ISKO. CAPÍTULO ESPAÑOL. CONGRESO (7º: 2005: BARCELONA) **448-461**

Development of the *Environmental Application Reference Thesaurus* (*EARTh*)

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Abstract

The paper addresses with the development of an environmental thesaurus in order to obtain an advanced tool for semantic control and knowledge organization to be applied to environmental information management. EARTh (*Environmental Application Reference Thesaurus*) was designed according to an approach to meaning representation that regards lexical meaning as a unitas multiplex, a unity that aggregates multiple traits organized according to a hierarchy. The thesaurus classification system comprises a vertical structure based on a limited set of categories, and is organized according to a tree semantic model. The tree structure analyses the meaning of the terms from a logical point of view. By placing each term in the classificatory-hierarchical structure, it aims to orientate the users toward the most essential characteristics of their semantics. The semantic analysis of terms is not limited to a static and univocal view. Each term is considered as a complex entity, where different layers of meaning are to be explored. The model envisages, in fact, the possibility of developing local arrangements of terminology, ensuring the openness and flexibility of the model, and allowing the representation of meaning according to different second-order perspectives. The implementation of an extended set of semantic relationships is also under way. The traditional thesaurus relationships will be arranged in a series of sub-relationships, whose semantic content is specified. In particular, the transversal relational structure that is based on associative relations will be strengthened, reinforcing the role of the thesaurus as semantic connector.

Keywords

thesaurus construction, subject analysis, categories, semantic relationships, environmental information, *EARTh*

1 Introduction

The present work is based on the assumption that many of the present issues in the field of knowledge organisation and information management can be traced back to meaning delimitation. While representing the semantics of a term different types of characteristics need to be considered. Problems arise when we have to choose which and how many semantic traits have to be included in the representation. There are, in fact, opposite needs and tendencies: on one hand there is the necessity to share a common and stable meaning of the terms in order to guarantee communication within a community. On the other hand, openness to further exploration of meaning should also be ensured so as not to impoverish its richness and complexity.

Is it then possible to define a hierarchy of semantic properties where a nucleus of them could also be identified – at least from an operative point of view – as «essential», without limiting the analysis of lexical meaning? (VIOLI 1997). One example may help to clarify this point better. In how many ways could «benzene» be defined? A biologist may consider its toxicity and the different routes through which it can enter an organism. An engineer would consider it as a fuel for combustion engine. A physicist may see it as a volatile and inflammable liquid. A fire brigade may regard benzene as a dangerous inflammable substance that cannot be extinguished with water, but only with foam. A chemist may see it as the precursor of a class of chemical compounds, etc. (FUGMANN 1993). So it seems that benzene could be defined in several different ways depending on the context in which it is considered. But we should also underline that all these definitions share a common premise: «benzene» *is first of all* a substance (that can have toxic effects, be used as fuel, can also cause accidents, etc.). This semantic trait seems to be ineliminable. By saying this, we are referring, of course, to the conceptualisation of benzene according to the current historical-cultural context of the Western tradition.

Lexical meaning can then be considered as a compound and structured set of diversified traits. Each term is viewed as a *unitas multiplex*, forming a unity that aggregates multiple traits organised according to a hierarchy. Different semantic traits have different weight in signification, and their different status depends on their cancellability degree (*VIOLI* 1997). We think that these considerations could be brought into the field of knowledge organisation also to design semantic control tools. Highly structured and refined, but flexible, tools are in fact needed to deal with issues such as information management on the web and semantic interoperability.

The goal of our project is the development of a thesaurus that can include the above assumptions, aiming to become an advanced tool to be applied for environmental information management. A thesaurus for the environment has been defined as «a vocabulary of a controlled indexing language, which enlists the environmental information objects» (PURAT 1998).

The need of systems able to rationalise environmental information management is a much-debated topic. In fact, in order to sustain environmental policy and research, access to high-quality information is required. To achieve this result, however, systems able to deal with the specific features of the environment sector (multidisciplinary character, high complexity, biocultural implications, etc.) are also needed. On the basis of this premise and referring also to suggestions coming from the development of applied ontologies, we are working on an environmental thesaurus format that also contains some innovative elements.

