1996, Schreiber and Terpstra 1996, Yost 1996).
- Problem-solving methods (Steels 1990, Musen 1992, Walther *et al.* 1992, Ericsson, Puerta and Musen 1994, Mizoguchi, Vanwelkenhuysen and Ikeda 1995, Tu *et al*. 1995).
- Software specification (Gruber 1991).
- Ontology engineering (Uschold and King 1995, Zarri 1995, Mizoguchi and Ikeda 1996, Uschold and Gruninger 1996).
- Object-oriented database design (Wand and Weber 1990, Takagaki 1990, Takagaki and Wand, 1991, Bonfatti and Pazzi 1991 and 1995, Graham 1991, Petitot 1995, ter Stal, van der Vet and Mars 1995).
- Portability issues (Genesereth and Fikes 1992, Gruber 1993).
- Natural language understanding and machine translation (Hobbs *et al*. 1987, Bateman *et al*. 1990, Lang 1991, Powers 1991, Bateman 1992, Klose, Lang and Pirlein, 1992, Knight 1993, Bateman 1993, Dölling 1995, Dahlgren 1995, Nirenburg, Raskin and Onyshkevych 1995, Mahes 1995, Catarsi 1995).
- Enterprise integration and engineering models (Kiriyama *et al*. 1989, Petrie 1992, Alberts 1993, Fox 1993, Top and Akkermans 1994).
- Common-sense reality (Hobbs and Moore 1985, Davis 1990, Stefik and Smoliar 1993, Smith 1995).
- Part-whole theories (Markowitz, Nutter and Evens 1992, Zadrozny and Kim 1993, Eschenbach, Habel and Smith 1994, Guarino, Pribbenow and Vieu 1994, Eschenbach 1995, Gerstl and Pribbenow 1995, Poli 1995, Artale *et al*. 1996, Pazzi 1996).
- Matter, space, time and causality modelling (Moens and Steedman 1988, Cohn, Randell and Cui 1995, Borgo, Guarino and Masolo 1995, 1996a and 1996b, Terenziani 1995, Kitamura, Ikeda and Mizoguchi 1996a and 1996b).
- Medical knowledge modelling (Abu-Hanna, Benjamins and Jansweijter 1991, Steve and Gangemi 1994, Abu-Hanna 1994, Falasconi and Stefanelli 1994, Gangemi, Steve and Rossi Mori 1995, Sim and Rennels 1995, Steve, Gangemi and Rossi Mori 1995, Tu *et al*. 1995, van Heijst *et al*. 1995, Steve and Gangemi 1996).
- Legal knowledge modelling (Kurematsu, Tada and Yamaguchi 1995).

From this welter of information we can conclude that there is a burgeoning KR research community which is opening up new avenues for research and undertaking important new projects.

However, this interest may easily dwindle or end up in a blind alley unless at least three problems are addressed very seriously:

- what are the boundaries of ontology; that is, what problems are ontological (rather than, say, epistemological, logical or linguistic, etc.)?
- what is the structure of an ontology?
- and who knows something about it?

On considering these problems, one notes immediately that the research community which has recently formed around the label ‘ontology’ is somewhat reticent on such matters. There seems to be general suspicion of something that may create innumerable problems; a suspicion, as we shall see, that is well-founded. On the other hand, whatever conclusions we may reach, it is unreasonable to address a scientific (and technological) problem without marking out its boundaries, without analysing its structure, and without listening to those who know something about it.

Before dealing with the above questions, I must clear the field of a further problem. The term ‘ontology’ is used with a wide variety of meanings, some of which seem merely to attach a new label to areas of inquiry that are already well delimited and consolidated. In these cases, by ‘ontology’ is meant no more than 'reference domain’ or ‘context’, without anything new being added to what usually goes by the name of ‘semantics’. I shall not be dealing with semantic problems in this work and consequently shall not be considering ontology in this sense. Let us now examine some other definitions of ontology.

Some definitions given in recent papers claim that ontology is

- a collection of general top-layer categories and associated relations and assumptions (Skuce and Monarch 1989).
- a formal description of the objects in the world (Musen 1992)
- an explicit specification of a conceptualization (Gruber 1993)
- a meta-layer theory (ontology as a viewpoint) (Wielinga *et al*. 1994)
- a world model (Mahesh and Nirenburg 1995)
- the content of logical pure forms (Sowa 1995)
- a declarative model of the terms and relationships in a domain (Eriksson, Puerta and Musen 1994).

Instead of discussing all the above definitions, I shall proceed by listing some criteria and by classifying the several items accordingly (for a different discussion, see Guarino and Giaretta 1995).

The classification of the various proposals will be organized on the basis of two oppositions whereby ontology is either scientific research (1) *oriented towards objects* or *oriented towards our concepts* (of objects), or (2) either *domain dependent* or *domain independent*.

The opposition between orientation towards objects and orientation towards concepts mirrors the difference between the two main senses in which ontology is understood in philosophy (that is, the Aristotelian and Kantian viewpoints respectively). In order to avoid confusions I would prefer to say that the two orientations mirror the distinction between what may be properly called ontology and what is usually called epistemology.

Ontology proper is characterized by an orientation towards objects. This amounts to saying that the main concern of ontology is the world in its many facets. Ontology models objects by resorting to concepts. It *uses* concepts. Analysis of the structure and of the formal and material components of the concepts we use to shape the world is the concern of a different discipline, not a problem for ontology. In fact, it is epistemology that covers the field of the theory of concepts.

The second of the above two oppositions (that between domain dependent and domain independent ontologies) determines the possibility of elaborating a general ontology. By definition, general ontology can only be domain independent. Otherwise it would simply be impossible to ask ourselves: “What ontological categories would make up an adequate set for carving up the universe? How are they related?” (Guha and Lenat 1990, xvii). It is clear that if (general) ontology provides a collection of general top-layer categories, an ontology is domain-independent (Pirlein and Studer 1995, 945). The opposite thesis, which claims that ontology is always and only domain dependent, amounts to saying that general ontology is a dream, something that cannot be the object of serious research.

The two oppositions taken together display a core general ontology. This core ontology is therefore oriented towards objects, and it is domain-independent. As an obvious corollary, the most spurious ontology will instead be oriented towards concepts and will be domain dependent. In between there lie the two intermediate cases.

We can now move to analysis of the definitions listed above. The result is presented in Table 1.

TABLE 1

Legend: O = Oriented towards objects; C = Oriented towards concepts;
D = Domain Dependent; I = Domain Independent

Skuce and Monarch (1989)	O	I	
Mahes and Nirenburg (1995)	O	I	
Musen (1992)		O	I
Sowa (1995)		C	I
Gruber (1993)		C	D
Eriksson, Puerta and Musen (1994)	C	D	
Wielinga *et al*. (1994)		C	D

Providing that the various positions have been correctly interpreted, it follows from our analysis that the perspectives elaborated by Skuce and Monarch (1989), Mahes and Nirenburg (1995) and Musen (1992) appear to be suitable candidates for the elaboration of a core (general) ontology. On the other hand, it is also clear that definitions are important starting points, although they are not the last word on the matter. We must look at the real work that effectively developed on their basis, and for this more complex analysis more thorough development must be given to the idea of ontology.

Our problem therefore is (i) to trace the boundaries of ontology, (ii) to present its structure, and (iii) to find the scientific communities that have the pertinent expertise . The definitions of interest to us here, can be summed up as follows: ONTOLOGY IS THE THEORY OF OBJECTS. And it is so of every type of object, concrete and abstract, existent and non-existent, real and ideal. Whatever objects we are or might be dealing with, ontology is their theory (Meinong 1960, Husserl 1970, Whitehead 1925).

