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Ontological methodology

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The interest in ontology may peter out unless three problems are addressed: What are the boundaries of ontology? What types are there of ontology? What is the structure of ontology? After distinguishing three main kinds of information (ontological, quasi-ontological and non-ontological) and three types of ontologies (descriptive, formal and formalized), the paper presents a few basic ontological sub-theories (theory of particulars, of levels of reality, of wholes, parts and boundaries, and the intensive–extensive opposition for determinations). The methodology of domain analysis is further addressed and the distinction between a domain's structure and the scheme of the canonical item of a domain is introduced.

KEYWORDS: ontology; particular; boundary; level; intensive; domain analysis.

1. Introduction

The considerable interest in ontology that has developed in recent years may peter out unless at least three problems are addressed *very* seriously.

1. What are the boundaries of ontology; that is, what problems are ontological (rather than, say, epistemological, logical or linguistic, etc.)?
2. What types are there, if any, of ontology?
3. What is the structure of ontology?

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. 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 distinguishing its types, and without analysing its structure.

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 (like those which use ontology for semantics). In my work (Poli 2001*a*, Chapter 2). I have discussed a variety of definitions of ontology and proposed criteria for their classification, and there is no need to repeat them here (for other proposals, see Guarino & Giaretta, 1995; Fridman Noy & Hafner, 1997).

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Following the path opened by such thinkers like Husserl (1970, 1989), Hartmann (1933, 1935, 1950, 1952), Peirce (1991–1998) and Whitehead (1978). I shall adopt a categorical viewpoint. Resorting to a categorical viewpoint means looking for 'what is universal' (either in general or in some specific domain). Those with a grounding in contemporary mathematics will recognize here a similar claim advanced by Bill Lawvere some decades ago: category theory, as a foundational theory, is based on "what is universal in mathematics" (Lawvere, 1969, p. 281).

The motto "looking for what is universal" may sound somewhat generic. A few more details may therefore be welcome. In this paper I shall call the reader's attention to the two following principles.

Firstly, the idea of ontology of interest to us here can be summed up as follows: Ontology is the theory of items. And it is so of every type of item, concrete and abstract, existent and non-existent, real and ideal. Whatever item we are or might be dealing with, ontology is its theory. The term "item" is neutral as to the choice between 3D or 4D ontologies; that is to say, between an object-based ontology or a process-based one.

Secondly, we distinguish general from domain ontology. Domain ontology deals with some special kinds of items (as encapsulated by expressions like "ontology of mathematics", "ontology of the literary works of art", "ontology of law", "ontology of economics", "ontology of artefacts", etc.). Domains may obviously be more or less specific. A trivial example is provided by the series: ontology of literary works of art $\Rightarrow$ ontology of works of art $\Rightarrow$ ontology of intentional objects (where the arrow goes from more specific to more generic). Moreover, domains may be more or less tangled. 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, others to the domain of drugs and chemicals, and still others to the domain of artefacts. The detailed structuring of a context of analysis with respect to the sub-domains of which it is composed may be and usually is a very complex task.

Domain-dependent ontologies concern categorically closed collections of items; on the other hand, a domain-independent ontology may be properly called general ontology. In both cases, ontology looks for universal structures.

Ontology should provide general criteria for the segmentation and the organization of domains. A glimpse at of what is meant by a sound methodological basis for a domain ontology is provided by the following quotation from the Polish–Russian philosopher of law Leon Petrazycki:

> Many theories [= ontologies], comprising no fallacy, are yet inadequate: one may form the concept of "a cigar weighing five ounces", predicate about that class everything known about material things in general (about solid bodies in general, the chemical properties of the ingredients of these cigars, the influence of smoking them on health, and so on); these "theories"—while perfectly correct—are manifestly inadequate since what is predicated with respect to "cigars weighing five ounces" is also true of innumerable objects which do not belong to that class, such as cigars in general.
>
> A theory may be inadequate either (1) because the predicates are related to classes which are too narrow... or (2) because the predicate is related to a class which is too broad (such as various sociological theories which attribute "everything" to the influence of one factor which in fact plays a much more modest part) (Petrazycki, 1955, p. 19).

Adequate ontologies should satisfy the following requirement: what is predicated must be true of the class of items with respect to which it is predicated. Petrazycki's conditions may be stated by claiming that adequate theories must be (i) universal and (ii) closed. Closed universal theories may be aptly called natural theories (Poli, 2002*a*).

2. The boundaries of ontology

I shall distinguish (1) between ontological and non-ontological information and (2) between ontological and quasi-ontological information for both domain and general ontologies.

To put things succinctly, information may be basically organized into at least three dimensions: the semiotic, the semantic and the ontological. Semiotic and semantic information are kinds of non-ontological information.

The semiotic dimension analyses the features of the signs used to convey information, and its main subsection is the language analysis module (Poli & Mazzola, 2000). The semantic dimension analyses forms of classification. Standards and other agreed-upon forms of classification pertain to this module. Cognitive and social categorizations (as for prototype theories) pertain to the semantics module as well. The ontological dimension analyses the item under consideration from the point of view of its intrinsic categories (see below for details).

Besides the distinction between semiotic, semantic and ontological analyses, 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 another 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, functions and so on are imported. But which particular version is used is not an ontological problem.

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

3. Types of ontology

I shall distinguish descriptive, formal and formalized ontology. Each of these ontologies comes in two guises: domain-dependent and domain-independent.

Descriptive ontology concerns the collection of information about the many items making up the whole world or the specific domain under analysis. In my understanding, the unity and the variety of the world is the outcome of the complex interweaving of dependence connections and forms of independence among its many items. Material things, plants and animals, as well as the products of the talents and activities of animals and humans, are items of the world's furniture. In other terms, 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 (Poli, 2001*a*, Chapter 5).

Formal ontology distills, filters, codifies and organizes the results of descriptive ontology (in either its local or global setting). According to this interpretation, formal ontology is formal in the sense used by Husserl in his *Logical Investigations*. Being formal in such a sense therefore means dealing with categories like *thing*, *process*, *matter*, *form*, *whole*, *part*, etc. These are pure categories that characterize aspects or types of reality and still *have nothing to do with the use of any specific formalism*.

Formal codification in the strict sense is undertaken at the level of *formalized* ontology. The task here is to find the proper formal codification for the constructs descriptively acquired and formally purified in the way just indicated. The level of formalized constructions also relates to evaluation of the adequacy (expressive, computational, cognitive) of the various formalisms, and to the problem of their reciprocal translations.

The close similarity between the terms "formal" and "formalized" is somewhat unfortunate. One way to avoid the clash is to use 'categorical' instead of 'formal'.

Most contemporary theory recognizes only two levels of analysis and often merges the level of the formal categories either with that of descriptive or with that of formalized analysis. As a consequence, the specific relevance of categorical analyses is too often neglected.

