Linking Specialized Knowledge and General Knowledge in EcoLexicon[1]

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Summary. Ontologies have been criticized because they demand too much work or because they are not sufficiently flexible to capture the dynamism and complexity of reality (Kingston 2008). However, even though any representation of reality is imperfect, ontologies are the type of computational knowledge representation that best approximates the domain being conceptualized. In fact, they have increasingly come into focus because of the need for knowledge management and shared knowledge in both general and specialized knowledge domains. EcoLexicon is a frame-based visual thesaurus on the environment, whose knowledge is stored in a relational database, and which is gradually evolving towards the status of a formal ontology (León et al. 2008; León and Magaña 2010). This paper describes the conceptual modeling techniques used in this knowledge resource, and the underlying theoretical premises that enable its contextualization and connection to general knowledge structures and resources.

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1. Introduction

There is a clear need for explicit models of semantic information (terminologies) to facilitate information exchange. One approach to this is through ontologies, which can be regarded as shared models of some domain that encode a view which is common to a set of users. A domain-specific ontology, which is composed of both concepts and instances within a certain field, along with their relations and properties, is a new medium for the storage and propagation of specialized knowledge (Hsieh et al. 2010).

Conceptually-structured terminological databases can thus be regarded as knowledge resources because terminological units are the specialized vocabulary items that encode the knowledge in a subject domain. However, in order for any knowledge resource to aspire to psychological and explanatory adequacy, its underlying conceptualization and design must be in consonance with the needs and expectations of a specific user group, whose main objective is generally to acquire knowledge about the specialized area. Evidently, in order for specialized knowledge to be more meaningful, it must be coherently structured. This coherence is enhanced by an explicit connection to general knowledge structures.

Nevertheless, one of the problems with specialized knowledge bases is that they are created as stand-alone products, and appear to be divorced from the general knowledge represented in upper-level ontologies. Upper-level ontologies are composed of general concepts and properties, and are a valuable tool for the contextualization of domain-specific ontologies since they can and should be extended so as to make explicit the link between general and specialized knowledge (Tripathi and Babaie 2008). This facilitates the acquisition and reuse of the data.

Nevertheless, a recurring problem is that the description of basic scientific concepts for the general public is often at odds with their description for scientists and engineers. Definitions of the same concept can be rather different, depending on the knowledge level of the targeted user group to the extent that they sometimes appear to have little or no relation with each other. For example, Lipschultz and Litman (2010) found that many entities that are defined as *forces* in WordNet are really not forces according to Physics. Consequently, *type_of* hierarchies extracted from general lexical resources often need to be manually or automatically revised. For this reason, explicitly linking a domain-specific ontology to a general knowledge resource requires conceptual modeling techniques that tailor general definitions so that they can be seamlessly extended to encompass and encode specialized knowledge representations of the same concept, which are valid from a more expert perspective.

This requires ontology building that is based on information extracted from a corpus of domain-specific texts and terminographic resources, as well as expert validation, rather than elicitation. Since, quite often experts do not know how to formulate their knowledge, there is often a large gap between the knowledge modeled in ontologies and texts documenting the same knowledge (Eriksson 2007). The extraction of conceptual representations from natural language texts is a way of overcoming this obstacle.

According to Cognitive Semantics (Talmy 2000), lexical meaning is a manifestation of conceptual structure. Both general and specialized lexical items can be regarded as conceptual categories of distinct yet related meanings that exhibit typicality effects. In this regard, ontology building and conceptual modeling can benefit from the semantic analysis of linguistic concepts, based on sound theoretical principles.

2. Ontologies

The term *ontology* originally comes from the field of Philosophy, and refers to a particular system of categories accounting for a certain vision of the world. As such, it is a constructed world model. However, in Terminology, *ontology* is defined in its Artificial Intelligence sense as an explicit specification of a conceptualization (Gruber 1995: 908). Gruber (ibid) makes a distinction between representation ontologies and content ontologies. Representation ontologies provide a framework, but no guidance on how to represent the domain. In contrast, content ontologies make claims about how the domain should be described.