The boundaries of ontology

Ontological information should be distinguished both from epistemological information and from quasi-ontological information.

ONTOLOGICAL VS. EPISTEMOLOGICAL INFORMATION

Defining the tasks and characteristics of ontology is important if we are to avoid confusion with epistemology; confusion that is often apparent in the literature. The difference can be evidenced by listing concepts of ontology and epistemology. Ontological concepts are: object, process, particular, individual, whole, part, event, property, quality, state, etc. Epistemological concepts are: belief, knowledge, uncertain knowledge, revision of knowledge, wrong knowledge, etc.

If ontology is the theory of the structures of objects, epistemology is the theory of the different kinds of knowledge and the ways in which it is used.

A much debated problem is whether domain knowledge can be represented independently of the way in which it is used in reasoning. In AI Clancey and Letsinger (1984) claim that both domain knowledge and problem-solving knowledge can be reused (provided the two kinds of knowledge are represented separately in the knowledge base), while Bylander and Chandrasekaran (1988) argue in favour of the opposite thesis. The main argument developed by Bylander and Chandrasekaran is the so-called interaction problem, which can be summed up by saying that “representing knowledge for the purpose of solving some problem is strongly affected by the nature of the problem and the inference strategy to be applied to the problem”.

I think that their diagnosis is correct; but the conclusions are wrong. The fact that there is a mutual or bilateral form of dependence between ontology and epistemology does not oblige us to conclude that we cannot represent their specific properties and characteristics separately. On the contrary, we should specify both what ontology can say about epistemology (a belief is a kind of object, it has parts and properties, etc.), and what epistemology can say about ontology (knowledge of the structure of objects is a kind of knowledge). This is a difficult task and mistakes are always possible, but there is no principled reason for denying its realizability, even if one understands why it is so easy to blur ontological and epistemological issues.

The ontological and epistemological perspectives interweave and condition each other in complex ways. They are not easily separable, amongst other things because they are procedures complementary to each other.

A further difference – similar but not identical to that between ontology and epistemology – is the difference between an ontological reading and an epistemological one.

Consider the sentence:

(i) Napoleon was the first emperor of France.

Its formal reading is:

(ii) Somebody was a something somewhere.

From a cognitive point of view, (i) may mean for instance that

(iii) The man portrayed by David in the likeness of a Roman Caesar was the first emperor of France (Ushenko 1958).

(ii) clearly does not imply (iii), whereas (iii) does imply (ii). In general, it is always possible to develop many different cognitive readings of the same sentence. These various readings depend on the information that is implicitly or explicitly added. If we do not add new information, the reading (iii) above is unjustified because the sentence (i) does not entail the information that Napoleon was portrayed by David.

In general, (ii) (the purely formal reading) is too poor; it is general but it says too little. On the other hand, (iii) is too strong, it is not sufficiently general and it depends on added information. The real difficulty for the ontological reading is that it lies somewhere in between. It is more than the purely logical reading and it less than the many different cognitive integrations.

The truly ontological viewpoint manifests the many facets of the object. It says not only that somebody was something somewhere, but that he performed an important institutional role (in fact the most important one) in some specific part of Europe, and it says that he was the first to perform that role. It says, moreover, that he was a human being and for this reason that he had a body and a mind, that he was alive, etc.

There is a myriad of information embedded in the sentence "Napoleon was the first emperor of France". The ontological reading should be able to extract and organise this information without resorting to any external source of knowledge.

Quasi-Ontological Information

Ontology does not say everything that there is to say about every aspect of the world. Besides the distinction between ontological and epistemological analysis, a further distinction must be drawn between properly ontological information and quasi-ontological information.

Ontology should be able to say that a certain object is situated somewhere, or that an event has taken place at a certain moment. But it does not have to say these things using the Gregorian calendar or a particular system of coordinates. We choose a system of measurement for every magnitude, but which system is chosen is purely a matter of convention, and the relative module should be substitutable if for some reason it becomes necessary to use some other system of reference (with appropriate adjustments).

The same applies to many other aspects of design. Somewhere there will be a module in which the ontology is calibrated to the measurement systems employed, and to such other purely pragmatic aspects as the language of the user interface. Likewise, there must be a place in which naturals, connectives, some functions, and so on, are imported. But which particular version is used is not an explicitly ontological problem.

A further quasi-ontological category consists of what I call 'signature'. This categories furnishes information on who has made the categorization, where, when and how. Such information is not always relevant, but there are some contexts in which it is important: in medicine, for example, it is sometimes vital to know who has made a diagnosis.

Aspects of this kind perform a role internally to a fully developed ontology, but they are not directly ontological components.

Before concluding this section, let me stress that, even if the range of ontological analysis is extremely wide, we should not interpret ontology as the science of everything from every point of view. There are many genuine problems that are not ontological problems. We should find a way to distinguish ontology from other scientific viewpoints. That is to say, ontology proper is not commonsense analysis, or linguistic analysis or logical analysis. It is not the theory of concepts, nor is it the theory of beliefs or of other mental attitudes. It is connected to all of them, but it is nevertheless different from them.

The Structure of Ontology

In this section I will try to give a feeling of the highly complex structure of ontology. The first step is to distinguish between the categories that enable us to analyse the *inner structure* of objects and the categories that enable us to classify the *external structure* of objects on the other.

INTERNAL CATEGORIES AND STRATA OF REALITY

The unity of the world is the outcome of the complex interweaving of dependence connections and forms of independence among the many objects of which it is composed. I shall seek to explain the features of this multiplicity by beginning with an apparently banal question: what is there in the world?

Numerous answers are available. For example, we may say that there are material things, plants and animals, as well as the products of the talents and activities of animals and humans in the world. This first prosaic list already indicates that the world comprises not only things, animate or inanimate, but also activities and processes and the products that derive from them.

It is likewise difficult to deny that there are thoughts, sensations and decisions, and the entire spectrum of mental activities. Just as one is compelled to admit that there are laws and rules, languages, societies and customs.

We can set about organizing this list of objects by saying that there are *independent objects* that may be *concrete* (mountains, trees, flowers, animals, houses and tables), or *abstract* (sets and other mathematical objects, propositions), and *dependent objects* which in turn may be *concrete* (colours and sounds, kisses, handshakes and falls) or *abstract* (formal properties and relations).

All these are in various respects objects of the world. Some of them are actually exemplified in the world in which we live; others have been exemplified in the past; and yet others will (hopefully) be exemplified in the future. Consequently temporality is the truly distinctive (specific) feature of reality (Brentano 1995, Husserl 1970, Hartmann 1963), and we may state that reality is everything that is located in time. Whatever the entities considered, they are real if they are temporally characterized. This first finding already tells us that the natural inclination to regard space and time as equally fundamental aspects of the real world is, from an ontological point of view, inexact. Ontologically, space characterizes only certain entities, namely material ones. But there are many other entities that are not spatial: mental acts, for instance.

It is widely claimed that the mode of being of material things cannot be the same as that of thoughts, actions, states of mind or intuitions. On this view, truth and error are mixed because, as we have seen, to be real does not entail possession of materiality. Only things and living beings are spatial, while, as well as these, the events of the mind and social events are temporal.

Having established this, forms of dependence and independence operate among the various types of reality. In fact, the universal glue of any whatever articulated ontology is provided by the network of dependencies among its objects. We may distinguish at least three ontological strata of the real world: the material, the psychological and the social (Hartmann 1935, Husserl 1989).