The three levels of ontology are different but not separate. In many respects they affect each other. Descriptive findings may bear on formal categories; formalized outcomes may bear on their twin levels, etc. To set out the differences and the connections between the various ontological facets precisely is a most delicate task (Poli, 2002*a*).

4. The structure of ontology

In this section I will try to give an idea of the highly complex structure of ontology. The first step is to distinguish between what we are talking about and its determinations. A number of deep problems are embedded even in this first move, in fact. But let us agree to leave them aside for a while. Resorting to traditional terminology, I shall address the first topic as the problem of "substance", and the second one as the problem of "determinations" (Poli, 2001*a*).

4.1. SUBSTANCE

My basic tenet is that the theory of substance comprises at least three sub-theories: the theory of particulars, the theory of levels of reality and the theory of wholes and their parts. Most traditional theories of substance fail precisely because they lack one or more of the above sub-theories. Furthermore, I distinguish an elementary theory of substance, given by the above-mentioned three sub-theories, from a non-elementary or higher-order theory of substance, given by the study of their interactions.

In this paper I only provide a very basic introduction to the elementary theory of substance.

4.1.1. Theory of particulars. Logic-driven thinkers tend to believe that we live in a "world of individuals". "Individual" is a logical concept, not an ontological one. It pertains at most to the ambit of formalized ontology. From the point of view of descriptive and categorical ontology, it should be replaced with richer concepts.

As already said, I shall propose adopting "item" as the most generic descriptive term. Subsequent distinctions should consider at least the following concepts: object, process, stuff and group. Each of these has its ontological features and deserves a proper theory. Higher-order items consider items composed by other items (groups of processes, etc).

My own perspective is thoroughly dynamic and thus follows the route opened by such thinkers as Brentano (1968, 1988), Husserl (1970, 1989), Hartmann (1933, 1935, 1950, 1952), Peirce (1991–1998) and Whitehead (1978). Among contemporary ontologists, Smith (1996) and Sowa (2000) defend similar positions. For the time being, we may leave deeper analysis of this more debatable point aside.

4.1.2. Levels of reality. We may distinguish at least three ontological strata of the real world: the material, the psychological and the social (Hartmann, 1935; Husserl, 1989; on the theory of levels of reality cf. Poli, 1998, 1999, 2001*a*, *b*, 2001*c*).

Specific forms of categorial and existential dependence exist among these strata. For example, a psychological item 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.

A relationship of matter and form holds among many items. 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 (Figure 1).

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

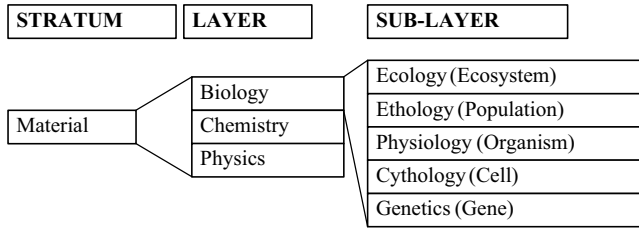


FIGURE 1.

functions as matter. The organic levels 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 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 as far as the social stratum is concerned. In both 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 these cases, the substratum of the higher level is not the matter of the lower level (Hartmann, 1952, pp. 68–69; Poli, 2001*c*).

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.

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. 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 (details in Poli, 2001*a*, 2001*c*).

Each stratum presents its own internal organization. Figures 1 and 2 and Table 1 provide a visual representation of their basic differences.

Analytic description of the mental realm is less straight-forward than that of the material realm, not only because of its intrinsic complexity but also because our scientific imagination does not comprise an elementary schematization such as that furnished by the physics–chemistry–biology series. Although space precludes presentation of many of the details here, it is important to provide at least a provisional description of the bearing structure of this realm.

According to Albertazzi (see at least Albertazzi, 1999*a*, *b*, 2001), the realm of the mind is structured on the basis of two primary oppositions. The first is between the objectual plane and that of the emotions. The latter *also* performs a role entirely analogous to that of reagents in chemistry. In this sense, they are configurations that facilitate or impede the processes characteristic of the complementary objectual plane. Matching the distinction between ''objects'' and ''reagents'' is that between ''presentation'' and ''representation''. The former concerns the particular phase of

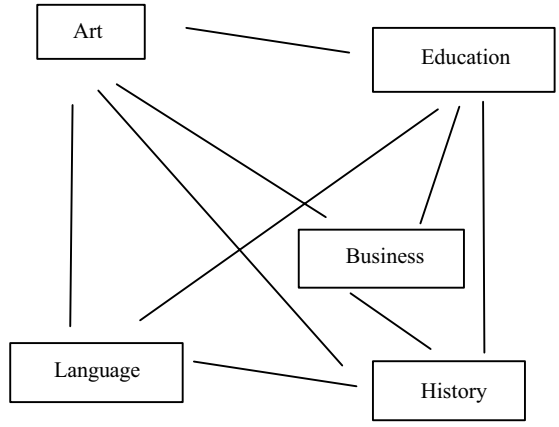


FIGURE 2.

TABLE 1

	Objectual dimension	"Reagents" dimension
Presentation	Modal Amodal	Emotional tone
Representation	ST Memory LT Memory Imagery Assumption Reasoning, etc.	Emotions

mental activity variously called the time of presentness, moment-now or specious present. This is a fundamental phase (lasting 700 ms on average) of entirely specific status, in that presentation is characterized by phenomena, like those of temporal inversions, which no longer occur in the subsequent domain of representation. Presentation divides primarily between modal phenomena engendered by sensory stimulation (relative to seeing, hearing, feeling, etc.) and amodal phenomena with a specific objectual yield despite the absence of a connected sensory stimulation (as in the well-known case of Kanizsa's triangle).

All higher mental activity (that of representation) is based on presentation phenomena varyingly reified, consolidated or schematized. The domain of representation is extremely rich and comprises memory (in its various forms), imagination, reasoning, assumptions, planning, etc.

I believe that the contemporary cognitive sciences have yet to focus on the scheme just briefly sketched. Instead they have concentrated on the objectual level of representation, which although extremely rich is intrinsically incomplete and lacks a general categorical framework.

Moving to the realm of social phenomena (Figure 2), this has yet another type of basic structure. The social world, in fact, is characterized by the presence of a set of tendentially universal and interacting domains. The dimension of (tendential) universality relates to the fact that each of these domains views the entire universe *juxta propria principia*. The worlds of legal rules, moral values, economic principles, institutions, art and so on, each use a totalizing interpretative frame which induces it to see reality as a whole from a particular point of view. The process moves through two stages: (1) normalization (elimination of irrelevant cases or situations) followed by (2) selection of an adequate typology of relevance. For the legal world all reality is subject to the law, for the moral world everything is good or evil, for the economic one everything has a price. Each of these standpoints can be applied more effectively if all irrelevant residues are eliminated from the outset (point 1).

A distinctive feature of the social realm is the two-fold action of its various domains: on the one hand, each of them operates individually according to its interpretative frame; on the other, all of them operate in parallel, influencing and determining each other.