2 THE *EARTh* SEMANTIC MODEL

EARTh (*Environmental Application Reference Thesaurus*) is based on a multidimensional classificatory and semantic model. The «vertical structure» of the Thesaurus – built through a deductive (top-down) –inductive (bottom-up) approach – is the fundamental constituent of such a model. This structure is basically mono-hierarchical. It has been developed according to a tree semantic model and is based on a system of *categories*, [1] – here conceived as the most general concepts or as the logical *progenitors* under which every single concept can be placed. It is organised in a framework composed of different levels and classification knots and comprises hierarchical relationships.

The first two levels of the classification system correspond to the categories. The first level includes four «supercategories»: *ENTITIES*, *ATTRIBUTES*, *DYNAMIC ASPECTS* and *DIMENSIONS*.[2] Entities constitutes «things». Attributes defines character of «things», at least in their static aspects. Dynamic aspects relates to transformations and operations connected to «things». Dimensions identifies the spatial and temporal circumstances where all this is manifested.

In the subsequent level of the classification, the supercategory ENTITIES is divided into *Material entities* and *Immaterial entities*. ATTRIBUTES includes three different categories: *Properties; Structure and Morphology*; *Composition*. DYNAMIC ASPECTS comprises: *Processes*; *Conditions; Activities*. DIMENSIONS refers to *Space* and *Time*.

1. The use of the term «category» requires some clarifications. The notion of category has taken different meanings in the history of Western thinking. It has been considered from an ontological and logical point of view as the foundation essential to distinguish *things* and to construct speech on logical basis; in linguistics a correspondence between categorical and grammatical figures has been investigated. Categories in a Kantian sense are *judgement forms*; in semiotics they are mainly viewed as metalinguistic operative models; they are studied in psychology as mental tools capable of creating order in data coming from experiences. The notion of category was, finally, extrapolated from philosophy to the science of classification where categories have also been viewed as the foundation (not always visible) of knowledge organization systems and are utilized for different purposes (BARITE 2000).