Specific forms of categorial and existential dependence exist among these strata. For example: a psychological object or event requires an animate physical object as its existential bearer. Should there be no person (and should there be no body of some such person), then neither will there be the correlative psychological states. Hypothesising forms of *existential dependence* does not entail resorting to more or less overt hypotheses of *reductionism*. The various ontological strata may be *existentially constrained* without this implying that they are *categorially constrained*. The categories or properties which enable us to describe the world of psychological states are different from the categories that enable us to describe the world of animate and inanimate objects.

A relationship of matter and form holds among many objects. In these cases, matter and form are correlative categories, so that any form may be the matter of a higher form, and any matter may be the form of a lower matter. The hierarchy thus constituted is a progressive overforming of matter and form. The nature of the physical world is clearly governed by this embedding principle: the atom is the matter of the molecule, but it is already an entity endowed with form; the molecule is the matter of the cell; the cell is the matter of the multi-cellular organism; and so on.

In the matter/form relationship, matter is a constitutive part of the object that results from it. The atom is part of the molecule, and the molecule is part of the cell. If we possessed the equipment, we could dissect cells to reveal molecules, and molecules to reveal atoms.

However, not all the dependences that structure the world are of a matter/form type. When one moves from the organic to the mental plane, one finds a dependence relation that is not reducible to the matter/form relation. One cannot say, in fact, that atoms or cells or organisms are the matter of the mind. Organic reality takes atoms and molecules and assembles them into a new form, consciousness, which is nevertheless not made up of organic forms. In the passage from the material to the mental there arises a *new* series of forms whereby corporeal life with its forms and processes no longer functions as matter. The organic layers are mirrored in psychic life: they influence it, they follow close upon it, but *they are not part of it* (Hartmann 1933). In effect, the life of the mind is not an overforming of corporeal life. It does not comprise organic processes, nor does it use them as its building blocks, even though it is supported by them and is influenced by them.

One finds another break between the mental stratum and the social stratum. Mental acts do not constitute the objective contents of social reality, just as organic elements do not form part of the mind. In both the passage from living to mental phenomena, and in the passage from mental to social ones, the series of overformings is interrupted. In these cases the dependence relationship is no longer of matter/form type but becomes one of a completely different kind: a bearer/borne relationship. In this case, the substratum of the higher layer is not the matter of the lower layer (Hartmann 1952, 68-69).

Analysis of the dependences among objects therefore requires us to distinguish at least two fundamental relationships: that among the layers and that among the strata of reality.

It may be thought that the distinction between strata and layers is unnecessary. In general, and in the absence of precise arguments claiming the opposite, I am on the Meinongian side: between two people (or two traditions) one of whom (or which) makes a distinction and the other does not, it is usually the case that the one who introduces the distinction has seen something that the other has not (Meinong 1921, see also Mulligan 1986 and Poli 1993/94).

A terminological note may be of use here. For the sake of clarity, I shall say that overforming relationships hold among ontological *layers*, while building-above relationships hold among ontological *strata*. Whereas by ‘overforming’ is meant that every category can constitute the ‘matter’ of a higher category, the term ‘building-above’ denotes a very different type of conditioning. In this case, the higher stratum requires the lower one only as its *external basis of existential support*, but not as matter to be supraformed.

TABLE 2

English term	Hartmann’s	relation	form of dependence

	German term	between	
overforming	Überformung	layers	matter/form
building-above	Überbauung	strata	bearer/borne

As we have seen, the ascending hierarchy of forms does not unfold without interruptions. It does not traverse the entire real world in a continuous sweep. On the contrary, there are (at least) two particular points at which the overforming process is interrupted.

Aristotle was right to stress the importance of the relationship between matter and form. His theory is still today substantially acceptable, if one remains within a particular ontological stratum. But it requires adjustment and development as soon as one considers the various strata of reality. In this case the matter/form relationship is inadequate and should be replaced with the bearer/borne relationship.

The above description of the building-above relationship therefore enables us to state that there exist at least three different strata of reality. Of these strata, that of material reality (both inanimate and animate) acts as the bearer for the other two strata. The material stratum bears the stratum of mental phenomena. Material and mind are the bearers of the stratum of social phenomena. Belonging to the social stratum are all phenomena of communication, and therefore the complex of social phenomena and customs, economic and legal realities, history, language, science, technology and the body of knowledge of every epoch, and morals. That the social stratum differs from those of material and the mind, and that its categories are not reducible to those of these strata, should be obvious.

Each stratum has its own principles, laws and categories. The nature of one stratum cannot be understood using the categories of another.

The dependence relationship among strata tells us that there are never minds without material bearers, and that there are never social phenomena without material and mental bearers. In further specification of the difference between overforming and building-above, one notes that if the world were structured by a single overforming relationship, the mind and the social would be made up of atoms, they would possess weight, and so on. Or we would have to say that mental and the social life 'contain' the organism (Hartmann 1933). The absurdity of these consequences suffices to highlight the difference between overforming and building-above.

Specific overforming relations organize the various layers distinguishable internally to each stratum. The forms assumed by this overforming are specific to each stratum and cannot be ingenuously generalized. In the material stratum, the overforming is mainly serial. The atom-molecule-cell example is sufficiently clear, but one should also remember the side-branches: man is an animal but not a plant.

The mental and social strata exhibit overforming mechanisms which are much more intricate than those that operate in the material stratum. In the case of the social stratum, the various layers constitute a community of contexts with numerous complex relations of dependence and reciprocal influence.

On the other hand, this segmentation into strata and layers gives rise to a different patterning of complexity in objects. Higher strata and layers *may* be less complex than lower strata and layers. Indeed, it is not always true that when one moves to a higher layer, the complexity increases.

Recent developments in systems theory seemingly provide important confirmation of Hartmann's theory of building-above relationships. I cite by way of example the theory of autopoiesis and its development in terms of social systems theory by Luhmann (1984).

Description of the strata and layers of reality intersects with description of the objects of which it is composed. We humans participate in all three strata (although we do not exhaust the multiplicity of any of them). We have a material (organic) base, we have a mind, and we are simultaneously social beings. But our material base is one of the many material bases offered by the natural world; just as our mind is only one possible mind, and our participation in the social world is never such that we can absorb it in all its aspects. For example, no individual possesses complete and absolute mastery of his or her mother tongue.

The stratified organization of reality should not be confused with the problem of the parts of a whole, and whether all the parts of a whole are of the same nature as the whole. Material objects may have non-material parts (for example, their centre of gravity). But the strata of an object are not parts of the whole.

TOP CATEGORIES

The top categories employed by a well developed ontology derive from the category 'object', and they themselves are objects. Each of them corresponds to the traditional concept of 'being' or 'entity', but each of them forms a particular context of analysis. As with the ancient analysis of transcendentals, it is always possible to pass from context to another, but each context has its own specificity.

The analysis of strata and layers has shed light on some fundamental aspects of the organization of reality, but it does not enable us to pass directly to objects. The various strata of reality, in fact, do not coincide with the gradations of existent entities, although they intersect with them. They are not only strata of the real world understood as a whole, but also strata of things themselves.

Whatever object we may wish to model, it is always something which exists somewhere in time and which is made of some material or is the bearer of some material.

OBJECT

I have repeatedly pointed out that I employ 'object' as a generic term. This is proper, but it is not enough. In order to bring out the actual semantic value of 'object' one must also assume that objects are always 'complex objects'. In other words, we must assume the ontological thesis that all objects are complex (the anti-atomicity argument). As Hacking states, "Logic, depth grammar, structuralism, and the like should postulate points of convergence or condensation, not atoms" (Hacking 1994, 30). To take up and generalize a remark by Bohm, we should "give up altogether the notion that the world is constituted of basic objects or 'building blocks'. Rather, one has to view the world in terms of universal flux of events and processes" (Bohm 1994, 9). Simple objects are idealizations relative only to the realm of abstract objects.