The above descriptions provide a few details of the 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 both the stratum of mental phenomena and the stratum of social phenomena. Each stratum has its own principles, laws and categories. The nature of one stratum cannot be understood using the categories of another (Poli, 1996, 1998, 2001*a*, 2001*c*).

Specific 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.

Almost all actually existent entities are multi-stratified. Which means that *the levels and strata of reality do not distinguish items. The levels are internal to items but not as their parts!*

Description of the strata and levels of reality intersects with description of the items 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 (Poli, 1998, 2001*a*, Chapter 8).

4.1.3. Wholes and their parts. The theory of wholes and their parts presents a number of different subsections. As to its first-order segment, we may distinguish (1) classification of wholes; (2) classification of parts; (3) classification of boundaries. Section (2) has been widely discussed in the past 15 years; section (1) has been less intensively discussed; and section (3) has received even less attention. I therefore skip analysis of point (2), deal briefly with point (1) and concentrate on point (3).

Wholes. I distinguish three kinds of wholes: aggregates, wholes in the proper sense and systems. Table 2 provides a way to distinguish among them.

TABLE 2

	Unity by proximity	Unity by solidarity	Dynamic unity
Aggregate	yes	no	no
Whole	yes	yes	no
System	yes	yes	yes

Aggregates consist of proximate parts. Wholes in the proper sense comprise parts "which go together" (recall Uexküll's motto: an object is that which moves together). Systems require a dynamic exchange between the whole and its parts.

Unity by solidarity is stronger than unity by proximity. This means that only some items that are aggregates are also (integral) wholes, and that some of the latter may be systems. Needless to say, the most difficult task is furnishing an adequate characterization of the dynamic components of systems. For the moment I merely point out that it is possible to determine various forms of dynamic unity, ranging from those that obtain in material systems of a physical nature to those that obtain in systems which, like living and social systems, are able to produce the elements of which they are composed.

In general, what is it that characterizes wholes? Exemplification of whole as something connected may be acceptable for items of the physical or biological world. But, what about sociological 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 *in the same way* as material items are. This observation highlights how close the interplay is between the theory of wholes and the theory of levels.

The above classification can be further clarified by adding that aggregates are characterized by relations among their parts. Wholes require both part–part relations and part–whole relations, whereas a proper characterization of systems requires information on three kinds of relations: part–part relations, part–whole relations and whole–part relations (Poli, 2001*a*, Chapter 7).

Boundary. The following long section provides a preliminary outline of the subtleties and richness of the problem of boundaries.

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 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 level of detail, every whole vanishes into a continuum, or 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 level of granularity.

A few of the intricacies of the topic of boundaries can be exemplified by considering boundaries in a geographical sense. Consider for instance the following two questions.

(a) Does the underground boundary of a state coincide with its surface boundary? (b) Is the surface boundary always a line? Perhaps surprisingly, we must answer no to both questions. For these reasons.

As to (a): On 23 October 1950 Belgium and the Netherlands defined an underground mining boundary in the vicinity of the Meuse which was independent of the boundary between the two countries on the surface. This was done to reduce the amount of exploitable coal left in the ground to the minimum (*United Nations Treaty Series*, 1964, Vol. 507; quoted by Prescott, 1987).

To (b): Austria and Yugoslavia agreed on 10 March 1953 to create frontier strips on each side of their common boundary. These strips consisted of 195 Austrian communes and 41 political communes in Yugoslavia. Citizens living within these zones were entitled to cross the boundary without the usual formalities if they owned property which straddled the boundary or if they were concerned with herding livestock or with forestry on the other side of the line. This agreement specified 34 crossing points which could be used for this purpose (*United Nations Treaty Series*, 1963, Vol. 467; quoted by Prescott, 1987).

There is at least one more aspect of geographical/political boundaries that warrants some discussion: the question of the "building blocks". The building blocks problem is as follows:

> If we look at the historical series of European boundary treaties we may realise that boundary construction followed a hierarchy of local administrative units with precisely defined limits. International boundaries established by the various treaties coincide with the limits of *cantons*, principalities, bailiwicks, *cercles*, counties, Commanderie of the Teutonic Order, circuits, *arrondissements*, bishoprics, duchies, *landgravies*, *communes*, and parishes. That is to say that in most regions of Europe the land is divided into small parcels, which are sometimes aggregated into larger administrative units. These local divisions provide a series of building blocks from which national territories could be fashioned. Thus the international bargaining centred on pieces of territory, and once their disposition had been decided there was a ready-made boundary, which might at different sections coincide with known boundaries between parishes, bishoprics, and bailiwicks. It is quite interesting to note that this advantage is not available to the same extent in the Balkans were feudalism as known and practised in western Europe did not exist (Pounds, 1947, p. 129).

Boundaries may be more or less rigid and of different kinds. The type of boundary that may be relevant on any particular occasion depends on the level of the whole.

An essential feature of boundaries is that they can be crossed. There are more open boundaries and less open ones, but they can all be crossed. On the contrary, a horizon is something that we cannot reach or cross. In other words, *a horizon is not a boundary*. The difference between horizon and boundary is useful in distinguishing between system and environment. "Since the environment is delimited by open horizons, not by boundaries capable of being crossed, it is not a system" (Luhmann, 1984).

If we pay sufficient attention to the general phenomenology of the interior/exterior opposition, a great deal of interesting information is forthcoming: for example, that strictly speaking a boundary is a line or a surface that entirely encompasses a whole. A partial boundary would generate a partial whole, and what this would be is difficult to say.

A second important aspect is that in our case "the word 'external' does not have a spatial meaning". Internal and external are terms relative to wholes or to systems, not to their spatial location. A quotation may explain what I mean: "Bacteria in the organism and poisons which get into its blood represent complexes which are, in the organizational sense, not 'internal', but external to it, because they do not belong to the system of its organizational connections. And those parts of the system which go out of its organizational connections, though spatially located inside it, should also be considered as being ... external" (Bogdanov, 1984, p. 81). In other words, interior and exterior are first and foremost relative to the system, not to its location within physical space.

Let me add that internal and external can also be taken as features describing the difference between the world of things and the world of organisms. In the mechanistic order, the world is regarded as constituted of entities which are *outside of each other*, in the sense that they exist independently in different regions of space (and time) and interact through forces. By contrast, in a living organism, each part grows in the context of the whole, so that it does not exist independently; nor can it be said to merely "interact" with the others, without itself being essentially affected in this relationship. The parts of an organism grow and develop together. It is not difficult to see that what has been said is true for many kinds of system, for instance for both biological and social systems.

Boundaries may be clear cut, precise, rigid, or they may be vague, blurred, shifting, or again they may be intermediate between these two typical cases, according to how the differentiation is structured.