   As has already been said, in the context of the present work categories are conceived in their primitive Aristotelian form as the most general concepts under which every single concept can be placed.
2. Dahlberg considers these supercategories as Ur-categories and she adopted them to classify the ten Aristotle categories (DAHLBERG 1994). According to this point of view the Ur-categories represent the ultimate logical foundation. But the adoption of such a perspective opens up many questions. For example, do categories have an ontological character? Is it then possible to conceive universal categories in the sense that, by navigating within whatever semantic structure developed in the context of different cultures and languages, the final destination is always the same? Which mediation role does the language that is still necessary to express the categorial system have?

```
entities
  material entities
  immaterial entities
attributes
  structure and morphology
  composition
  properties
dynamic aspects
  processes
  conditions
  activities
dimensions
  space
  time
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FIGURE 1: *EARTh* categorical system: supercategories and categories

As has already been said, the categories are the basis of the semantic model. *First of all* the semantics of terms is, in fact, described by the categories where they are located.[3] The vertical structure analyses the meaning of the terms according to a logical perspective. It can be considered as an operative tool which by providing the categorial interpretation of the meaning of the terms and by placing them in the classificatory-hierarchical tree aims to orientate the users towards the most «essential» characteristics of their semantics. Nevertheless, it does not limit the conceptual analysis of terms to a static and univocal view. Awareness of the semantic complexity associated with each term is maintained. Different layers of meaning have to be explored, even if there is a hierarchy of semantic traits and each one of them contributes to lexical signification with a different specific weight.

The model envisages the possibility to develop additional arrangements of terminology. For example, a thematic organisation of terms could be elaborated. A theme or a subject is conceived here as a sector of interest that reassembles the terms linked to it (while the tree structure tends to scatter them under their referral logical category). The system of themes (or other classifications), as it was conceived, should be

3. Following a bottom-up perspective, terms could be analysed according to a progressive hierarchical scale. In this scale, conceptual features are progressively discarded following an intensional perspective (while in an extensional perspective the number of things associated to that intension is increased). The maximum level of generality is thus reached. Categories represent the top of this vertical structure. Fugmann has described this process as follows: «In the process of ascending (generic) hierarchy one is losing one conceptual feature after another, and this should occur in the order of their essentiality (…) the most essential one being the one preserved in the end of this process» (FUGMANN 1993, p. 18-19). Fugmann calls «conceptual categories» the top concepts in the hierarchies and facet the group of concepts below a category.

AIR	Air
CLI	Climate
COS	Cosmos
ECO	Ecosystems
LAN	Land and Landscape
ORG	Organisms
SOC	Society
SOI	Soil
URB	Urban areas
WAT	Water
AGR	Agriculture
CON	Construction
ECN	Economy
ENE	Energy
FIS	Fishery
FOR	Forestry
HEA	Health and Nutrition
HUS	Husbandry
IND	Industry
INF	Information and Education
LGS	Legislation
MIL	Military issues
NUC	Nuclear issues
PLC	Policy
POL	Pollution
REC	Leisure activities
RES	Research
SAF	Safety
SER	Services
TRA	Transport
WAS	Wastes

FIGURE 2. *EARTh* system of themes

developed according to the specific needs of the applicative context. In our project, we have developed a demo/draft version of a system of themes that has been utilised to classify the terms, and could also be used for the management of information in the field of environmental policy.

From a semiotic point of view, this model should allow meaning representation according to different «second order» perspectives and acceptations. In fact, the possibility to apply additional classification models would ensure openness and flexibility to the model. Returning to the above example, benzene will be classified in the vertical structure as an *entity* (supercategory), that is material (*material entities* is the second level category), non-living *(non-living entities* is the third level), till it is

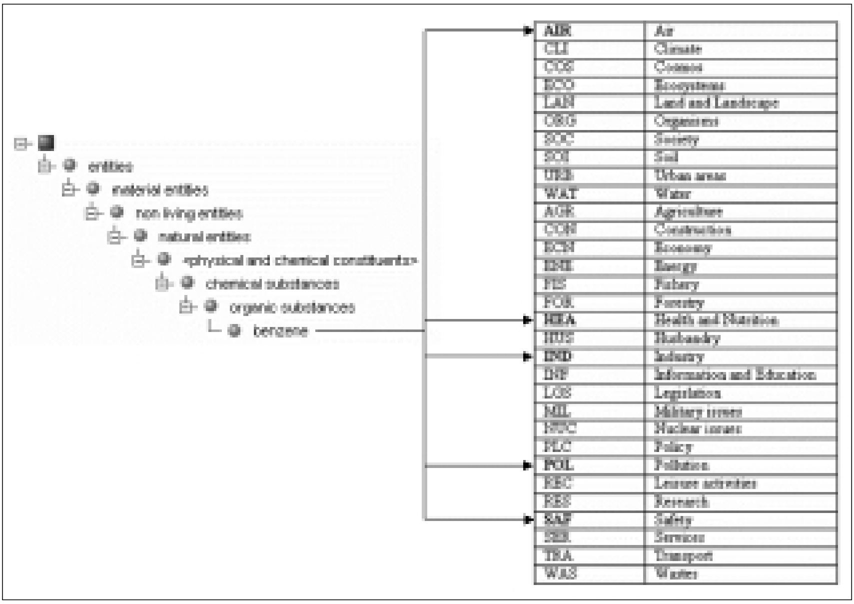

FIGURE 3. Classification of «benzene» according to the vertical structure and the systems of themes

placed in the classificatory / hierarchical tree as an organic chemical substance. Other views of «benzene» as a pollutant, toxic substance or fuel could emerge, instead, according to the additional classifications that reflect the perspective of the specific subject. Of course, also RTs can help in expressing additional semantic traits but in this case it can happen only at level of single term.

The possibility to obtain, if needed, more agile and less structured versions of the Thesaurus – fully compatible and linked with the overall structure – or also sectorial microthesauri[4] to be used for different applications is an added value of this approach.

3 *EARTH* RELATIONAL STRUCTURE