The assumption of anti-atomicity entails a number of important consequences.

Firstly, every object, precisely because it is complex, is a whole with parts (both as components and as functional parts). The complexity of the object also determines the fact that the parts of the object interact with each other according to various kinds of dependence internal to the object. This means that an object has a structure and consequently structural stability. But this is not enough. If objects are complex, it is natural to distinguish an *interior* from an *exterior* (environment) and to posit the presence of a *frontier* (boundary) between them.

Secondly, an object, besides being a whole with parts, is also a substance with determinations. These determinations tell us what the object is, in the various ways that this can be stated (for example, both that 'it is_white' and 'it is_an_animal'). Its substance consists of whatever underlies and unifies the various determinations.

A third aspect concerns the complexity of those objects which are structured into several layers (material, biological, etc.). In this case, we must not confuse the part-whole and substance-determination structurings with structuring by strata and layers.

Fourthly, the object "is *something on which one can have a perspective* (Smith 1996, 117). This in turn entails that "*the presence of an object inherently involves its absence*. The reason is simply the standard one: in order for a subject to take an object as an object, there must be separation between them – enough separation to make room for intrinsic acts of abstraction, of detachment, of stabilization. So it is essentially an ontological theorem that no object, for any given subject, will be wholly *there,* in the sense of being fully effectively accessible. Or to put it more carefully: in order to be present, ontologically – i.e., in order to be *actually* present – an object must also be (at least partially) *absent*, metaphysically, in the sense of being partly out of effective reach (Smith 1996, 232-233; I have used 'actually' for Smith's 'materially').

Generally speaking, all represented objects are intrinsically incomplete objects, and this is because every represented objected is intrinsically connected to a specific perspective. The objectivity of the object is the aspect which stabilizes the situation by systematically coordinating possible perspectives with the so-called perspective 'from nowhere'.

PROCESS

Whatever exists in space-time has temporal and spatial extension. Everything said in the last section about the category 'object' must now be repeated about the category 'process'. From my point of view, the categories 'object' and 'process' are equivalent, so that the following phrase from Uexküll quoted by Lorenz (1973) chimes perfectly with my position: "an object is that which moves together".

The only difference between object and process is that, in relation to the categorizing actor, the apparent constancy of objects stems from the fact that the object changes much more slowly than the subject. As Hartmann (1933) points out, what we call a 'thing' is only a stage of *relative stability* within a process.

Like objects, all real processes – i.e. all processes able to exert some influence – possess some degree of stability (Thom 1972). From what has just been said, however, it is clear that 'stable' "does not mean static or atemporal!" (Smith 1996, 258). Everything that is dynamically real is partially stable, and consequently also potentially unstable because stability is always stability relative to the interior of the everchanging universal flux.

Like all the other categories, also the category of 'process' imports its typical structures into ontology. In this case we have the various stages typical of every process, which consist at minimum of the initial stage of the beginning, the stage of 'presence', and the final stage of the end.

PARTICULAR

Most ontological theories begin with the opposition between particulars and generals (universals). The fundamental tension between particularity and generality resides in the fact everything that is spatio-temporally constrained is particular (concrete), while everything that we conceive in thought is general (abstract).

One effective resolution of these difficulties necessarily starts from a context of analysis which explicitly considers the actors involved. Categorization requires two realities: the world to be categorized, and the 'part' of the world that does the categorization. Generally speaking, we can reconstruct the categorization procedure by coupling a substrate space (the one to be categorized) with a black box which records and processes the signals emanating from the substrate space. The black box segments the substrate space into basins and relative attractors, which we may call categories (see Petitot 1985 for formal details). From this point of view, *everything* that constitutes or originally exists in the substrate space can be particular, without this requiring that the categories themselves are particulars. Conversely, the categories may be general without this entailing that the objects of the substrate space are general as well.

INDIVIDUAL

Orthogonal to the opposition between particular and general is the difference between individual and non-individual (Smith 1996, 124). Some, but not all, objects are also individuals: all abstracts and some concretes are such. Leaving the case of abstracts aside, this means that not everything in the world is individual. Among concretes, in fact, besides individuals we must also consider masses and features: which means that the extension of the category individual is less than that of the categories object, process or particular.

The difference between individual and non-individual objects can be stated as follows: "Individuality is what allows one to say of one object that it is one; of two, that they are two ... Because they are discrete, ... individuals support a notion of half, as well as of two. Unlike water, if you put individual and individual together, you get two individuals, not just more. By the same token, if you take an individual apart, you get parts or fragments, not just less" (Smith 1996, 119-120). The fundamental difference, therefore, is between objects which admit to the operations '1-2' or '1-½' on the one hand, and objects which follow the 'more' or 'less' logic on the other.

Masses, however, are not the only examples of non-individual particulars. Another one is provided by what Strawson (1959) calls 'feature'. A feature is a local property without being the property of any object. Consider statements like 'it is foggy' or 'it is raining'. These refer to a particular situation, but they do not refer to any discrete object as the substrate of that property. What is it that is foggy or raining? What does 'it' refer to? The only plausible answer is 'the world' or some pertinent 'fragment' of it. It is the world (or some non-individual fragment of it) that is foggy or raining, not this or that individual in it.

Since 'fog' or 'rain' are not predicated of any individual, they are not properties. It is advisable, following Smith, to reserve the term 'property' for qualities that require individuals, the term 'feature' for things that do not. We must therefore distinguish between "that do and do not require *individuals* for their exemplification" (Smith 1996, 126).

Two consequences ensue. First, "there is no reason to suppose that a lack of precise boundary, or the existence of an intermediate grey area, need undermine the distinction between particularity and individuality" (Smith 1996, 128). Second, "physics sustains a basic notion of particularity, but not of individuality" (Smith 1996, 155).

SUBSTANCE AND DETERMINATION

As we have seen, the principal category of reality is the category of 'process'. 'Process' has two natural complements: (1) state and (2) substance.

By 'state' is meant the counterpart of process at any given moment (Werkmeister 1990, 105). "If 'process' is a category of what is real, then 'state' or situation must also be a category, for in every process there are 'states'" (Werkmeister 1990, 110). This gives rise to two consequences which should be spelled out in full: (1) "the mere succession of states ... is not yet a process. It is a process only when the states in succession are related by a transition from one into another" (Werkmeister 1990, 111); (2) The fundamental relationship of process and state gives rise to the conception of 'dynamic structures' (Werkmeister 1990, 105).

'Substance' is what remains identical in the continuous series of interrelated changes constituting the process,. Hence, "substance does not lie outside process but is in it as that which perseveres" (Werkmeister 1990, 106).

Since the substance is what remains constant *in* the process, it is essential to understand that the substance is *functionally dependent* on the process. Given a process that enjoys some minimal condition of stability, we may assume that there is something constant within it and we may seek to analyse and describe this something constant within the process.

From the point of view of classical Aristotelian metaphysics, the theory of substance concerns not only (1) that which persists, but also (2) *matter* – defined in antithesis to form as that which is indeterminate – and (3) the function of *substrate* (*hypokeimenon*).

Hartmann's theory – which I follow here – is able to recover the various components of the traditional doctrine of substance, develop them and generalize them. It differs from the traditional theory in that it has the category of 'substance' *depend functionally* on the category of 'process'. This means that substance "has no being other than as a principle; and this means that it has no 'being in itself'" (Hartmann 1950, 290 ff).

Sinoptically:

1. Substance is not something outside the process but is in it. It is not timeless but has the form of duration, as has the process.
2. Substance is not the process itself but something that, though in process, resists it and persists.
3. Substance is both persistence and the substratum of persistence. What kind of substratum it is cannot be ascertained a priori.

