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Categories and facets in integrative levels

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Abstract

Facets and general categories used in bibliographic classification have been based on a disciplinary organization of knowledge. However, facets and categories of phenomena independent from disciplines can be identified similarly. Phenomena can be classified according to a series of integrative levels (layers), which in turn can be grouped into the major strata of form, matter, life, mind, society and culture, agreeing with Nicolai Hartmann's ontology. Unlike a layer, a stratum is not constituted of elements of the lower ones; rather, it represents the formal pattern of the lower ones, like the horse hoof represents the shape of the steppe. Bibliographic categories can now be seen in the light of level theory: some categories are truly general, while others only appear at a given level, being the realization of a general category in the specific context of the level: these are the facets of that level. In the notation of the Integrative Level Classification project, categories and facets are represented by digits, and displayed in a Web interface with the help of colours.

Keywords: building-above relationship; disciplines; facet analysis; fundamental categories; Integrative Level Classification; Nicolai Hartmann; levels of reality

1 **Classifying phenomena vs. disciplines**

Most bibliographic classification schemes have been based until now on disciplines. That is, what they classify is not directly phenomena of the world, but rather the fields and approaches by which humans know the world. Indeed, in these schemes main classes are disciplines, like "philosophy", "chemistry", or "sociology", and thus their subdivisions are subdivisions of these disciplines. This is what happens in the Dewey Decimal Classification, the Universal Decimal Classification, and the Library of Congress Classification, the most used schemes in libraries throughout the world.

Faceted schemes, like the Colon Classification and the Bliss Bibliographic Classification 2nd edition, have introduced the basic innovation of facet analysis into their structure. However, what is analyzed into facets are still disciplinary main classes. We have the facets of chemistry, the facets of sociology, and so on. Some of these facets, e.g. "reactant" or "catalyzer", overlap with facets of the studied phenomena; but others, e.g. "experimental conditions" or "application", refer to the methods and theoretical structure of the discipline. A molecular compound has no experimental conditions or application of its own: it gets them only when it becomes the object of chemical study (Gnoli 2006).

Many scholars in bibliographic classification have observed that the disciplinary approach is not the only possible one, and that together with benefits (like reflecting the most frequent approach of researchers) it also brings limitations, especially for interdisciplinary and innovative research.

Indeed, disciplines act as a canonical grid forcing the users to follow their conceptual structures, thus failing to find cross-disciplinary relations between information items that could be fruitful (Kyle 1959; Austin 1969*a*; Foskett 1970; Weinberg 1996; Beghtol 1998; Williamson 1998; Gnoli *et al.* 2007; Szostak 2007). Interdisciplinary classification is especially desirable in the present age of increasing cross-fertilization between knowledge fields, and of information exchange on a global scale, making it impossible to foresee the identity of users that will access a particular knowledge

base: today, classification should serve an international and intercultural user target (Beghtol 1998).

To abandon disciplines as the primary structuring principle of knowledge organization means that what should be organized are now directly phenomena of the world (as known by us). A classification scheme should then have phenomena as its primary subdivisions. It should make its users able to express, instead of the concept "the objects of zoological studies", directly that of "animals", without any a-priori implication that they be studied by zoology, or veterinary medicine, or food science, or transport history. This does not mean that the theories and methods of disciplinary studies cannot be expressed in the classmarks: but they will be one optional specification among others, while priority will be given to phenomena (Szostak 2007).

2 Integrative level classification

One suitable principle to classify phenomena independently from disciplines has been found to be the notion of *integrative levels*, also referred to as "levels of organization" or (less accurately) "levels of complexity". These terms refer to the observation that world phenomena belong to different ontological levels, spanning from the material, to the organic, the mental, and the cultural (Poli 1998). This notion can be found in various formulations in the writings of many philosophers and scientists. In the modern age, it is connected with the idea of a cosmic evolution, through which more and more organized entities have been formed (particles, atoms, molecules, celestial objects, cells, organisms, minds, societies, cultures), while the simpler ones have continued to exist alongside (e.g., while animals have evolved to intelligent forms, bacteria continue to be the most widespread, and in a sense successful, form of life (Gould 1996)).

In a more explicit form, the notion of increasing levels of organization can be traced back to the works of Auguste Comte and of Herbert Spencer, who have influenced classification theorists like

Henry Evelyn Bliss. In the 20th century, an English speaking line of thinkers passes through Samuel Alexander, Conwy Lloyd Morgan, George Conger, and Joseph Needham, coming to the formulation of "laws of integrative levels" by James K. Feibleman; while more recently, similar ideas have been expressed by Max Pettersson (bibliography in Gnoli and Hong (2005)).