The usefulness of a well-defined and well-structured domain-specific thesaurus for the management of information – also on the Internet – is well acknowledged. However, there is a widespread opinion that the thesaurus format – as the International Standard conceives it – does not completely fit the current needs of knowledge organisation systems.

4. Different microthesauri (for example, a water microthesaurus, a soil microthesaurs, etc.) can be obtained by isolating terms belonging to a specific subdomain (in this case a theme), utilising the system of categories and also other elements of the vertical structure to organise and classify the terms, add more specific terms to complete the conceptual and terminological representation of the domain.

One of the main problems posed by traditional thesauri seems to be the fact that they provide a poorly differentiated set of relationships between terms, distinguishing only among hierarchical relationships, associative relationships and equivalence relationships. It has also been said that since thesaurus relationships are characterised by semantic vagueness, they are not applied consistently. This causes ambiguity in interpretation and can result in unpredictable semantic structure (SOERGEL 2004). The solution that is commonly proposed to overcome these limitations and to enable more powerful searching and intelligent information processing entails the reengineering of «traditional» KOSs into systems containing domain concepts linked through an extended network of well-defined relationships and a rich set of terms identifying these concepts (SOERGEL 2004).

In the *EARTh* project, we are trying to bring these assumptions in, to a certain extent. For this reason, the implementation of a more refined set of semantic relationships is at present under way. Standard relationships will be arranged into richer subtypes, whose semantic content is specified. Linguistic structures will express semantic relations. The augmentation of thesaurus relationships will ensure a stronger semantic control – also because different relationships can hold each other in check (FISHER 1998) – and open up new application possibilities for information retrieval (TUDHOPE 2001). Their enrichment and the increased semantic clarification of the relations could enable, for example, a better semantic description of Web resources and guide a user in meaningful information discovery on the Web (SOERGEL 2004). Besides, it will increase the possibility of using them also for artificial intelligence applications. Traditional thesauri, in fact, were not designed for their semantic structure supports limitedly automated information processing (SOERGEL 2004)

Nevertheless, from another point of view we hold the awareness of the intrinsic complexity of contemporary lexicons that are very rich systems of redundancies, polysemies, and so on. It would thus seem reasonable to adopt a hermeneutical attitude open to «accept», to a certain extent this *weak* nature of lexicons. This means that we have to provide tools capable of ensuring a stronger semantic control as much as possible. But we have also to take great care in avoiding an excess of «compulsory way» or artificially compressed meanings. While applying a highly elaborated net of semantic relationships unwanted effects of this kind could in fact be generated.[5]

Moreover, we also believe that ensuring a high modularity of these systems is another important requisite to be achieved. This should also allow other kinds of utilisation by users that simply do not need or may not make such fine a distinction of the thesaurus relations (MILSTEAD 2003) – in this case it could even become a problem more than a solution-and who are interested in using a simpler or more traditional version of the thesaurus relational structure.

5. Such considerations are especially referred to the lower levels of the hierarchical trees where this kind of problem is most expected to happen.

The following is a brief description of the work that has been done on semantic relationships.

3.1 Hierarchical Relationship

Thesaurus standards and the scientific literature include three kinds of hierarchical relations: «generic», «partitive» and «instance», which are conflated into one generic «hierarchical relationship». Perhaps this is the most misused relation. Many relations, in fact, that are labelled as BT/NT in existing controlled vocabularies are based on a document-retrieval definition of «broader-narrower» and they could be better interpreted as associative relations. For document-retrieval definition of BT/NT we address a pragmatic relation oriented towards the function of the search process (FISHER 1998).[6]

In *EARTh*, only hierarchies that are *logically* based will be included. Moreover we will differentiate the three types of relations and as far as the generic and the partitive relations are concerned, subtypes will be identified.

3.1.1 Generic relations

The simultaneous and parallel application of different subdivision criteria will ensure the polydimensionality of the hierarchies and the formation of intrahierarchical semantically homogeneous clusters. Node labels will show different characteristics of subdivision. On the basis of this work we will also try to distinguish what we can consider as *conceptual taxonomical* relationships from hierarchies where the added conceptual differences don't seem of the same importance as those allowing the creation of taxonomies *sensu stricto*.