4. There is no valid argument in support of an absolutely persisting ‘something’. Whatever the substratum may be, it is always only relatively persistent (Hartmann 1950, 284; Werkmeister 1990, 115; with some differences).

WHOLE AND PART

The problem of whole and part admits to various readings. At minimum we must distinguish between the ontic interpretation and other interpretations of ontological-scientific nature.

The cornerstone of the ontic interpretation is that the world is *one*. Brian Cantwell Smith aptly points out that ‘one’ in this case

- is not ‘one’ in the sense in which we can say ‘one’, ‘two’, ‘three’;
- is not ‘one’ in the sense that an object can be separated from a background;
- is not ‘one’ in the sense of being unified or homogeneous.

“What is meant, rather, is (i) that the world is nowhere cloven wholly in two, neither between subject and object, nor between concrete and abstract, nor between empirical and logical, nor between any two other kinds of things; (ii) that there is nothing other than it” (Smith 1996, 103). From an ontic point of view, the dependence relationship between parts and whole proceeds essentially from whole to the parts. This means that the whole is not a synthesis of its parts. On the contrary, “*the pieces are (partially) sedimented or extruded from the whole*” (Smith 1996, 270).

This reading of the category of ‘whole’, however fundamental, cannot be generalized to many other ontological types of whole. For those like myself who believe that philosophical inquiry should be developed in strict accordance with the results of scientific research, some further reflection is advisable. On the one hand, in fact, it is plain that science is connected to the complementarity of analysis and synthesis. In this sense, it may be said that classical physics is characterized by an in-built analysis of the world into constituent parts (such as atoms or elementary particles). These are then recomposed together to provide, by means of synthesis, any system; interactions are linearly and locally described; the resulting hierarchy of structures is grounded on such constituent parts.

On the other side, in contemporary science, the age of *pure* analysis seems to have ended. It is well known that non-linear systems have properties that, in general, cannot be expressed in terms of decomposition into ultimate, unstructured, pointlike parts plus a suitable sets of relations among them.

In general, what is it that characterizes wholes? Exemplification of whole as something connected may be acceptable for objects of the physical or biological world. But what about social wholes (like ‘family’ or ‘community’) or institutional ones (like ‘university’ or ‘city’)? These too are wholes, they have their history, properties, parts, and so on, but they are not connected. Or they are not connected in the same way as a material object.

We may make use of the concept of integrality to characterize wholes. But it is evident that something can be a whole even if it is not (an) integral. For example, a man whose hand has been amputated is still a whole, but he is not (an) integral. To use a definition that dates back to Aristotle, an integral is something which has all that parts that by nature it should have, although it is not easy to clarify what the expression ‘by nature’ means. In any event, what emerges from the example that I have deliberately chosen is that the expression ‘by nature’ does not necessarily relate to something like ‘essential part’. Whatever definition of essential part one (perhaps) accepts, it not obvious why a hand should be deemed an essential part of a man, unless we resort to a universal version of so-called mereological essentialism, which states that a whole is always essentially composed of its parts.

We must therefore follow a different route. A promising line of attack is recognition that a whole comprises different types of parts and different types of relation among parts. Put more precisely, the various parts of every type and their reciprocal relations constitute structures which contribute to some aspects of the whole. At minimum we can ask ourselves:

1. whether the part is separable from the whole,
2. whether the parts are spatial or temporal,
3. whether the part plays a specific functional role with respect to the whole,
4. whether the parts are homeomerous.

Secondly, every whole has a boundary which separates it from its environment. By virtue of possessing boundaries, a whole is something on the basis of which there is an interior and an exterior. Put in different but not alternative terms, we may also say that a whole is something which displays some form of independence with respect to an environment. Observing that, when analysed at a sufficient layer of detail, every whole vanishes into a continuum, or according to which every whole depends on something else, does not raise major difficulties. The fact that the boundaries of the whole are not absolute does not imply, in fact, that these are purely apparent boundaries. Wholes and their boundaries are realities which effectively operate at the appropriate layer of granularity.

Thirdly, many wholes are themselves composed of other wholes. In dealing with wholes composed of other wholes, the problem arises of calibrating the 'weight' of the more general whole with respect to the 'weight' of the boundaries of its component wholes.

I now conduct more detailed discussion of the difference between separable and non-separable parts.

SEPARABLE AND NON-SEPARABLE PARTS

However difficult it may be to specify the distinction between separable and non-separable parts, a preliminary definition of the difference may be forthcoming from examination of the case of inanimate material objects. In this situation, we may call separable parts those which can be removed from the whole without anything else taking their place. The exact meaning of 'remove' depends on the type of object. An inanimate object behaves differently from an animate, psychological or institutional object. If we take a physical object like a chair, a part of it which can be removed is for example the back or the legs. The removal of separable parts may have a destructive effect on the whole.

Non-separable parts are instead those which can be recognized and distinguished but which cannot be removed (Husserl 1970, 3rd Investigation).

There are various kinds of non-separable part. At minimum we may distinguish:

- functional parts (sub-systems),
- qualities,
- boundaries,
- *de facto* non-separability.

The general non-separability of a system's functional parts or functional sub-systems depends on the fact that the nature of sub-systems is determined by the nature of the whole. Consider the eventuality of separating the electrical or braking system of a car, or the nervous system of an animal.

The non-separability of qualities is a non-separability of kind, not of instance. When some quality is 'removed' from the whole, a part of the same kind usually takes the place of the part that has been removed. In effect, what is really inseparable is not so much the individual part *qua* part as its genus. If I remove the colour red from a table, it becomes of another colour or it assumes another colour, but it is still in some way coloured. For categories like colour, weight, shape, size, consistency, etc., material objects are structured in such a way that they may display different instances of these categories in the course of their histories, but they nevertheless always have them. A table may be of different shape, colour, weight, consistency, etc., but it will always have a certain specific shape, colour, weight, consistency, etc.

Everything that we usually call a property or quality or attribute belongs to this class. I then distinguish both types of part into further sub-categories. For separable parts I distinguish between the case in which all the parts are given simultaneously (and I obtain things, systems, aggregates) and the case in which they are given in succession (and I obtain processes and events). Boundaries, finally, are also non-separable parts.

The last type of non-separable part comprises *de facto* inseparable parts. The property of being separable differs between things and events. Separable in the case of things is whatever can be placed *somewhere else*, while in the case of events it is whatever can be placed *in another temporal moment*. Despite this difference, the concept is clear: separable is whatever can be placed *elsewhere* in space or time.

In fact, however, it often happens that also the spatial or temporal parts of a whole are not at all separable. If we consider the case of artifacts, their material parts can be melted, glued, milled, welded, filed, sanded, drilled, bent, or at any rate subjected to processes whereby they are no longer separable (Simons and Dements 1996).

Similar objections can be raised with reference to biological and social particulars. Regarding biological particulars, it is asserted for example that not all the separable parts in a body are in fact separable. A finger or a hand is separable, but a head is not, because in this case what we have no longer have a body but a corpse. The same applies to many social wholes. A quartet without one of its members is no longer a quartet, at most it is a trio.

We must conclude from these examples that separability is a sufficient but not necessary condition for being a part. It is said in these cases that everything that is separable is assuredly part of an object, but not everything that is a part is really separable. In other words, it is stated that, for the reasons just given, ‘separable’ should not be taken to mean ‘effectively’ or ‘concretely’ separable, but ‘virtually’ or ‘ideally’ separable. A conclusion of this kind seems plausible but it enormously complicates the problem.