Needham and Feibleman have been sources for the specialist librarians working in the Classification Research Group (CRG) during the 1960s, who were charged by NATO to explore the possibility of a new general classification scheme (Gnoli and Poli 2004). The CRG tried to apply the laws of integrative levels to the construction of a general scheme of phenomena, and discussed results and problems of this approach (Foskett 1961; 1970). The NATO project was very innovative in terms of classification theory; it was discussed for some time in the specialized literature, but was not funded further and never reached the stage of a published usable classification scheme.

The notion of integrative levels was later used by Ingetraut Dahlberg to identify and order the ten main classes ("areas") of her Information Coding Classification (Dahlberg in this issue). She referred both to Feibleman and to Nicolai Hartmann, who had developed an independent theory of levels in the context of German ontology. Although their notions of levels are similar, Hartmann insists more on the categorial novelty of the properties of each stratum, than on the continuity between the lower and the higher levels; furthermore, he distinguishes between ontical *strata* (being only four), and their secondary subdivisions, called *layers* (Hartmann 1940; Poli 2001).

Since 2004, a new research project (ILC) within the Italian chapter of the International Society for Knowledge Organization (ISKO) has resumed work on the application of integrative levels to phenomenon classification. A provisional scheme is being developed and tested by classing bibliographical records in several domains (Gnoli and Hong 2006). The scheme structure is similar to that of the NATO project, with the main classes, marked by capital letters, each corresponding to

an integrative level. Subclasses are marked by further letters and also arranged by evolutionary criteria, while digits mark the facets of each class:

M	organisms		
Mq	animals		
Mqv	chordates		
Mqvt	mammals		
Mqvtn	whales		
Mqvtn5	whale organs		
Mqvtn5n	whale nervous system		
Mqvtn5nr	whale brain		

3 Categorical systems governing facets

As for facets, the ILC scheme makes use of the consolidated techniques of faceted classification. These include identifying a set of facets in each main class, that appear as the most useful to model it. They can be understood as shorthands for the most frequent and relevant relations existing between each phenomenon and other phenomena. A standard citation order must then be established between these facets, to express them within compound subjects in a predictable order, and to sort compound subjects in a most effective sequence.

A guide to the identification and ordering of facets can be provided by a set of *fundamental categories*. These are general categories, valid throughout all classes, to which the facets belong (Vickery in this Special Issue). For example, the class of organisms can have a facet of physiological processes, including digestion, respiration, excretion etc., and this facet can belong to

the fundamental category of Energy, as it represents a dynamic feature of organisms. Thus, categories summarize the kinds of relationships expressed in facets, and give them a standard order.

Ranganathan claimed that fundamental categories are in number of five, and called them Personality, Matter, Energy, Space, and Time (often recalled by the acronym *PMEST*). In later editions of his works, Matter was distinguished into Matter-property and Matter-material. In the notation of his Colon Classification, each category is introduced by a certain punctuation mark: so that the facet of physiological processes, being a realization of the Energy category, would be introduced by a colon. The first three categories can occur in more than one *round*: a facet of Energy can be followed by a second-round facet of Personality, or of Matter, and so on.

Ranganathan represents them by *facet formulas* of the type of "1P 1M 1E 2P 2M 2E 3P S T".

Given their general applicability, fundamental categories have an obvious philosophical interest. The categories of Ranganathan have been variously related to Aristotle (Glazier and Glazier 2003), to Spencer (Gatto *pers. comm.*), or to Indian philosophy (Freschi 1989); in particular, they look analogous to the categories of Dravya, Guna, and Karma in the Vaiśeṣika school (Mazzocchi and Gnoli 2006).

Bibliographic categories also show analogies with linguistic categories or roles, especially the so-called deep cases (Fillmore 1968) to which cases and prepositions in any natural language could be reduced. This should not be a surprise, as a classification after all is an artificial language, having its own syntactical structures and rules like any language. The syntax of facets can be described in terms of predicate logic (Gnoli 2006). Verbal indexing languages, like thesauri and subject headings, also use relations and operators to connect concepts, that are functionally equivalent to facets: the various systems have been compared and summarized in a limited set of categories by Perreault (1965).

Authors of faceted classification schemes after Ranganathan have also used grids of fundamental categories: for a comparative review see La Barre (2006, p. 277). Experience with the construction of many special schemes persuaded the members of the CRG to introduce a revised set of categories (Vickery 1958; 1960). Some of Ranganathan's categories were kept, although in some cases their name was modified (Table 1): in particular, the esoteric term "Personality", meaning the focus object of a field of study, was substituted by Object or Thing or Entity. Matter was better distinguished into Part, Material, and Property; Part was in turn distinguished by Vickery into Constituent part (like bricks and glass in houses) and Organ or functional parts (like floor and roof in houses). Ranganathan's Energy was distinguished into Process or Action, happening spontaneously in the observed entity, and Operation, done on the entity by an external agent, often a human or a tool used to perform the operation. This agent goes in a new Agent category, which in practice corresponds, in both meaning and position, to the second-round Personality of many classes in the Colon Classification. On the categories of Space and Time, probably the easiest to grasp, most authors agree.