In some cases, this distinction seems to be achievable. In the biological field, for example, where there is a consolidated taxonomical tradition, we can quite easily distinguish the relationship between «animals» and «mammals» from the relationship between «animals» and «terrestrial animals». But in other sectors, things are historically less definable.

3.1.2 Partitive relations

We are also working to differentiate the part-whole relationship. We started our work considering past research in this field and taking Winston, Chaffin & Herrmann's *Taxonomy of Part-Whole Relations* as main reference, which distinguishes the following subtypes: integral object-component; collection-member; mass-portion; stuff-object; activity-feature; area-place (WINSTON 1987), and the work done by the SAC Subcommittee

6. «Concept A is broader that concept B whenever the following holds: in any inclusive search for A all items dealing with B should be found. Conversely B is narrower than A» (SOERGEL in FISHER 1998)

on Subject Relationships / Reference Structures of the American Library Association (GREENBERG 1997).

We are also considering how the partitive relation takes form when it is viewed according to the different categories – a material entity will have material parts; a process or an activity could be comprised of different phases or steps; etc. Finally, we are also evaluating the feasibility of differentiating the relations between parts and a whole from the whole-complex relations.

3.2 Associative Relationship

Associative relation includes a heterogeneous and undifferentiated set of relations.[7] It can express many kinds of association between terms that are not hierarchically based.

In our work – with the reference of the work done by the SAC Subcommittee on Subject Relationships / Reference Structures (GREENBERG 1997) and research in this field by Schmitz-Esser (SCHMITZ-ESSER 1999) – we will try to specify the nature of the relations and to differentiate RTs in subtypes (i.e., «field of study / object of study» relationships, «field of study / practitioner» relationships, «causal» relationships, «processes / entity undergoing processes» relationships, etc.). We will also try to extend the range of useful RTs types, although they probably constitute a series that is intrinsically open and their topics are strongly connected with the characteristics of the operative context.

In this way, the transversal relational structure, which is based on associative relations, will be strengthened. A net-like knowledge representation model will actually be developed, and could then integrate the taxonomic-hierarchic tree-like model.

By reinforcing the RTs structure we aim also to emphasize the «weak ties», the bridges which – by limiting the «degrees of separation» - render the structure of connections of a conceptual field evident (TRIGARI 2003). This will be particularly important in order to deal with the thesaurus's subject, the environment, which is a highly complex and interconnected domain. And it will also be useful in order to deal with the networked and barely hierarchical information and knowledge management on the Internet, and better reflect the emerging mental maps of the information searcher. (TRIGARI 2003).

To better represent and visualize this transversal structure, we are also looking to the possibility of designing additional ways of browsing the thesaurus based on the RTs and showing different *microworlds* of connected concepts and terms (TRIGARI 2003).

7. ISO 704, in fact, defines them in the following way: «an associative relation exists when a thematic connection can be established between concepts by virtue of experience».

3.3 Equivalence Relationship

While hierarchical and associative relationships are more conceptually-based relations, equivalence relationships concern, instead, lexicalisation. Synonymy refers to meaning similarity and it has also been defined as interchangeability between terms, although it is very difficult to think about the existence of an absolute synonymy (VIOLI 1997).

In any event, a distinction will be made between *actual* synonyms and simple lexical variant forms (i.e., plural/singular forms, spelling variants, acronyms, abbreviations, etc). For both of them we shall try to identify different subtypes.

Quasi-synonyms will not be included at this stage in the system.[8]

4 *EARTh* TERMINOLOGICAL CONTENT

The EARTh terminological content is derived from various multilingual and monolingual sources of controlled environmental terminology. The first source used was GEMET (*GEneral Multilingual Environmental Thesaurus*) developed in 1999 by CNR and UBA-Umweltbundesamt, Germany, on behalf of the European Environmental Agency. Other sources are: the *Italian Earth Sciences Thesaurus*; *EnvDev*, the *Terminological Bulletin for the Rio de Janeiro Conference on Environment and Development*; terminology collections concerning specific sectors (i.e., Inland Waters, GIS, Remote Sensing, Ice-Snow domain, Environmental Education, etc).

A further conceptual and terminological enrichment has been defined. Particular attention has been paid to including the terminologies coming from the most recent development of environmental sciences as well as to cover topics that assume strong relevance nowadays.It must be said that often the incompleteness of the terminology collections depends on the kind of approach that is utilised. The environment is in fact analysed mainly with a static and sectorial approach, reflecting a vision pertaining to classic science and to environmental policy that transforms its paradigms in operational terms. This implies limited openings, for example, to the development of contemporary science (i.e., chaos theory and complex thinking), even if it has had a prominent role in offering renewed approaches and methods to analyse the environmental issues. One goal of the present work is to take into consideration these issues, by adopting a more inclusive approach, concerning both conceptual coverage and semantic organisation.