First of all, it should be noted that the difficulties that arose in the preceding analysis all connect with questions concerning the *identity* of parts or wholes. If we run down the list of examples, we see that the troublesome cases are of the type: once the parts have been detached from the whole they are different from what they were when incorporated into the whole (problem of the identity of parts, which applies for example to pieces), if certain parts are removed from the whole, the latter becomes a different type of whole (body-corpse, quartet-trio). But these are problems more closely connected with the identity of parts and wholes than with the part-whole relation. Consequently, we must keep questions of identity separate from questions to do with the ‘part-of’ relation.

If we set problems of identity aside, it becomes natural to define ‘part’ as anything that can be separated from the whole, even if the actual separation may have the effect of changing the qualitative nature of the whole, or even of destroying it.

With the appropriate variations, the difference between separable and non-separable parts holds for every type of whole.

Parts are not wholes, but they can always be transformed into wholes. Let us start from a whole, with its dependent parts, its boundaries, etc. In principle it is always possible to take a part of that whole and analyse it as a whole. This means that the element is analysed in and of itself, without being considering in terms of its connections / functions / dependences *vis-à-vis* the whole with which we started. The various types of parts react differently to analysis. From an ontological point of view, separable parts are potentially wholes. This means that we can analyse parts without subjecting them to ontologically significant transformations. By contrast, non-separable parts only become wholes as the result of a reification process (i.e. a process which transforms them from dependent entities into independent ones). The same procedure of ‘reification’ or ‘autonomization’ applies to all forms of dependence.

DEPENDENCES

From an ontological point of view, the theory of dependence analyses the deeper-lying connections that enable us to say that the world is *one* world. I have already said that there are various forms of dependence. In particular, I distinguished among the following forms of dependence:

- Stratum- and Layer Dependence;
- Substance-Determination Dependence;
- Part-whole Dependence;
- Kind Dependence.

Stratum-layer, substance-determination and whole-part dependences have already been discussed; kind dependence will be discussed in the next section. Before starting the analysis of external categories, I would like to resume the main distinctions among the internal categories of general ontology in the following Table 3.

TABLE 3

Internal Categories	
1. General Categories	Categories which hold for all the ontological layers: time, space, object, process, particular, individual, mass, feature, substance, determination, matter, form, bearer, borne, whole, part.
1.1. Top Categories	Object, process, particular.
1.2. Layers	Stratum, layer.
1.3. Dimensions	Time, space.
1.4. Oppositions	Matter-form, bearer-borne, substance-determination, whole-part.
1.5. Dependences	Between each kind of opposition, between layers.
2. Layer Categories	Categories which hold for any ontological layer.

EXTERNAL CATEGORIES AND THE TAXONOMY OF BEINGS

Besides the ‘internal’ categories, we also need a large quantity of ‘external’ categories if we are to describe and classify objects. It is external categorization that has been most thoroughly developed by KR. Although it seems conceptually more straightforward than internal categorization, the enormous quantity of detail to be organized gives rise to entirely original problems.

We will say that anything with a certain structural unity is something of a certain kind. For an object to be an object of a certain kind its general determining properties, those that make it a member of a kind, must be describable in terms of appropriate generalizations. Let us assume that in the case of natural kinds, these generalizations are the laws used by the sciences: which amounts to saying that “if we are to produce an interesting account of natural kinds, we should insist that members of natural kinds ... must lend themselves to scientific explanation” (Wilkerson 1995, 31).

I begin with the distinction between natural kinds and dependent kinds. In general, there is broad agreement that electron, proton, neutron, narcissus, chimpanzee, stickleback, carbon, gold and water are natural kinds, whereas table, nation, banknote, rubbish, cliff, perennial and bush are not. It is likewise generally agreed that, if there are natural kinds, they fall into at least two groups. There are *kinds of stuff*, such as carbon, gold, water, cellulose, and there are *kinds of individual*, such as tiger, chimpanzee, stickleback, narcissus. On the other side, we may distinguish non-natural kinds into *functional kinds*, such as table and banknote, and *contextual kinds*, such as cliff and bush.

I assume that appropriate generalizations with regard to functional kinds are linked to the practices, disciplines and technologies employed to name, recognize, classify, use, produce and alter the objects that belong to them. This variegated complex of cognitive and operational practices can be given the general label of *technologies*. Obviously, there is no clear-cut distinction between sciences and technologies: science is involved in numerous technologies, and technologies use the most varied of sciences. AI in particular is a practice that raises numerous important scientific problems and compels even very well-consolidated sciences to reconsider their theories. As mentioned, I shall discuss functional kinds with reference to technologies. The argument that I wish to develop is that the relation that connects natural and functional kinds is of the same nature as the relation between sciences and technologies.

The other case concerns those situations in which the appropriate generalizations depend on the context concerned. Obviously, in this case discussion will centre on contextual kinds.

I now examine these cases in some detail. First, it is advisable to dwell for a moment on the difference between sciences and technologies. The key reason for linking the natural kinds to the sciences is that the latter, however much they are obviously interconnected, represent irreducibly different points of view. “An excellent reason for taking biology seriously is that the biological properties of things obviously depend directly on their physical and chemical properties. But the explanatory apparatus of biology cannot in practice be reduced to the explanatory apparatus of physics or chemistry or both” (Wilkerson 1995, 39). Any science has its own ‘window’ on the world, selecting (through the pertinent predicates) only those objects that are at the ‘right’ layer of magnitude and energy.

On the other hand, the explanatory apparatus of technologies, “though no doubt relative to a fairly high layer of size or complexity, is not emergent. It is, as it were, perpetually provisional, and is constantly being reduced to, or connected with, or supplanted by, the explanatory apparatus of some discipline characteristically concerned with entities of some lower layer, notably physics, chemistry and biology”. In other words, “geology and geography would be impossible if there were no physics and chemistry of the various elements and compounds that constitute our planet” (Wilkerson 1995, 40).

Therefore, we will say that objects whose structural unity is described by sciences are objects of a certain natural kind, whereas objects whose structural unity is described by technologies are objects of a functional kind. In his theory of natural kinds, Wilkerson defines them in terms of three conditions: (i) possessing real essence, (ii) being subject to scientific investigation, and (iii) being determined by an intrinsic property. For my part, I do not see how conditions (i) and (iii) can be precisely specified, for which reason the reconstruction set out in this chapter almost wholly uses condition (ii). For the time being, I resume Wilkerson’s analysis of contextual kinds.

Contextual kinds can be well represented by the following examples: “Gardeners talk cheerfully of seedlings, saplings, trees, shrubs, bushes, climbers, perennials, annuals, pot plants, and so on, but none of these terms pick out a real essence; none are likely to appear in reports of serious scientific investigation; and none refer to a kind determined by an intrinsic property. One and the same plant will grow as a tree under one set of conditions and as a shrub under others (e.g. many *Eucalyptus* and *Acer* species). One and the same plant will be an annual or pot plant in a temperate European climate and a shrub in a hot African climate (e.g. *Pelargonium* species). One and the same plant is a shrub in western Ireland and a hardy perennial in Nottingham (e.g. *Fuchsia magellanica*). None of those terms pick out an intrinsic property and none of them correspond, even approximately, to any botanical classification”. “Yet none of the terms has any connection with convention, artifice or culture” (Wilkerson 1995, 37).

Wilkerson notes that the same point can be made about geographical and meteorological kinds: “Geographers talk of beaches, cliffs, mountains, valleys, seas and volcanoes. Meteorologists talk of depressions, anti-cyclones, winds, thunderstorms, clouds and hurricanes. But the terms do not pick out things with real essences, they do not figure in scientific generalisations and they do not pick out any relevant intrinsic properties. One and the same lump of material will count as a mountain in one environment, as a valley floor in another, and as part of the sea bed in yet another. One and the same reaction counts as a thunderstorm if it happens on a large scale in the open air, but if it happens under the bonnet of my car it is called a short circuit and my car fails to start” (Wilkerson 1995, 37-8).