CRG authors emphasize that this grid of categories is not absolute, and should act more as a guide than a prescription: different facets and facet orders can be defined in those fields and applications where a need for them is felt. Thus, in the CRG tradition the pragmatic side of categories prevails on the philosophical. Vickery lists other possible categories, like Measure and Patient occurring after Property, or Interaction after Process. Mills and Broughton (1977) use several CRG categories in the design of the Bliss Classification 2nd edition, moving Patient after Operation and adding after it Product and By-product for technological disciplines. Broughton and Slavić (2007) kept ten categories for the FATKS project, which was devoted to the classification of humanities, with the interesting addition of Theory after Time. Broughton (2006, p. 53) believes that "arts and humanities often require some additional ones (form, style, genre)", although these seem to be

facets of a specific domain, that can be reduced to existing categories like Quality.

Dahlberg (1978; this issue) claims that concepts can be analyzed into their facets by a system of categories based on that of Aristotle. In her Information Coding Classification, knowledge fields are analyzed according to a set of "system principles", called the Systematifier. These are categories referring to the aspects of a knowledge field and represented by digits, like theoretical foundation 1, methodology 3, special forms 6, applications 8, environment of study 9. Unlike standard facets, they can be applied recursively, so that area 2 "matter and energy" has a special form subclass 26 "chemistry", and an application subclass 28 "power technology"; chemistry in turn has an application subclass 268 "applied chemistry", and so on. However, if one does not know the system already, one can hardly predict the meaning assigned to every subclass. This way of analyzing classes is also original in that categories do not have specific subclasses (*foci*), as in classical faceted classifications, but only sub-categories, sub-sub-categories, and so on.

The system of categories identified for the ILC provisional scheme basically works as in classical faceted classifications. Categories are expressed by digits, and get the meaning of more specific facets in the different classes. An important theoretical difference is that classes are not disciplines, but phenomena of the real world, as explained in section 1. With respect to the CRG standard order of categories, some variations have been adopted after several attempts: Agent has been moved before Part (Organ and Element) and Process, giving thus more relevance to the characterization of a phenomenon in terms of its origin, derivation, and factors. Before Agent is a category not found in Ranganathan and Vickery, but suggested by Kyle (1959, p. 20) as a key feature for social sciences: that of Purpose. At the lower integrative levels of material entities, Agent and Purpose can be interpreted as the origin and destination of a phenomenon, e.g. the spring and mouth of a river. One category that is fully original in ILC is that of Pattern, meaning the way in which the structure of a phenomenon mirrors that of another one, like it happens in a mental representation of a perceived

object, or in the subject of a picture. The ordered list of categories (Table 1) ends with Modality, used to specify the way in which a phenomenon is known (real, possible, hypothetical, fictional) and the theories dealing with it (Szostak 2007); this resembles the Theory category in FATKS.

Ranganathan	Vickery-Broughton	Dahlberg	proposed
Discipline/Basic subject	Discipline/Field	0 Concept	
, Personality	Object/Thing		Phenomenon
	Quality/Type	1 Theory/Principle	9 Quality/Type
			8 Pattern
		8 Application	7 Purpose/Result
	N Part-organ	2 Object/Component	5 Organ/Subsystem
; Matter-material	N Part-constit./Material		4 Element
; Matter-property	M Property	4–6 Attributes	
: Energy	K Process/Action	3 Activity/Process	3 Process/Transform.
	J Operation		
, 2nd round Personality	E Agent	7 Production	6 Agent/Premise
. Space	D Place	9 Distribution	2 Place/Neighbourh.
' Time	C Time		1 Time/Ordinal
	A Theory		0 Modality

Table 1: categories according to various authors in faceted classification (facet indicators for Vickery-Broughton are those used in FATKS)

4 Ontological relations between categories and levels

After reviewing the notions of integrative levels (section 2) and of fundamental categories (section 3), we now have to investigate the relation between the two. The CRG study took categories as the

primary division of phenomena, and then arranged each of them according to integrative levels (Austin 1969*a,b*). However, it is also possible to proceed in the reverse order: applying categories as an analytical tool to model each level. This yields a worthy result: that of a classification scheme organized primarily by levels, where the sequence of main classes is not very different from those of general bibliographic classifications like Colon or Bliss, though what is classified are now phenomena instead of disciplines.