In recent years, another distinction has also arisen between formal ontologies and linguistic ontologies, which differ from each other in their degree of formalization and their size. A formal ontology is much smaller than a linguistic ontology. It is a controlled vocabulary that expresses a representation language for the specification of a conceptualization. This language has its own grammar that facilitates the expression of terms within a domain, and contains formal constraints related to the way terms can combine with others. A formal ontology is thus a set of rigorously defined terms and concepts used to describe and represent a knowledge area, as well as sets of relations, properties, and values.

In contrast, linguistic ontologies are generally much larger and strongly language-dependent since they focus on the words used in one or more languages. WordNet (Fellbaum 1993, 1998) is probably the most well-known linguistic ontology since its upper-class words are often used as top-level concepts in formal ontologies. Accordingly, linguistic ontologies can provide the basis for formal ontologies.

Evidently, one of the overriding priorities in Terminology is to define data in as standardized a way as possible. An ontology has the advantage of anchoring linguistic representations in one or various languages to the same conceptual representation and thus fomenting data interoperability. Specialized domain ontologies thus help to eliminate conceptual and terminological confusion. They specify a set of generic concepts that characterize the domains as well as their definitions and interrelationships. It is now widely acknowledged that constructing such a domain model is crucial to the development of knowledge-based systems. This initial design of the skeleton of the domain is a task that can have far-reaching consequences.

3. Conceptual modeling

Conceptual modeling is the activity of formally describing aspects of the physical and social world for purposes of understanding and communication. The conceptual modeler thus has to determine what aspects of the real world to include, and exclude, from the model, and at what level of detail to model each aspect (Kotiadis and Robinson 2008). The way that this is done depends on the needs of the potential users or stakeholders, the domain to be modeled, and the objectives to be achieved. A principled set of conceptual modeling techniques are thus a vital necessity in the elaboration of resources that facilitate knowledge acquisition and understanding. Such resources would ideally allow non-experts to understand a given domain by focusing on and capturing essential knowledge. This can only be done if specialized knowledge descriptions build on the core knowledge that non-specialist users already possess.

3.1 Information extraction

When designing the conceptual structure of a domain, one of the first issues to be dealt with is the extraction of information upon which conceptual organization can be based. As previously mentioned, some prefer to collect this information from experts in the field by means of structured interviews or questionnaires. The knowledge structure is thus designed intuitively after discussing concepts with a group of domain experts. This method has the disadvantage of being based on a restricted set of opinions. Furthermore, despite the fact that experts may be very knowledgeable in their particular field, they are not experts in metacognition. In other words, they may know a great deal about their domain, but are not aware of how they know what they know, or how this knowledge is structured.

However, another way to extract domain knowledge is by using specialized texts and knowledge-rich contexts (Meyer 2001). In this type of text-based approach, conceptual structure is specified on the basis of linguistic information. Language structure is thus regarded as a reflection of conceptual structure (Langacker 1987).

3.2 Situated representations

When terms are activated in texts, they set in motion a wide variety of underlying conceptual relations and knowledge structures. Indeed, contexts are triggering mechanisms that foreground certain relations over others. According to Barsalou (2005), a given concept produces many different situated conceptualizations, each tailored to different instances in different settings. Context can thus be said to be a dynamic construct that activates or restricts knowledge. This means that the most generic or top-level categories of a domain ontology can be configured in a prototypical domain event or action-environment interface (Barsalou 2003). The result is a template or frame applicable to all levels of information structuring. The resulting general frame enhances knowledge acquisition since the information in term entries is internally as well as externally coherent (Faber et al. 2007). It also helps to make explicit the link between general and specialized knowledge.