The usual dynamic is the following. It begins with vague, random oscillations. These introduce differences among the diverse areas of a region. The formation of borderline phenomena (of tension, pressure, competition) only occurs later, provided that the differences prove to be sufficiently significant. Even later there arises a centre or a node whose function is primarily to maintain the boundaries (Strassoldo, 1979, p. 162). Only at this stage do the boundaries become established and the initial differences due to random fluctuations acquire some solidity. In other words, boundaries logically and historically precede the centre (Di Sopra, 1975).

In terms of what has been said so far, it is natural to view boundaries from the standpoint of the barrier effects that they create. Boundaries separate or divide an interior from an exterior. On the other hand, it is equally evident that no system can survive in total isolation. From this point of view, boundaries give rise not only to barrier-effects but to link-effects as well: "Boundaries permit exchange of energy in many directions, that is between the parts, the parts and the whole, and between the whole and its environment" (Grinker, 1967*b*, p. 137).

Barrier- and link-effects are obviously not the only characteristics of boundaries. Other properties are the degree of closure or openness, multiplicity and the dynamics consequent on it.

Generally speaking, a closed boundary generates an internal situation characterized by limited differentiation. The interior is highly homogeneous and it is distinct from whatever lies outside. Hence, it follows that whatever lies externally is inevitably viewed as different, inferior, inimical; in short, as something to be kept at a distance. A second consequence of closed boundaries is the polarization of the space internal to the system into a centre and a periphery.

Open boundaries instead allow and encourage greater internal differentiation and therefore greater development of the system. In its turn, a population with marked internal differentiation, that is, with a higher degree of development, as well as having numerous internal boundaries is also surrounded by a nebula of functional and non-coincident boundaries (Strassoldo, 1979, p. 149). The distinction between centre and periphery tends to be replaced by a multiplicity of centres.

A complex society has many different types of boundary. Besides the obvious political and geographical boundaries (which often coincide), there are numerous others which do not coincide: economic or linguistic ones, for example. In general, a problem often deemed fundamental is the so-called problem of the "incongruity of national boundaries, and of minimizing them". In other words, the problem is one of finding "boundaries which reduce conflicts among nations to the minimum. From this point of view, the incongruity, the non-coincidence, the interpenetration of the different kinds of boundary (military, linguistic, geographical, economic, cultural, social, etc.) that entangle the state is seen as a lamentable deviation from the Platonic and Fichtian ideal-type of state: self-sufficient, autonomous, autarchic, sovereign, internally homogeneous and externally independent" (Strassoldo, 1979, p. 139).

From the preceding analysis some important consequences follow. First, social systems are always at least partially open systems. The only absolute boundary that we can reasonably posit for them (at least at the moment) is the entire planet. Second, boundaries are multiple and only randomly overlap with each other. A corollary to this feature is that social systems have never been delimited by boundary lines, but if anything by border areas (Strassoldo, 1979, p. 149). We may also say that "boundaries come in bundles" (Bertalanffy, 1972, p. 37).

The situation that requires analysis, therefore, is one characterized by the presence of numerous non-coincident boundaries. In this case, we realize that one of the principal reasons for dynamicity is precisely this non-coincidence. Efforts to harmonize, coordinate or integrate boundaries, whether political, administrative, military, economic, touristic, or otherwise, generate a dynamic which constantly re-equilibrates the boundary situation. The border area becomes highly active, and it is in this sense that we may interpret the remark by Ludwig von Bertalanffy that "ultimately, all boundaries are dynamic rather than spatial" (Bertalanffy, 1972, p. 37).

We have thus passed from discussion centred on a single boundary to a situation in which there are many of them: a border area, that is, which tends to become an autonomous zone with a life of its own. The boundary becomes an *organ* endowed with its own behaviour.

Corresponding to the logic of boundaries is a more or less correlative logic of centres. If to every boundary there corresponds a centre responsible for its maintenance, the dynamic of boundaries reverberates in a corresponding dynamic of centres.

The multiplicity of boundaries, and the dynamic that derives from it, generate interesting phenomena. Campbell (1958) was the first to point out that boundaries tend to reinforce one another. I quote Platt on the matter: "The boundary-surface for one property ... will tend to coincide with the boundary surfaces for many other properties ... because the surfaces are *mutually reinforcing*. I think that this somewhat astonishing regularity of nature has not been sufficiently emphasized in perception-philosophy. It is this that makes it useful and possible for us to identify sharply defined regions of space

as 'objects'. This is what makes a collection of properties a 'thing' rather than a smear of overlapping images. ... any violations of boundary-coincidence have an upsetting fascination for us, as in tales of ghosts, which can be seen but not touched'' (Platt, 1969, p. 203).

These latter remarks lead naturally from analysis of social systems to analysis of living ones. On passing to living systems, everything said so far as regards social systems evidently also applies to living ones.

The reference to living systems enables further aspects for a theory of boundaries to be identified with greater ease. Starting from the assertion that, for living systems as organisms, boundaries assume the appearance of a limiting membrane, it is evident that membranes have differing degrees of openness and closure to the environment. This means that they comprise a bundle of overlapping boundaries which individually or jointly comply with specific codes. Secondly, ''the intactness of this limiting membrane is essential for the integrity of the internal environment of the organism'' (Grinker, 1967*a*, p. 110).

Thirdly, a typical phenomenon of living systems, and of organisms in particular, is that their boundaries frequently contain 'gates'. A mouth is the most obvious example.

A further generalization is now necessary. When speaking of boundaries it is entirely natural to view them as external, and it is in this sense that they have been understood so far. However, closer examination reveals that every external boundary generates an internal one. The idea that systems have only an external boundary was typical of the last century. Ruesch writes: ''In the nineteenth century we viewed things as having only one boundary—namely, the outside. Freud, I think, was the first one who postulated that an entity had an inner and an outer boundary'' (Ruesch, 1967*a*, p. 37).

Some examples may be of help. For instance, the generation of the difference between centre and periphery due to the presence of a closed boundary corresponds to the generation of a delimitation of the centre with respect to the delimitation of the boundary of the whole. Further variations of the centre with respect to the periphery only confirm the point. The 'degree of structurality' of the centre (complexity, rarity, level of organization, variety and so on) is closely correlated to the size of the area of influence marked out by its boundaries. We may thus first distinguish the space of the centre delimited by the internal boundary. The various senses of the term 'centre'—which denotes a place which, compared with the environment, displays a particular hierarchy (of differentiated functional or structural roles) or a static spatial property (of position, extension, symmetry) or a dynamic one (of gravitation, attraction or divergence)—do not alter the essential datum that the centre is delimited by a boundary internal to the system. Secondly, we may distinguish the space of the periphery in which the sub-systems that constitute the substratum of the system reproduce themselves. This space is delimited by the external boundary. The third space is external space, that which lies outside the external boundary of the system (Di Sopra, 1975, pp. 61–62).