In the perspective of integrative levels, a category can either hold throughout all levels, or emerge only from a specific level onwards. Indeed, Hartmann (1940; 1952) claims that both general and level-specific categories exist. The appearance of the latter is just what makes us able to identify a given level: a level can be identified, or maybe even defined, by the novel facets appearing in it. In other words, levels are ways to analyze reality into "categorially homogeneous regions" (Poli and Obrst 2008, section 4.2).

Many of the categories used in bibliographic classifications can be taken as general. This seems to be the case with Thing, Type, Pattern, Property, and Part. Indeed, any entity can possess them, including algebraic structures, which lay at the basic level of abstract forms. On the other hand, categories such as Process, Origin, Destination, Space, and Time imply at least some spatio-temporal dynamics, which occurs only from the material levels onwards; although space, time, and causation have been taken by many philosophers as a fixed framework, in modern physics they are known as distinct phenomena appearing at a certain stage (though an early one) in the cosmic evolution (Davies 1996; Gnoli 2006, section 3).

However, more abstract interpretations of these categories are also possible. Process can also be understood in the generalized sense of a mathematical transformation from one state to another; Destination can be understood in terms of the results of logical operations, or attractors in complex

systems; Space can be interpreted in the more general sense of environment or neighbourhood (also in its mathematical meaning), and Time can be one manifestation of an ordered series. In this way, the general categories identified on an empirical basis in bibliographic classification can be now interpreted in a generalized and abstract sense (Table 2). This general sense is that of the lowest integrative level, A, including the abstract entities of logic and mathematics. Level theory thus infers the opportunity to reformulate the names of general categories, in order to make them less level-specific and truly "general": that is, to speak about Elements rather than Materials, about Transformations rather than Processes, etc.

In the higher integrative levels, new categories appear, together with those already existing at the lower levels. For example, no category of purpose exists at the material level: the notion of purpose only makes sense from the level of social products onwards; ascribing some purpose to a rock would be an ontological violation of the stratified structure of the world (Lorenz 1976; Gnoli and Poli 2004, p. 155). However, we can describe purpose as a specific high-level form of the general category of Result. In terms of bibliographic classification, this is equivalent to say that a general *category* (Result), within a given class of phenomena (products) takes the form of a more specific *facet* (purpose).

Once appeared, a category can occur again at higher levels: purpose is a facet of products, but it can also be one of culture (like in research aimed at finding therapies against cancer). According to Hartmann, indeed, categories can occur again in higher levels, though there they are modified and "controlled" by the new context. On the other hand, not all categories would occur again in higher levels (space occurs in matter and life but not in mind); more research would be needed on how this principle could be applied in classification.

5 Layers and strata

In Hartmann's theory of levels, a distinction is made between two kinds of levels: *layers* and *strata*. The physical levels which are taken most often as example of integrative levels (particles, atoms, molecules, bulk masses, etc.) are layers. Layers are in a relation of *overforming* between each other; that is, each layer is materially constituted with elements of the preceding one: atoms are made of particles, molecules are made of atoms, masses are made of molecules. Similarly, in the organic domain, organisms are made of cells, and populations are made of organisms.

In the ILC faceted notation, the overforming relation can be represented, where needed, by the Element category 4: the classmark for "stars made of hydrogen" can be obtained by connecting the notation for "stars" in level H with that for "hydrogen" in level E, by the facet indicator 4 meaning "made of element".

A series of levels forms a stratum (Table 2): particles-atoms-molecules-bulk matter form the material stratum, while cells-organisms-populations form the organic stratum. Hartmann treats strata as a different kind of level, in that the relation between strata is not of overforming but of *building-above*. Although organic objects do depend on matter for their existence, they cannot be described simply as made of matter elements. In the transition from matter to life, something more essentially new occurs, a more "radical emergence" (Scott 2005). The same can be said of the other two strata usually acknowledged, the mental one and the social/cultural one ("spirit" in Hartmann's terms): minds are not just materially made of living objects, and societies are not just materially made of minds.

In the social stratum Hartmann further distinguishes the "personal spirit" of each cultural human, the "objective spirit" of the collective manifestations of culture, and the "objectivated spirit" of their products (similar to Kyle's "mentefacts") that can even survive the societies originating them, like

as in the examples of dolmens or Odyssey. Indeed, different facets can be observed at least in social-technological products and in cultural works.