8. Quasi-synonymy is characterised by an indeterminate nature. Its definition is usually based on pragmatic assumptions. Although the meaning of terms interpreted as quasi-synonyms is different – there is, of course, a certain degree of overlapping – such terms are considered as synonyms for indexing purposes (ISO 1996). Quasi-synonyms are then regarded as interchangeable only in some operative contexts.

5 Multilingualism and cultural diversity issues

Through managing multilingualism, issues of cultural diversity will also be taken into consideration. Structural divergences that could concern multilingual thesauri -here we are referring to *regional* diversities that happen in the context of a common general culture, as the Western culture- will be considered (Hudon 1997). Nevertheless problems posed by cultures that are epistemologically far removed from ours will also be taken into account. Nowadays connection at planetary level is strongly increased. Different cultures and knowledge forms meet on global platforms. We realise that different cultures hold different visions of the world and this is reflected in the way they organise knowledge too. We will evaluate in which way the future development of the thesaurus could integrate a multicultural perspective.

6 EARTh software

The Thesaurus was uploaded and is currently handled using *SuperThes*,[9] an innovative software developed with the scientific supervision of EKOLab in the frame of an International cooperation including CNR, UBA-Austria, UBA-Germany and the TBHS company (Batschi 2004). SuperThes is characterised by adaptability, flexibility and interoperability. The internal data storage is Unicode–compliant, enabling the use of every written language as long as operating system support exists. The software has satisfied all the requirements concerning the selection and the semantic and morphological processing of the terminology. It makes it possible to manage problems related to the utilisation of multiple sources, developed in different operational fields and characterised by different approaches, concerning conceptual structuring and terminological representation.

7 *EARTh* preliminary version

A preliminary version of about 7000 terms, in English and Italian, classified according to the above model, is expected to be ready by 2005.

8 Final considerations and possible applications

In the field of thesaurus theory and construction, a transition phase has been probably reached. It is clear that something should be changed in order to reflect present needs better. This is also confirmed by initiatives

9. <http: //uta.iia.cnr.it/software.htm#SuperThes>

concerning the development of new standards.[10] But neither does it seem the configuration that new-generation thesauri should acquire. In this paper it has been presented a project where the possibility to develop a thesaurus with a more refined structure is explored. The goal was to provide a more powerful tool for semantic control and knowledge organisation. At the same time we have tried to elaborate a model that maintains semiotic openness and to strengthen the role of the thesaurus as «semantic connector».

EARTh is an environmental semantic map that could be utilised for different purposes. It could be interesting, for example, to evaluate the use of *EARTh* – considering how it is structured – for dealing with interoperability issues and as a switching tool for mapping among different environment-related thesauri. Nowadays, networked information access to heterogeneous data sources requires interoperability of controlled vocabularies. Thesauri are, in fact, created, with different points of view and can be based on different forms of conceptualisation. Their development reflects different scopes and can involve different levels of abstraction and detail. *Switching* thesauri able to create dynamic and semantically based correspondences among different vocabularies are then urgently needed.

Another possible -not *traditional*- use of the Thesaurus strikes us as quite interesting. A thesaurus which, like *EARTh*, is expected to have a refined semantic structure can also be considered as a tool for domain-specific navigation on a conceptual basis. Indeed, current research indicates new roles of thesauri. They are increasingly seen as maps of subject domains or semantic networks, knowledge representation and organisation systems, patterns of knowledge (KOSOVAC 1998). Moreover, if the passage from one function to another is not automatic, disciplines such as cognitive science, applied linguistics or artificial intelligence can view and study thesauri as models of conceptualisation reflecting our *Weltanschauung* and employed to structure knowledge domains according to logical and semantic criteria.

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10. NISO is revising the standard for thesaurus construction: ANSI/NISO Z39.19, *Guidelines for the Construction, Format, and Management of Monolingual Thesauri.* A revision and extension of the British standards for monolingual and multilingual thesauri is in under way as well (BS 8723: *Structured vocabularies for information retrieval – Guide*).

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