If boundaries are understood in the manner just described, ''for all this to be possible, systems must produce and utilize a description of themselves'' (Luhmann, 1984). And this they do only if ''they constitute and maintain themselves through the production and conservation of a difference with respect to the environment using their boundaries to regulate this difference. Without a difference with respect to the environment not

even self-reference would exist ... in this sense boundary maintenance coincides with maintenance of the system''.

A structurally stable system must be able to adjust the degree of openness and closure of its boundaries to its inner complexity. At least two dynamics are involved here. On the one hand, too open boundaries allow the development of greater differentiation and hence the greater development of the system, but they eventually dissolve its identity. On the other hand, too closed boundaries maintain a strong systemic identity but they hamper the development of more articulated inner differentiations. The chances of survival depend to a large extent on these boundary dynamics.

At this juncture, I can further complicate my analysis by passing from the whole/environment situation to the situation in which there are simultaneously many wholes and therefore many environments, or one in which there is a higher-order whole characterized by its own environment. In a certain sense, it is obvious that: ''No systems live in an environment that is only composed by one further system. Therefore a distinction between system/environment relations and system/system relations (or: intersystem relations) must be pointed out. This difference is central for any accurate analysis of boundaries, just because boundaries are all too often considered as identical for both relations'' (Luhmann, 1982, p. 235).

Other factors to consider in constructing a systematic theory of boundaries are, for example, size, situation, density and proportion (Ruesch, 1967*b*, p. 341), as well as scale of observation and the direction of energy–matter flows. However, I have insufficient space to examine these further aspects here.

We may now collate the information extrapolated so far in the following synopsis

1. Cardinality	(as a single boundary or as a border area).
2. Nature	(external, internal).
3. Form	(open/closed, mobile/static).
4. Structure	(gates, filters and overlappings).
5. Dynamic	(changes in location, boundary exchange).
6. Maintenance	(integrity, growth, destruction) (Ruesch, 1967*b*, pp. 345–7, with additions Poli, 2001*a*)

In conclusion, I wish to add a pair of final remarks. The analysis set out in this section has been conducted with deliberate omission of any reference to levels. Boundaries, for that matter, are also boundaries among the different levels of an item. Explicit consideration of the problem of stratification into levels as well would have made the analysis significantly more complex.

We have seen that substances have a very complex structure comprising (1) particular (2) level, and (3) composition [see Poli (2001*a*) for further details]. Particular concerns the items' basic nature, level relates to the theory of levels of reality (material, psychological, social, each subdivided into appropriate sub-levels; in this paper I have not addressed the problem of the ideal stratum); composition concerns part–whole relations. Further aspects, like the problem of the levels of command (echelons, in Miller's terminology: see Miller, 1978; Miller & Miller, 1992) have not been addressed.

4.2. DETERMINATIONS

Determinations can be classified according to different criteria. Two major criteria are the determinable/determinate opposition and the intensive/extensive opposition. I have just published a wide-ranging analysis of the determinable/determinate opposition and refer interested readers to it (Poli, 2002*b*). In this paper, I briefly recall the basic features of the intensive–extensive opposition.

The following table sums up the main data on extensive oppositions. Extensive oppositions: 1. always exist between two points; 2. for every genus there is only one specific instance; 3. the instantiated attribute of the whole contains smaller parts (diverse as instances) of its genus (volume in volumes, shape in shapes); 4. are never lower dimensional; can be summed (aggregated); 5. have a prothetic order (based on "more than").

Complementarily, intensive determinations: 1. may be punctiform in nature (they are not necessarily extended); 2. for every genus, a whole may have many specific instances; 3. do not contain smaller parts (diverse as instances) of the genus; 4. may be lower-dimensional attributes of other attributes; 5. cannot be summed (aggregated) (the colour of a whole is not the sum of the colours of its parts, if anything it is the pattern of the colours of its parts); 6. have a metathetic or positional order (based on "different from").

The characteristics of extensive and intensive determinations are taken from Johansson (1989), with the exception of the last one, which is from Stevens (1986) (the terminology of the two authors is different, however).

A particular may have only one volume, mass, density pattern, colour pattern. These are extensive determinations. However, a particular may have various colours and various densities. These are intensive determinations.

Extensive and intensive determinations are also distinguished by space and time (see Table 3).

5. Again on levels

There are general categories that apply to all the ontological strata: for example, the category of part. 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

TABLE 3

	Intensive in time	Extensive in time
Intensive in space	Colour, field strength, density, mixtures, tendencies, states, velocity, character traits	Change (of velocity, of colour), point-formed motion
Extensive in space	Volume, mass charge, voltage, shape, density and colour patterns	Motion, function, action, work

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 specifications of part for each ontological level.

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

Each ontological level is characterized by the presence of a group of categories typical of that level. The first task, therefore, is to find the most general categories typical of that level. There will then be groups of categories that mark out particular sub-levels.

Two important points require mentioning 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 general 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 artefacts. 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 artefacts, 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. It is this ''transversality'' that makes the categorization of many domain ontologies such a complex undertaking.

6. Methodology of domain analysis

From an ontological viewpoint, at least two major aspects should be addressed: (1) the universal basic structure of a domain, and (2) the basic scheme of the domain's prototypical items. Let us look at these separately.

6.1. A DOMAINS' BASIC STRUCTURE

I shall distinguish among a domain's external, internal and mixed dimensions. To aid understanding, I shall exemplify my proposal by considering two different complex domains, namely those of sport and of literary works of art.

The first two dimensions are by far the most relevant. I therefore start with their analysis. The internal dimension concerns information related to the concrete performance of any sport, whereas the external dimension regards everything related to the organization, the regulation and the study of sports. Internal dimensions for the domain of literary works of art comprise the writing down of the work, whereas external dimensions are linked to its fruition (copyrights, publication, etc.). For both

domains, mixed dimensions concern areas of systematic overlapping with other domains.

Table 4 provides details on the domain of sports [and the sub-domain of fencing; basic data from Giusteschi and Fazio (1997*a*, *b*) and personal communications with the authors].

Internal dimensions concern the effective playing of sport. Actual performances, training, analyses of basic and complex movements, intentions sustaining performed movements (attack, defence, feint) are all proper aspects of internal dimensions. Generally speaking, sports are based on movements that we all are able to perform (running, jumping, throwing, etc.). These ground movements are possibly linked to or enhanced by specific tools (weight, javelin, racket, foil, etc.). Basic or ground movements depend on our biological constitution.

As a consequence they cannot gainsay the results yielded by the anatomical and physical study of the human and animal body. In reality, however, the basis of sport is neither medical nor biological but phenomenological. What truly counts is our experience of movement (running, for example, or jumping), the pleasure or satisfaction that we gain from it, and perhaps our desire to enhance the experience as much as possible. Medical, physiological and biochemical knowledge comes into play only afterwards as sources of information enabling us to achieve certain goals more efficaciously.