The building-above relation between strata generally remains unanalyzed and quite mysterious. As it is not a material dependence, what is it at all? While discussing the steps of cosmic evolution, biologist François Jacob (1970) observes that the two major breaking points, the appearance of life and of thought, both correspond to some new form of memory. This idea can be a clue, suggesting that the relation between strata be some kind of *representation*, that is, reproduction of the forms of an object in another object. A similar notion of *pattern matching* is put forward by Konrad Lorenz (also making reference to Hartmann): in a sense, the forms of organisms are a representation of their environment, a "knowledge" of it (coded in their genes), by which they can act in appropriate ways to survive and have descendants. This can be visualized easily in the morphology of a fish, showing a genetic "knowledge" of the hydrodynamic properties of its marine environment; or in the morphology of a horse hoof, adapted to the geometric properties of the steppe (Lorenz 1976, section 1.2). In this sense, Lorenz agrees with Karl Popper in considering evolution as a progressive acquisition of "knowledge": first from the inorganic environment into the genetic memory, then from both into the more flexible mind of animals, and then again from it into the collective recorded knowledge of humans.

Each stratum can thus be seen as a new series of layers, where the forms existing in the lower strata are reproduced, that is represented, in a new medium. This relationship can be expressed in ILC by the Pattern category 8. In the mental stratum, we can have a perception \circ of an organic object M , say a horse: $\circ 8_m$ (or of a material object, or of a logical object); in the technological stratum, we can have an artifact \top , say a saddle, designed to be used with a horse; and in the cultural stratum we can have an art work \times representing a horse.

The distinction between layers and strata is not represented in the list of ILC main classes: the notational base of 26 letters is suitable to represent layers, and no need has been felt until now to group them into strata for practical uses. However, such grouping can be productive for categorial analysis, helping to define the facets of layers belonging to the same stratum in a more consistent way.

In Table 2, columns on the right show the facets of each stratum. To take the case of the Result category 7, in the material stratum it may take the form of a direction facet: material phenomena are dominated by forces, causes and effects, and can be described in mechanical terms as changing from an initial state towards a new state. In the organic stratum, the Result category takes the form of a function facet: structures not only change in a direction passively, but also realize biological functions evolved to fit their environment. In the mental stratum, the facet of value appears: intentional subjects feel pleasure and pain, and label situations and their possible developments with positive or negative values. In the social layers, the facet of purpose appears: the organized activity of humans is directed towards practical aims, like producing food, shelter, and wealth, which in turn serve the mental values and the organic functions. Finally, in the cultural layers (objectivated spirit), aesthetic and intellectual activities can be free from any immediate practical aim, and develop in "a tension free field", to use Eibl-Eibesfeldt's words; yet facet 7 can be understood in the sense of research lines and trends.

6 Representing dependence relationships between levels

In developing a classification of phenomena, each class should be assigned to the most appropriate level. Based on what we have seen above, considering its facets will be of help in finding its best place in the schedule of integrative levels: the fact that bicycles are designed for some purpose and made of some material is a clue that they must lay somewhere in the technological layers.

Another criterion is given by relationships of *existential dependence*, like overforming and building-above – that is, any relationship such that the phenomenon (bicycle) could not exist in absence of others (human users, streets, ...) on which it depends (Gnoli *et al.* 2007). The phenomenon should be given a notation of the highest level on which it depends (its "highest common factor"), or higher. The following rules should hold:

- (1) a phenomenon p dependent on two levels A and B , with $A < B$, should be given a notation at level B (i.e. be a subclass of B) or higher;
- (2) two phenomena p dependent on levels A and D , and p' dependent on levels B and C , with $A < B < C < D$, should be given notations such that $p' < p$.

The application of these rules is not always trivial. Let us consider the class of sedimentary rocks: any classificationist would probably like to make it a subclass of that of rocks. But many sedimentary rocks originate from deposits of marine animal shells, laying at the higher level of organisms. Has this to be considered a case of dependence of sedimentary rocks on animals? Here, the notion of disintegrative level (Austin 1969*b*, p. 91-95; Gnoli and Poli 2004, p. 155-156) seems to play some role. Actually, these sedimentary rocks are made of disaggregated fragments once belonging to animals, not of full animal elements: do these disaggregated fragments still belong to the level of organisms, or have they fallen back to that of minerals?

As we proceed along the series of levels, relations between them become more and more complicated. Indeed, as each level depends on the lower ones, higher levels have relationships with a greater number of other levels. While material and organic levels can be arranged in a linear sequence quite easily, mental, social, and cultural levels look more "tangled", in Poli's words. Their sequence is less obvious, and can change according to different authors. Still, the work of Hartmann

and others suggests that the notion of levels can model not only the natural phenomena, as some believe, but also the products of the human spirit.

Like other classificatory relationships, dependence between levels can be modeled in two dimensions as a lattice (Priss 2000 and in this issue): each phenomenon will be an element in a partially ordered set, connected with one or more preceding phenomena on which it depends.