In what follows I shall assume the fundamental hypothesis that, *for each of their ontological layers,* all objects belong to at least one natural kind and to one or more dependent kinds (functional or contextual). For any layer, the natural kind of every object is connected with the causal links of the object. In this sense, the scientific point of view differs from the functional and contextual point of view in that the former seeks to 'isolate' the causal connections that determine the individual object independently of its functional or contextual kinds.

Let us consider 'table' or 'rubbish heap' and try to understand why these objects *as such* are not natural kinds. Wilkerson explains the matter limpidly: "If I know that the stuff in front of me is rubbish, or that the object over there is a table, I am in no position to say what it is likely to do next, nor what things of the same kind are likely to do ... Obviously I can make safe predictions about the behaviour of my table or rubbish heap under certain circumstances. I know the likely outcome of putting my kitchen table on the bonfire, or of leaving a heap of vegetable waste undisturbed in a hot climate. But the point is that, in making my predictions, I am exploiting the fact that every object, or quantity of stuff, will belong to at least one natural kind, even if it also belongs to one or more non-natural kinds ... I am not predicting the behaviour of the table *as a table*, but rather its behaviour *as a quantity of cellulose* ... As Aristotle remarked: a bed and a coat and anything else of that sort, *qua* receiving these designations ... have no impulse to change. But in so far as they happen to be composed of stone or of earth or of a mixture of the two, they *do* have such an impulse, and just to that extent (*Physics* II,1, 192b16-20)" (Wilkerson 1995, 32-34).

Put in general terms, natural kinds codify the causal network that govern the internal dynamics of objects.

The reference to internal dynamics may be nothing more than a modern version of a thesis which, as we saw in the quotation from Wilkerson, dates back to Aristotle. For Aristotle, in fact, plants and animals have a special ontological status because they possess 'nature', whereas he connects the doctrine of natures with a doctrine of *independence*. Plants and animals are natural kinds because their existence does not depend on the existence of other objects. "What makes a chimpanzee a chimpanzee, or a daffodil a daffodil... is its intrinsic nature, that is, a feature that does not depend on the existence of something else". "In contrast, what makes something a table or a bed or a house depends crucially on its relations to something else. For example, something is a bed if and only if it can act as a comfortable nocturnal resting place for human beings" (Wilkerson 1995, 25).

Hence the distinction between natural and dependent kinds is made to depend on the distinction between intrinsic properties and relational properties. The problem is only postponed, however, because it is unclear what criteria should be used to delimit the intrinsic properties. Consequently, my decision to rely primarily on the network of causal connections seems distinctly plausible.

Above I drew the distinction between the functional and contextual families of dependent kinds.

Functional dependence states that certain things exist only in virtue of a relation to something else. Say, "something is a fuel pump because of a functional relation to an internal combustion engine, and something is a pillar because of its functional relation to a bridge or a roof. In other circumstances the fuel pump might be a water pump, and the pillar might be hardcore for a new road". Functional dependence may also be conventional. As Wilkerson reminds us, "sometimes an object is what it is because of a definite, though perhaps implicit, convention. Certain lumps of metal or pieces of papers are coins or banknotes because, according to a statute or statutory instrument, they can be used as a means of exchange" (Wilkerson 1995, 52).

However, the introduction of dependent kinds does not resolve matters entirely. For example, "whether or not a plant is a tree or a shrub has nothing to do with its relational dependence upon something else. If it has a single woody stem and breaks into branches some feet above the ground, it is a tree, and if it is woody and breaks into many stems very close to the ground, it is a shrub" (Wilkerson 1995, 54). To account for this situation we must introduce, besides the natural kinds and the dependent kinds, also hybrid kinds: "The kind *vegetable* is a hybrid of natural and dependent kinds. It is strictly not a natural kind, for it includes plants of different species, even of different genera and families, in a way that does not correpond even aproximately to any formal taxonomy. Other examples of that sort of hybrid are fruit, pot plant, herb, pet ..., cattle, medicine" (Wilkerson 1995, 57-8).

Hybrid kinds may be highly specific: "Farmers and greengrocers divide apples into the kinds dessert, cooker and cider, and butchers distinguish the kinds ham, bacon and pork. The first distinction is at best a distinction between layers of acidity, and has little botanic significance... and the second distinction reflects the different ways in which pig carcasses are cured" (Wilkerson 1995, 58). Hybrids of functional and contextual kinds are: ski slope, surfing beach, gravel pit, oasis, biennial.

As the above examples show, a minimally adequate theory of kinds must be able to distinguish not only among natural, functional and contextual kinds but also among the various cases of hybrid ones.

The theory of kinds presented in the above section is synthesised in the following Table 4.

TABLE 4

Kinds		
1. Natural	1.1. Stuff	carbon, gold, water
	1.2. Individual	tiger, stickleback
2. Dependent	2.1. Functional	table, banknote
	2.2. Contextual	cliff, bush
3. Hybrid	3.1. Between 1 and 2	vegetable, fruit, medicine
	3.2. Between 2.1 and 2.2	surfing beach, biennial

OVERALL ARCHITECTONIC: GENERAL, REGIONAL, DOMAIN AND APPLICATION ONTOLOGY

At minimum, an adequately developed ontology should be able to distinguish among:

- general ontology (top layer categories and oppositions, plus their dependence connections);
- regional ontology (theory of an ontological category: see below);
- domain ontology (analysing an ambit of reality, which is usually given by a specific set of phenomena belonging to diverse ontological strata), e.g. medicine, artifacts;
- applied ontology (described in terms of its use).

Let us look at the general features of these ontologies, beginning with general ontology.

General ontology concerns itself with (i) internal categories and (ii) oppositions, plus (iii) their dependence connections. Regarding internal categories, we are growing increasingly aware that the top layer is a context which is extremely difficult to handle. For this reason it is of maximum importance to employ an organization of the prime categories that is as transparent as possible.

As we have seen, there are general categories that apply to all the ontological strata: for example, the category of 'part', which means that 'part' is a category of the general ontology. However, the fact that this is a general category does not entail that it is a univocal category. In effect, the concepts of 'part' that apply to the material stratum differ substantially from the concepts of 'part' typical of the mental or social strata. Note the deliberate use of the plural here: concepts of 'part' are not only different from stratum to stratum but they may also be different from layer to layer. We are therefore in need of both an extremely general characterization of 'part' and of specifications of 'part' for each ontological layer.

However much the various top-layer categories may assume different values in the different strata of the ontology, they must nevertheless have something in common. Although ‘part-of’ differs as regards inanimate and animate objects, in both cases we always speak of ‘parts’ and distinguish ‘parts’ from the other categories.

Regional ontology studies the various ways in which a category is realized in the diverse ontological strata, ascertaining the possible presence of a general theory which subsumes its various concretizations. While general ontology is more concerned with the architectonic of the theory, regional ontology is more sensitive to the details of the individual categories. Both of them, however, are obviously necessary.

We know that each ontological layer is characterized by the presence of a group of categories typical of that layer. The first task, therefore, is to find the most general categories typical of that layer. There will then be groups of categories that mark out particular sub-layers. The ontology of medicine, for example, is an area in which certain of its components clearly belong to a sub-domain of the living world, while others pertain to sub-domains of the psychological and social spheres. I use the term ‘domain ontology’ to refer to the detailed structuring of a context of analysis with respect to the sub-domains of which it is composed.

Two important points require making as regards the use of this approach. The first is that one always talks of groups of categories. There are no real domains characterized by one single top-category. In general, a domain is characterized by complexes of categories which interact with each other. The second point is that domain ontologies are not solely the outcome of the way a particular ontological stratum is sliced up. Domain ontologies, in fact, are often the result of a complex combination of local realms belonging to different ontological layers and strata.