The grounding of sport in the experience of our elementary movements is then augmented by the more complex forms of experience that have accumulated historically (duelling, etc.). Both the elementary forms of movement and the more sophisticated ones tied to subsequent historical developments undergo a process of refinement and stylization that leads to codification of explicit rules (permitted movements, etc.). All professional sports, and the majority of amateur ones, are governed by explicitly formulated rules.

The purpose of training is to transform natural movements into movements codified by the rules and to acquire the automatisms necessary for adequate and efficient performance of those movements.

The structure of a sports contest is not limited to the more or less successful execution of certain movements; it also involves classification of the contestants according to their performance. This aspect introduces a further dimension: besides enjoyment of the movement (whether natural or conventional) there is enjoyment of the competition and of possible victory. Which means that the various movements must be coordinated so that a positive outcome is achieved. For example, in the case of two-sided contests in which an individual or group must counter the moves of an opponent, the latter must be attacked, perhaps by resorting to forms of deception (feints, etc., within the bounds set by the regulations). Other types of sporting contests may display a different phenomenology of the actions involved.

Unlike the inner dimension, the external one is a social dimension which is closely related to institutional structures (rules, regulations, associations, tournaments) and the material facilities that enable the sport to be played (stadiums, sports arenas, various types of facility).

Although the internal dimension is also social in nature, it emphasizes the intentional aspects of sport. Unlike purely mental intentions, the physical ones of sport are mostly

TABLE 4

1. External dimension
  1.1. Descriptive
    1.1.1. Terminology
      1.1.1.1. General Terminology
      1.1.1.2. Specific Terminology (Relative to any particular discipline)
    1.1.2. Type
      1.1.2.1. Tennis
      1.1.2.2. Fencing
      1.1.2.3. Football
      1.1.2.4. Etc.
    1.1.3. Mode
      1.1.3.1. Amateur
      1.1.3.2. Professional
    1.1.4. Ground
      1.1.4.1. Field
      1.1.4.2. Ring
      1.1.4.3. Etc.
    1.1.5. Placement
      1.1.5.1. Indoor
      1.1.5.2. Outdoor
    1.1.6. Equipment
      1.1.6.1. Clothing
      1.1.6.1. Tool
        1.1.6.2.1. Weapon
          1.1.6.2.1.1. ForFencing
            1.1.6.2.1.1.1. Sabre
            1.1.6.2.1.1.2. Epee
            1.1.6.2.1.1.3. Foil
        1.1.6.2.2. Etc.
      1.1.6.3. Apparatus
        1.1.6.3.1. Electrical Apparatus
        1.1.6.3.2. Etc.
      1.1.6.4. Etc.
  1.2. Structural
    1.1.2. Organization
      1.2.1.1. FIFA
      1.2.1.2. CONI
      1.2.1.3. Etc.
    1.2.2. Competition
      1.2.2.1. Olympiad
      1.2.2.2. Championship
      1.2.2.3. Tournament
      1.2.2.4. Etc.
    1.2.3. Rule
      1.2.3.1. For Fencing
        1.2.3.1.1. Organization
        1.2.3.1.2. Competition
        1.2.3.1.2. Event
          1.2.3.1.3.1. Athlete
          1.2.3.1.3.2. Official
            1.2.3.1.3.2.1. Jury
            1.2.3.1.3.2.2. AuxiliaryPersonnel

1.2.3.1.4. Judging
1.2.3.1.4.1. GeneralConvention
1.2.3.1.4.1.1. ObservanceOfThePhrase
1.2.3.1.4.1.2. Time
1.2.3.1.4.1.3. Target
1.2.3.1.4.1.4. Measure
1.2.3.1.4.2. ActualApplication
1.2.3.1.4.3. Materiality
1.2.3.1.4.4. Analysis
1.2.3.1.5. Equipment
1.3. History
1.4. Theory
2. Internal dimension
2.1. Basic
2.1.1. Movement
2.1.2. Intention
2.1.2.1. Position
2.1.2.2. Action
2.1.2.2.1. Offensive
2.1.2.2.1.1. PreparationOfAttack
2.1.2.2.1.2. Attack
2.1.2.2.2. Defensive
2.1.2.2.2.1. ParryResponding
2.1.2.3. Fault
2.1.2.4. Tactic
2.2. Aspect
2.1.1. Training
2.1.2. Playing
2. Mixed dimension
3.1. Medicine
3.2. Law
3.3. Economics
3.4. Press

externalized and are expressed in specific movements and combinations of movements. Of course, also involved are the athlete's directly subjective intentions (determination and will to win) as well as intermediate ones tied to the dynamic of the contest (the fear of winning typical of certain phases of tennis matches).

Note that the external and internal dimensions are also distinguished by their different ontological characterization: most of the external items are objects, while the internal ones are processes (events).

The case of literature is very similar. A literary work of art can be viewed as the concrete product of its author's intentions. Because it is reified, a literary object is independent of its author and has its own existence. While sport is based on movements, their codification, and their coordination to achieve victory, a literary work is based on words, phrases and other linguistic structures which convey the author's intentions. Thus, just as a single movement is not a sport, so a single word is not a literary work. A set of movements and a set of (written) words may respectively become sports events and literary objects. In both cases there are amateurs and professionals,

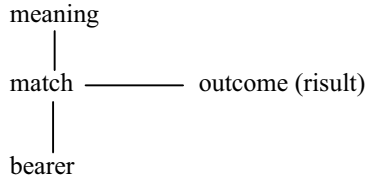
and in both cases the professional is someone able to perform the activity to the maximum extent.

The main difference between the domain "sport" and the domain "literary works of art" is the following. In the case of sport, the inner dimensions concern structural and functional analyses of *doing sport*, while in the case of literature they concern structural and functional analysis of (particular) *objects*. This difference springs from the unit of reference, which in the case of sport is an event, while in the case of a literary work of art is an object. Information about this aspect (whether we are dealing primarily with objects or events or some other category) is provided by the next structure: the basic scheme of the canonical item of a domain.

6.2. BASIC SCHEME OF THE CANONICAL ITEM OF A DOMAIN

I shall exemplify the schemes relative to sport and a literary work. Both sport and literary works are social realities. Which means that they have a stratified structure characterized by a directly social nucleus with two fringes: below they require material bearers that bring social phenomena into existence; above they require meanings.

The nucleus for sport could be the following:



The unit of reference is the sporting contest. This has a material base (stadium, gymnasium, ring, swimming pool, etc.) and instantiates contents (the idea of competition, challenge, etc.). The event has outcomes (at minimum a result).

The category *match* is a complex involving numerous participants which, as shown by Table 5, can be divided into active and passive (vis-à-vis the contest).

The category *match* pertains to the category *process*, as discussed in the previous section. Each of the participants is a social actor with specific properties, etc.

We may now turn to the case of literature. Literature is a social phenomenon (a social product) which can be described on the basis of the following structure.