Knowledge management applications like list browsing and query result sorting, besides more traditional book shelving in libraries, also require reduction of the lattice to a linear series, that is to a totally ordered set. To establish a non-arbitrary sorting of levels, ordering principles can be provided by the dependence relationships we have seen. A tentative list of this kind of rules is the following:

- (3) a level (layer) must follow all levels on which it depends;
- (4) the stratum to which a layer belongs should be identified by the facets appearing in it;
- (5) a level should be grouped in a single sequence together with those belonging to the same stratum: in other words, a level should follow more closely those on which it depends by overforming, than those on which it depends by building-above.

7 Representing facets

As mentioned in section 2, in the ILC notation classes and subclasses of phenomena are represented by letters, while their facets by digits. Each facet takes the digit of its corresponding category: a facet of purpose will have facet indicator 7, because 7 is the digit of the Result category to which purpose belongs. This has consequences on the citation order of facets, as in each compound subject facets are cited, by default, in the inverted order of their indicators: Xx7x3xx and not Xx3xx7x.

More specific facets can also be represented in ILC by two or more digits. The meaning of these facets is the combined meaning of the two categories: an environment facet is represented by 25, namely category 2 of spatial relations specified by category 5 of structural components, together meaning something like "the components of the space". In the same way are defined other specific, multi-digit facets. This system reminds of Dahlberg's recursive categories (section 3). One difference is that here the concepts obtained by recursively applying categories are facets, rather than ordinary subclasses; thus they can have different specific foci: 25r "in forest environment", 25w "in rural environment", etc.

ILC classmarks can be built by any combination of the appropriate facets of a phenomenon, according to the rules of faceted classification. As ILC is *freely faceted* (Austin 1976), facets are not bound to any specific discipline; instead, any phenomenon (either faceted or not) can be combined with any other. Relations not provided a-priori in the scheme, like "influence of the presence of whales on tourism", are called *phase relationships*. In traditional disciplinary classifications, they are represented by operators other than facet indicators. In freely faceted classification, however, there is no reason to use different categories for them: the notions of facet and phase tend to merge here. For example, the influence phase relationship can be well represented by the same digit 6 used elsewhere for facets of agents, factors, etc. The two phases connected by it can be enclosed in brackets, to avoid ambiguity with more local facets: Xy2eec25w) 6 (Mqvtñ) "tourism in rural Scotland influenced by whales".

In the ILC Web interface <<http://www.iskoi.org/ilc/ilc.php>>, facets are written in different colours, so helping users to grasp them, especially while browsing long lists. The use of colours to represent facets has been adopted already in other applications, especially the FACET project (Tudhope *et al.* 2002).

In ILC, the colour of a facet is determined by its category. Besides black for basic classes, ten colours have been defined, according to the following principles:

- categories represented by greater digits (of "increasing concreteness" in Ranganathan's terms) are displayed in brighter and darker colours;
- adjacent categories are displayed in very different colours.

In this way, the following colours have been chosen:

0	Modality	DED51F	yellow
1	Ordinal, Time	0095E6	light blue
2	Neighbourhood, Space	30B639	light green
3	Transformation, Process	F257C8	fuchsia
4	Element	5E9497	indigo
5	Subsystem, Structure	CD7B0C	orange
6	Premise, Agent	AE0000	red
7	Result, Direction	007144	green
8	Pattern	060080	dark blue
9	Quality, Property	802600	brown

The hexadecimal codes are those used in the HTML markup language to display colours in web pages. A PHP script is programmed to read the category digit and apply the corresponding colour code to the whole displayed notation. Multi-digit facets are represented in the same colour of the category of their first digit: facet 25 has the same colour of facet 2. Indentation is also produced automatically, based on the number of characters (either letters or digits) in each classmark: longer codes are more indented; this makes easier to identify all the subclasses and the facets of a given class.

8 Conclusion

We have seen that the ontological perspective of integrative levels can contribute to traditional classification theory in several ways. The most relevant in the context of this journal seems to be that fundamental categories can be redefined in more universal, level-independent ways. This does not affect the way they work, but makes them more general and applicable to any level: instead of having to warn classifiers that the Purpose category is only applicable to human activities, we now can treat it as a specific facet of the more general Result category.

Facets and levels are the two main structural principles available to classify phenomena. Indeed, Herre et al. (2006) and Poli and Obrst (2008) consider both for structuring high-level ontologies. In this paper and a previous one (Gnoli 2006) I have considered ways in which these two basic principles can interact. A key element of this interaction are categories, as facets can be seen as the particular realization of categories in different levels.