Consider for example the case of artifacts. These are at minimum objects of the inanimate material world. To characterize their ontology, however, we must examine other dimensions as well, like the ‘design’, ‘manufacture’ and ‘marketing’ of artifacts, and these are dimensions of the social world. The ontology of artifacts is therefore an ontology that operates crosswise to the sequence of the ontological layers and strata. The same applies to the previous example of the domain ‘medicine’. It is this ‘transversality’ that makes the categorization of many domain ontologies such a complex undertaking.

By ‘applied ontology’, finally, is meant exactly what the name implies: the concrete application of the ontological framework to a specific object (a particular hospital, for example).

STANDARDS

It is entirely obvious that ontology *qua* technology is still in its early stages. At the moment, the research community seems to have reached broad agreement only on the fixing of *linguistic* standards. In this area, KIF and Ontolingua are rapidly becoming accepted and soundly-established standards of exchange and translation. This is certainly an important development, but it is one that can be called authentically ontological only by illegitimate extension of the concept of ontology. Translation standards are not ontological components; if anything they are quasi-ontological ones.

An example may be of help. We all know that in recent years important standards for software construction have become established. One thinks, for example, of the Standard Template Library (STL) developed by A. Stepanov for the C++. This is certainly a positive step forward, but it is one that involves formal components, not ontological ones. We shall be able to talk of similar development in ontological terms only when we have a Standard Template Library for *ontological categories and constructs*: to use, for example, in structuring analysis of the LEVELS of objects and their forms of dependence and independence, in analysis of categories like PROCESS, THING, EVENT and WHOLE. At an intermediate layer, so to speak, between ontological and cognitive analysis, it would be extremely useful to have templates available for analysis of the categories used to recognize and classify reality, just as it is essential to have sophisticated tools for the analysis, construction and organization of lexical fields. All this, however, still seems a long way off. And this is no accident: we have a long way to go because, amongst other things, there is still no general consensus even on the general features of an ontology and on the features of whatever should accompany ontological analysis.

For this reason the most urgent task is to continue with the work of conceptual clarification of categories and of their organization. In effect, it is plain that each of the topics addressed in the various sections of this paper calls for further inquiry, and that several areas of ontology have yet to be explored. If we look at the literature we soon realize the extent to which analyses have lacked systematicity. For instance, whereas in the last fifteen years there has been an enormous burgeoning of interest in the concept of PART, this is certainly not the case of the correlated and ontologically more important concept of WHOLE.

Co-operations

From all what I have written, it is clear that ontology needs the contributions of mathematicians, logicians, linguists, psychologists and philosophers. Collaboration with philosophers is possibly the most difficult and even upsetting one, because getting to grips with philosophy – in the area of both analytic philosophy and of what is known as continental philosophy – is a difficult and even frustrating business.

Philosophy in the English-speaking world is almost exclusively analytic. It is a philosophical paradigm, by now in decline, whose legitimate effort to conduct rigorous and methodologically correct inquiry has been reduced to impotence by two assumptions. First, analytic philosophy shares with the mainstream of continental philosophy an epistemological error whereby ontological problems and inquiries are converted into the problems and inquiries of the theory of knowledge. Second, analytic philosophy differs from continental philosophy in its assumption that philosophy *is* analysis of language. Matters are no better as regards continental philosophy, which besides the epistemological fallacy mentioned above, suffers from at least one further shortcoming: its general lack of methodological rigour.

Much of the decadence of contemporary philosophy is attributable to the fact that the two most influential philosophers of the last fifty years – Wittgenstein and Heidegger – rejected the alliance between science and philosophy. One can only hope that contemporary philosophers will come to realize that they have blundered into a blind alley and will revert to a more natural standpoint.

If philosophy is naturally allied with science, the philosophers to whom we refer can only be philosophers who have acknowledged the alliance between philosophy and science. I set out earlier the reasons why the most recent proposals of both analytic philosophy and continental philosophy are unsuitable for our purposes. We must accordingly take a step backwards and see whether immediately previous philosophy has something useful to offer. And, in fact, we find in German-speaking philosophy of the late nineteenth and early twentieth centuries a group of thinkers who defend the two principles of alliance with science and the autonomy of ontological problems. The latter principle states that ontological problems cannot be reduced to those of the theory of knowledge. This position was first set out by Franz Brentano, who declared that “the genuine method of philosophy is none other than that of natural science” (Brentano 1968), and it was developed in numerous directions by Brentano’s pupils: most notably by Edmund Husserl and Alexius Meinong, or Roman Ingarden, who studied under Husserl. Another German thinker who, although he studied neither under Brentano nor under his pupils, nevertheless reflected their doctrines, and Husserl’s especially, is Nicolai Hartmann, *perhaps the most important ontologist of this century*. A philosophers in the English-speaking world to have argued substantially similar positions – although one not directly influenced by the above authors – has been Alfred North Whitehead.

Framing The Ontological Problem

It seems possible to say that in this essay I have elaborated what might be called a possible *framing* of the ontological problem. I use the term ‘frame’ rather than ‘analysis’ or even ‘solution’ because numerous problems obviously remain due to the lack of both detailed analysis of the ontological categories and of a method for the formal translation of the ontological categories and their dependences.

The principal of these still open problems, I believe, are the following:

- the development of a paradigm or of a template able to account for the stratified nature of reality;
- the functional nature of substance;
- development of an adequate concept of whole;
- elaboration of criteria for the determination and distinction of natural and derived kinds;
- elaboration of a theory of ontologically transparent dynamics.

To use Husserl's way of speaking, these are problems pertaining to the 'material' side of ontology and they are clearly intertwined with the 'formal' side of ontology. The problem arises when – as is curstomary today – formal ontology is forced to directly imitate formal logic. I cannot see why the categories of formal ontology should be reduced to those of individual, property/relation and state of affairs. Even if we accept that these categories are a starting point, it must be clearly maintained that they are *only* a very first and preliminary starting point. But now the point is: what next? Considering that the research community uses some form or another of a *typed* first order logic, the most natural next step is to provide analysts with tools able to produce both a clear and well organized net of types and to say what should be placed inside types. Pure logic is no answer. To provide answers you should have some form or another of material ontology giving you information about which types are exemplified and which depends on which, and which are part of which, etc. etc.

As far as I know, a detailed formal ontology so explicitly linked to the outcomes of a well elaborated material ontology has still to be produced.

Conclusion

Ontology needs the achievements of all the sciences if it is to accomplish its aims. Even if we accept the Philosopher’s claim that, by virtue of the problems it addresses, ontology is *philosophia prima* (first philosophy), because of the answers it proposes ontology can be only *philosophia ultima* (last philosophy). In between there is science.

Broadly speaking, the variously articulated research communities of philosophers, linguists, psychologists and engineers have still not found a way to relate to each other systematically.

However, in dynamic terms, one easily foresees mounting social and institutional pressure for tools able to model fragments of reality in terms that are both adequate and efficient. And from this point of view, we are all at fault. Those colleagues who concern themselves with artificial intelligence seemingly pay closer attention to manipulation and technique than to knowledge. Likewise, those who concern themselves with general issues suffer from the reverse problem, that of navigating in a sea of theories for which the rationale is sometimes unclear.

For my part, I grow increasingly convinced that the same problems will force the former to address theories, and the latter to address the limitations of our current capabilities. Provided, that is, that both sides have the will, the ability, the desire and the courage to do so. If they decide to tackle these problems, it becomes reasonable to identify and systematically develop those areas of convergence and contact now existing.

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