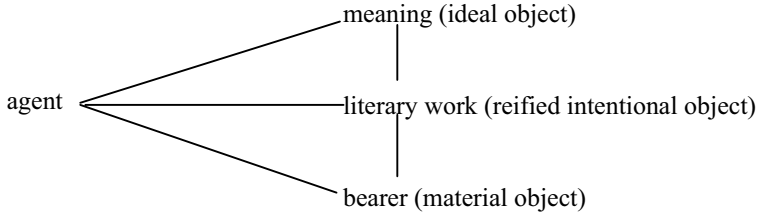
1. The agent (author) produces an object (literary work) which instantiates (exemplifies, concretizes) his/her intentions. A literary work is therefore firstly an *intentional object*.

TABLE 5

Active participants:	internal (contestants) external (referees) auxiliaries (technicians of various kinds)
Passive participants:	supporters

2. Secondly, once produced, a literary work has its own existence independent of the author. It is therefore a *reified intentional object*.
3. A literary work necessarily requires a material bearer, a support which enables it to take concrete form (manuscript, book, journal, CD-Rom, videotape, etc).
4. Equally necessarily, a literary work instantiates (exemplifies, concretizes) meanings (which are ideal objects).

The base scheme is therefore as follows:



The first feature to note is that each of the categories used is defined with respect to more primitive ontological categories. In all cases we have an *object* (and not, for example, a process or a group). The various objects are distinguished with respect to the levels of reality that characterize them: the bearer is *material*, the literary work is *reified intentional* (one of the forms of the social level), the meaning is *ideal*, the agent (author) is a complex reality which for the moment we may take to be *mental* (this is the aspect that interests us because it is the source of the intentional acts that give rise to the intentional object reified in the literary work). In reality, also the agent is multistratified in its structure, but for the moment we may ignore this.

The next step is to articulate the various categories that make up the scheme just seen.

Leaving *agent* and *bearer* aside, the main problem is the articulation of *meaning* and *literary work*. These two levels are connected as type and instance: like, for example, ''poetry'' and ''Faerie Queene''. Besides analysis at this highly general level, numerous more sectoral ones are conducted: of the relationship among the notions of honour, love, pain, pleasure, etc., and the specific ways in which these are expressed in literary works. In their turn, these various modes are grouped into historically determined styles (i.e. as schematic, prototypical ways to express content: the essential references on the relationships between ontology and aesthetics are Ingarden, 1973, 1989; Hartmann, 1933, 1950; cf. Poli, 1998).

7. Standard Template Library

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 *formal* standards. In this area, KIF has become an accepted standard 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. Formal languages are part and parcel of formalized ontology, but they cannot be extended to cover the fields of either descriptive or categorical ontologies.

In other words, what we really need is a Standard Template Library for *ontological categories and constructs*: for use, for example, in structuring analysis of the LEVELS of objects and their forms of dependence and independence, in the analysis of categories like PROCESS, OBJECT, GROUP, PART and WHOLE. Moreover, we need semiotic and semantic frameworks. Indeed, it would be extremely useful to have templates 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 far 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 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 15 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.

8. Filterings and extensions

The picture thus outlined does not offer easy short cuts. On the other hand, only a unitary picture such as this may enable the study of the multiple relations of dependence and autonomy among the various ambits of reality, without having to reduce reality to some form or other of gratuitous existential autonomy.

In cases where ontology is used for particular applications—NLP or databases, for example—the framework described must both be suitably *filtered* or *frozen* (with respect to suitable parameters) and *extended*.

The 'freezing' will enable calibration of the various sections of general ontology to the specific intended application. For example, one can "reduce" the problem of temporality by separating the time dimension from other dimensions and assigning it an ordering structure (linear, branching, discrete, continuous, differentiable, etc.). In this way, time becomes an external parameter, and the dynamic operates internally to a qualitative phase space $\mathbf{T}\times\mathbf{Q}$.

Obviously, different freezing procedures may give rise to different sub-ontologies or to different forms of ontology.

On the other hand, the "extension" procedure will add semiotic and cognitive components. Consider, say, conceptual lexica and linguistic corpora. It is a well-known fact that terms can be categorized at several levels. This means that every term should be accessible by default only in its generic sense (infarct = heart attack), while its generic meanings are made explicit when general ontology is activated and its special meanings are only made explicit when specific domain ontologies are activated. On the other hand, both general and domain ontology contain categories which do not have analytical correspondences in generic knowledge. A knowledge of general ontology

provides extended and deeper structure to generic knowledge, whereas knowledge of the domain fills or saturates it.

9. Cooperations

From what I have written, it is clear that ontology needs the contributions of mathematicians, logicians, linguists, psychologists, social scientists and philosophers. Collaboration with philosophers is possibly the most difficult. Years ago, McCarthy noticed that "Either no one in AI, including retreated philosophers, understands philosophical theories well enough to program a computer in accordance with their tenets, or the philosophers haven't even come close to the required precision. Actually it seems that some of the empiricist philosophies may be precise enough but turn out to be inadequate when one attempts to use the most modest computer programs" (Lifschitz, 1990, p. 244). The situation is even worse than that because the two most influential philosophers of the last 50 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 revert to a more natural standpoint.

On the other hand, 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. For this reason, both analytic philosophy and continental philosophy are unsuited to 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 19th and early 20th 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 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 20th century* (see references. The only available English introduction to his thought is Werkmeister, 1990). Philosophers in the English-speaking world who have argued substantially similar positions—although not directly influenced by the above authors—have been Charles S. Peirce and Alfred N. Whitehead.

10. Conclusion: who knows something about ontology?

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 can easily foresee 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 general 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.

References

Albertazzi, L. (1999*a*). The time of presentness. A chapter in positivistic and descriptive psychology. *Axiomathes*, **10,** 49–73.

Albertazzi, L. (1999*b*). Form metaphysics. In L. Albertazzi, Ed. *Shapes of Forms. From Gestalt Psychology to Phenomenology to Ontology and Mathematics*. Dordrecht: Kluwer, 1999, pp. 257–305.

Albertazzi, L. (2001). The primitives of presentation. Parts, wholes, and psychophysics. In L. Albertazzi, Ed. *The Dawn of Cognitive Science. Early European Contributors*. Dordrecht: Kluwer, 2001, pp. 29–60.

Bertalanffy, L. von (1972). The history and status of general systems theory. In G. J. Klir, Ed. *Trends in General Systems Theory*. New York: Wiley, 1972, pp. 21–41.

Bogdanov, A. (1984). *Essays in Tektology. The General Science of Organization.* Seaside, CA: Intersystems Publications.

Brentano, F. (1968). Habilitationsthesen (1866). In F. Brentano, Ed. *Über die Zukunft der Philosophie*. Hamburg: Meiner.

Brentano, F. (1988). *Philosophical Investigations on Space, Time and the Continuum*. London: Croom Helm.

Campbell, D. T. (1958). Common fate, similarity, and other indices of the status of aggregates of persons as social entitites. *Behavioral Science,* **3,** 14–25.