Many categories used in different classification systems are roughly equivalent between each other (Table 1), suggesting that we are not far from a satisfying universal list of categories. Two categories used in the ILC project, however, are more original. The Modality category appears to be useful to represent the approach, viewpoint, and formal aspects of document subjects, as already done in various ways in classification practice, and explicitly suggested by Szostak's (2007) analysis by phenomena, theories, and methods. The Pattern category appears to be substantially new. Its need is felt to express relations between a phenomenon and an object represented in it, like a picture or a poem and their subject. The notion of pattern can also throw some light on the unanalyzed relationship of building-above, being at the basis of the identification of strata as opposite to layers.

Categories and facets, in turn, can benefit level theory in helping to group consistently the levels which share the same or akin facets. The emergence of higher levels can occur in branched ways: both rocks and cells spring from the integration of molecules (Foskett 1970). The representation of levels in a linear sequence, required for documentation, has been realized until now only in approximate and intuitive ways (rocks are listed before cells because they are "simpler" or "lower"). We have found that a more rigorous linearization implies several open problems. The ideas and rules exposed in section 6 are only a first exploration in this direction. Formal principles to represent classes of phenomena more accurately, such as two-dimensional graphs and as mono-dimensional total orders, can be found only after more research work.

References

- Austin D (1969*a*) Prospects for a new general classification. *J Librarianship* 1(3):149-169
- Austin D (1969*b*) The theory of integrative levels reconsidered as the basis for a general classification. In: Classification Research Group, *Classification and information control*. Library Association, London, pp 81-95.
- Austin D (1976) The CRG research into a freely faceted scheme. In: Maltby A (ed) *Classification in the 1970s: a second look*. Bingley, London, pp 158-194
- Beghtol C (1998) Knowledge domains: multidisciplinary and bibliographic classification systems. *Knowl Org* 25(1-2):1-12
- Broughton V (2006) The need for a faceted classification as the basis of all methods of information retrieval. *Aslib Proc* 58(1-2):49-72
- Broughton V, Slavić A (2007) Building a faceted classification for the humanities: principles and procedures. *J Doc* 63(5):727-754

- Dahlberg I (1978) Ontical structures and universal classification. Sarada Ranganathan Endowment for Library Science, Bangalore
- Davies P (1996) The day time began. *New Scientist* 2027:30-35
- Fillmore CJ (1968) The case for case. In: Bach E and Harms RT (eds) *Universals in linguistic theory*. Holt, Rinehart and Winston, New York, pp 1-88
- Foskett DJ (1961) Classification and integrative levels. In: Foskett DJ, Palmer BI (eds) *The Sayers memorial volume*. Library Association, London, pp 136-150
- Foskett DJ (1970) *Classification for a general index language*. Library Association, London
- Freschi F (1989) The Vedic origins of Ranganathan's concept of personality. *Quaderni utinensi* 13-14:101-102
- Glazier JD, Glazier RR (2003) Cultural roots of modern classification. In: Frías JA and Travieso C (eds) *Tendencias de investigación en organización del conocimiento: Proc VI Congreso ISKO-España, Salamanca, 5-7 mayo 2003*. Universidad de Salamanca, p 211-215
- Gnoli C (2006) The meaning of facets in nondisciplinary classifications. In: Budin G, Swertz C, Mitgutsch K (eds) *Knowledge organization for a global learning society: Proc 9th ISKO Int Conf, Vienna, 4-7 July 2006*. Ergon, Würzburg, p 11-18
- Gnoli C, Bosch M, Mazzocchi F (2007) A new relationship for multidisciplinary knowledge organization systems: dependence. In: Rodríguez Bravo B, Alvite Díez ML (eds) *Interdisciplinarity and transdisciplinarity in the organization of scientific knowledge: Proc VIII Congreso ISKO-España, León, 18-20 Abril 2007*. Universidad de León, pp 399-409
- Gnoli C, Hong M (2005) References on Integrative level classification. ISKO Italia.
<http://www.iskoi.org/ilc/ref.htm>. Cited 31 Jul 2007
- Gnoli C, Hong M (2006) Freely faceted classification for Web-based information retrieval. *New Rev Hypermedia & Multimedia* 12(1):63-81

- Gnoli C, Poli R (2004) Levels of reality and levels of representation. *Knowl Org* 31(3):151-160
- Gould SJ (1996) *Full House*. Three Rivers, New York
- Hartmann N (1940) *Die Aufbau der realen Welt: Grundriss der allgemeinen Kategorienlehre*. De Gruyter, Berlin
- Hartmann N (1952) *New ways of ontology*. Greenwood press, Westport
- Herre H, Heller B, Burek P, Hoehndorf R, Loebe F, Michalek H (2006) *General formal ontology (GFO). 1: Basic principles*. University of Leipzig. <http://www.onto-med.de/en/theories/gfo/>. Cited 15 Oct 2007
- Jacob F (1970) *L'intégron*. In: *La logique du vivant*. Gallimard, Paris, pp 320-345
- Kyle BRF (1959) An examination of some of the problems involved in drafting general classifications and some proposals for their solution. *Rev Doc* 26(1):17-21
- La Barre K (2006) *The use of faceted analytico-synthetic theory as revealed in the practice of website construction and design*. PhD dissertation, Indiana University. <http://courseweb.lis.uiuc.edu/~klabarre/facetstudy.html>. Cited 11 Oct 2007
- Lorenz K (1976) *Behind the mirror: a search for a natural history of human knowledge*. Methuen, London; Jovanovich, Harcourt Brace
- Mazzocchi F, Gnoli C (2006) *Il Vaisesika e le categorie di Ranganathan*. *AIDA Informazioni* 24(3-4):17-28
- Mills J, Broughton V (1977) *Bliss bibliographic classification, 2nd edn. Introduction and auxiliary schedules*. Butterworth, London
- Perreault JM (1965) *Categories and relators: a new schema*. *Rev Int Doc* 32: 136-144. Republ in: *Knowl Org* 21(4), 1994:189-198
- Poli R (1998) *Levels*. *Axiomathes* 9(1-2):197-211
- Poli R (2001) *The basic problem of the theory of levels of reality*. *Axiomathes* 12(3-4):261-283

- Poli R, Obrst L (2008) The interplay between ontology as categorial analysis and ontology as technology. In: Healy M, Kameas A, Poli R (eds) TAO: Theory and applications of ontology, v 1, ch 9
- Priss U (2000) Comparing classification systems using facets. In: Beghtol C, Howarth L, Williamson NJ (eds) Dynamism and stability in knowledge organization: Proc Sixth Int ISKO Conf, Toronto, July 10-13, 2000. Ergon, Würzburg, pp 170-175
- Scott A (2005) Emergence. In: Scott A (ed) Encyclopedia of nonlinear science. Routledge, New York, pp 261-262
- Szostak R (2007) Interdisciplinarity and the classification of scholarly documents by phenomena, theories, and methods. In: Rodríguez Bravo B, Alvite Díez ML (eds) Interdisciplinarity and transdisciplinarity in the organization of scientific knowledge: Proc VIII Congreso ISKO-España, León, 18-20 Abril 2007. Universidad de León, pp 469-477
- Tudhope D, Binding C, Blocks D, Cunliffe D (2002) Representation and retrieval in faceted systems. In: López-Huertas M (ed) Challenges in knowledge representation and organization for the 21st century: Proc 7th ISKO Conference, Granada, July 10-13, 2002. Ergon, Würzburg, pp 191-197
- Vickery BC (1958) Classification and indexing in science. Butterworths, London
- Vickery BC (1960) Faceted classification: a *guide to the construction and use of special schemes*. Aslib, London
- Vickery BC (1975) Classification and indexing in science. 3rd edn. Butterworths, London
- Weinberg BH (1996) Complexity in indexing systems: abandonment and failure: implications for organizing the Internet. In: Hardin S (ed) Global complexity: information chaos and control: Proc 59th ASIS Annual Meeting. <<http://www.asis.org/annual-96/ElectronicProceedings/weinberg.html>>. Cited 11 Nov 2006
- Williamson NJ (1998) An interdisciplinary world and discipline based classification. In: Mustafa el

Hadi W, Maniez J, Pollitt SA (eds) Structures and relations in knowledge organization: Proc 5th
Int ISKO Conf, Lille, 25-29 Aug, 1998. Ergon, Würzburg, pp 116-124

layers	strata	Hartmann	9	8	7	6	5	4	3	2	1	0	disciplines
A forms	form	logical	Quality	Pattern	Result	Premise	Subsystem	Element	Transformation	Neighbourhood	Ordinal	Modality	mathematics
C spaces D particles E atoms F molecules G bulk matter I celestial obj. J rocks K landforms	matter	material	property	shape	direction	cause	component	constituent	dynamics	position	time	determination	physics
L cells M organisms N populations	life	organic	character	adaptation	function	ancestry	organ	organic matter	metabolism	habitat	era	reproductive success	biology
O behaviours P consciousness Q signals	mind	psychic	skill	perception	value	input	sense	idea	action	context	phase	actuation	psychology
R social welfare S land products T artifacts U wealth V organizations	society	spiritual	feature	ergonomics	purpose	factor	department	material	procedure	territory	age	implementation	social sciences
W cultures X art works Y knowledge Z wisdom	culture	spiritual	style	aboutness	trend	source	section	medium	elaboration	milieu	epoch	diffusion	humanities