Di Sopra, L. (1975). *Lo spazio merce*, Venezia: Marsilio.

Fridman Noy, N. & Hafner, C. D. (1997). The state of the art in ontology design. *AI Magazine*, 53–74.

Giusteschi, C. & Fazio, A. (1997*a*). Terminology advances the culture of sport. *Proceedings of the 10th Congress IASI* "*Sports Information Without Borders*", Paris 10–12 Giugno.

Giusteschi, C. & Fazio, A. (1997*b*). A tool for the organization of sports terminology. *Proceedings of the 10th Congress IASI* "*Sports Information Without Borders*", Paris 10–12 Giugno.

Grinker, R. R., Ed. (1967*a*). *Toward a Unified Theory of Human Behavior*. (2nd edn) New York: Basic Books. (1st edn 1956).

GRINKER, R. R. (1967*b*). Comparisons between systems of organization. In R. R. GRINKER, Ed. *Toward a Unified Theory of Human Behavior* (2nd edn) pp. 135–141. New York: Basic Books (1st edn 1956).

GUARINO, N. & GIARETTA, P. (1995). Ontologies and knowledge-bases. Towards a terminological clarification. In N. J. I. MARS, Ed. *Towards Very Large Knowledge Bases*, pp. 25–32. Burke, VA: IOS Press.

HARTMANN, N. (1933). *Das Problem des geistinen Seins*. Berlin: De Gruyter.

HARTMANN, N. (1935). *Zur Grundlegung der Ontologie*. Berlin: W. de Gruyter.

HARTMANN, N. (1950). *Aesthetik*. Berlin: de Gruyter.

HARTMANN, N. (1952). *The New Ways of Ontology*. Chicago.

HUSSERL, E. (1970). *Logical Investigations*, London: Routledge & Kegan Paul, 2 Vols.

HUSSERL, E. (1989). *Ideas Pertaining to a Pure Phenomenology and to a Phenomenological Philosophy*. Dordrecht: Kluwer.

INGARDEN, R. (1973). *The Literary Work of Art: With an Appendix on the Functions of Language in the Theater*. Evanston, IL: Northwestern University Press.

INGARDEN, R. (1989). *Ontology of the Work of Art*. Athens, OH: Ohio University Press.

JOHANSSON, I. (1989). *Ontological Investigations*. London: Routledge.

LAWVERE, W (1969). Adjointness in foundations. *Dialectica*, **23,** 281–296.

LIFSCHITZ, V. Ed. (1990). *Formalizing Common Sense. Papers by John McCarthy*. Norwood, NJ: Ablex Publishing Corporation.

LUHMANN, N. (1982). Territorial borders as system boundaries. In R. STRASSOLDO & G. DELLI ZOTTI Eds. *Cooperation and Conflict in Border Areas*. pp. 235–244. Milano: Angeli

LUHMANN, N. (1984). *Soziale Systeme. Grundriss einer allgemeinen Theorie.* Frankfurt: Suhrkamp.

MILLER, J. G. (1978). *Living Systems*. New York: McGraw-Hill.

MILLER, J. L. & MILLER, J. G. (1992). Greater than the sum of its parts I. Subsystems which process both matter-energy and information. *Behavioral science,* **37,** 1–38.

PEIRCE, CH. S. (1991–1998). In N. HOUSER & C. KLOESEL and members of the Peirce Edition Project Eds. *The Essential Peirce*. 2 Vols., Bloomington: Indiana University Press.

PETRAZYCKI, L. (1955). *Law and Morality* (partial tr. by H. W. BABB, with an intr. by N. S. TIMASHEFF). Cambridge, MA: Harvard University Press.

PLATT, J. (1969). Theorems on Boundaries in Hierarchical Systems. In WHYTE, WILSON and WILSON 1969, pp. 201–213.

POLI, R. (1996). Ontology for knowledge organization. In R. GREEN Ed. *Knowledge Organization and Change*. pp. 313–319. INDEKS Verlag: Frankfurt /Main.

POLI, R. (1998). Levels. *Axiomathes*, **9,** 197–211.

POLI, R. (1999). *Framing Ontology* http://www.formalontology.it.

POLI, R. (2001*a*). *Alwis. Ontology for knowledge engineers*. Ph.D. thesis, Utrecht.

POLI, R. (2001*b*). Foreword. *Axiomathes*, **12,** 5–9.

POLI, R. (2002*a*). Descriptive, formal, and formalized ontologies. In D. FISETTE Ed. *Edmund Husserl's Logical Investigations 1901–2001: Origins and Posterity of Phenomenology*. Dordrecht: Kluwer, forthcoming.

POLI, R. (2001*c*). The basic problem of the theory of levels of reality. *Axiomathes*, **12,** 261–283.

POLI, R. (2002*b*). W. E. Johnson's determinable–determinate opposition and his theory of abstraction. *Poznan Studies in the Philosophy of the Sciences and the Humanities*, forthcoming.

POLI, R. & MAZZOLA, G. (2000). Semiotic aspects of generalized bases of data. In E. KAWAGUCHI, H. KANGASSALO, H. JAAKKOLA & I. A. HAMID Eds. *Information Modelling and Knowledge Bases XI*. pp. 1–11. Amsterdam: IOS Press.

POUNDS, N. I. G. (1947). *An Historical and Political Geography of Europe*. London: Harrap.

PRESCOTT, J. R. V. (1987). *Political Frontiers and Boundaries*. London: Allen & Unwin.

RUESCH, J. (1967*a*). The observer and the observed: human communication theory. In R. R. GRINKER Ed. *Toward a Unified Theory of Human Behavior* (2nd edn) pp. 36–54 (1st edn 1956). New York: Basic Books.

Ruesch, J. (1967*b*). Analysis of various types of boundaries. In R. R. Grinker Ed. *Toward a Unified Theory of Human Behavior*. (2nd edn) pp. 340–361. (1st edn 1956) New York: Basic Books.
Smith, B. C. (1996). *On the Origin of Objects*. Cambridge MA: MIT Press.
Sowa, J. F. (2000). *Knowledge Representation: Logical, Philosophical, and Computational Foundations*. Pacific Grove, CA: Brooks/Cole Publishing Co..
Stevens, S. S. (1986). *Psychophysics. Introduction to its Perceptual, Neural, and Social Prospects*. New Brunswick (USA) Oxford: Transaction Books 1986 (1st edn, Wiley, New York, 1975).
Strassoldo, R. (1979). *Temi di sociologia delle relazioni internazionali*. Gorizia: ISIG.
Werkmeister, W. (1990). *Nicolai Hartmann's New Ontology*. Tallahassee: Florida State University.
Whitehead, A. N. (1978). *Process and Reality* (corrected version D. R. Griffin & D. W. Sheburne, Eds, New York and London: The Free Press.
Whyte, L. L., Wilson, A. G. & Wilson, D. (1969). *Hierarchical Structures*. New York: Elsevier.