In Terminology, the theoretical approach that incorporates these insights is known as Frame-Based Terminology (FBT) (Faber et al. 2006, 2007; Faber 2009, 2010). FBT uses certain aspects of Frame Semantics (Fillmore 1982, 1985, 2006; Fillmore and Atkins 1992, 1998) to structure specialized domains and create non-language-specific representations. Such configurations are the conceptual meaning underlying specialized texts in different languages. FBT focuses on the following: (i) conceptual organization; (ii) the multidimensional nature of terminological units; (iii) the extraction of semantic and syntactic information through the use of multilingual corpora. Accordingly, FBT conceptual networks are based on an underlying domain event, which generates templates for the actions and processes that take place in the specialized field as well as the entities that participate in them. Its practical application is a terminological knowledge base on the environment known as EcoLexicon (http://ecolexicon.ugr.es).

4. EcoLexicon

EcoLexicon is a visual thesaurus of environmental science, whose knowledge is gradually evolving towards the status of a formal ontology (León et al. 2008; León and Magaña 2010). EcoLexicon is a multilingual knowledge resource on the environment with 3,147 concepts and 14,142 terms in Spanish, English and German though terms in more languages are currently being added (Faber et al. 2006, 2007). This resource is for both language and domain experts as well as for the general public. It can be accessed by a user-friendly interface that includes a ThinkMap conceptual representation as well as other terminological, graphical, and conceptual information.

Figure 1 shows the entry for the concept of GROYNE, a coastal defense structure that retards littoral drift and erosion. Users do not have to see all this information at the same time, but can browse through the different windows and consult the data, depending on their needs.

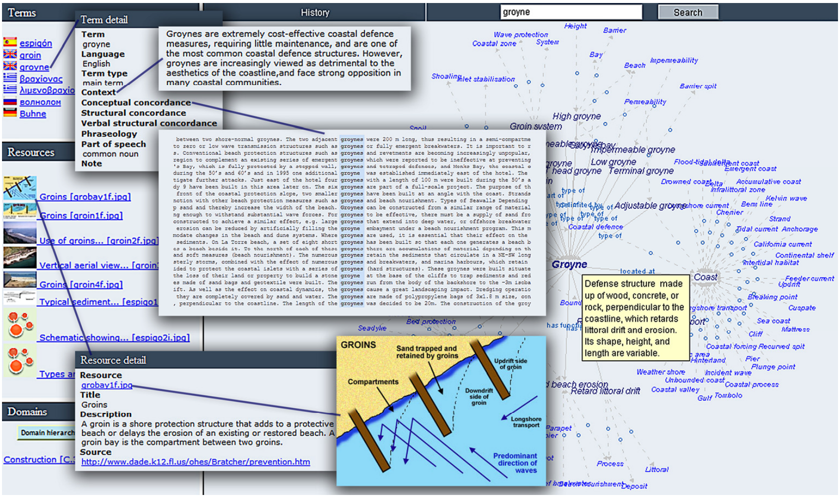

FIG. 1 – *EcoLexicon user interface*

The ontology underlying this environmental knowledge base is primarily organized around direct representations of physical objects and processes (e.g. ALLUVIAL FAN, EROSION, WEATHERING, etc). This basic set of concepts act as a 'scaffold', and their natural language descriptions provide the semantic foundation for data querying, integration and inferencing (Samwald et al. 2010). In this knowledge base, environmental concepts are codified in terms of natural language definitions that are visually represented as a network of both hierarchical and non-hierarchical semantic relations that have been semi-automatically extracted from a multilingual corpus. Even though this representation still needs to be further enriched and systematized so as to allow more sophisticated reasoning processes, it permits EcoLexicon to be connected to other ontologies and resources.

EcoLexicon can be regarded as a linguistically-based ontology since its conceptual design is based on information extracted from specialized texts and the structure of terminological definitions. In the environmental knowledge domain, top-level concepts are OBJECT, EVENT, ATTRIBUTE, and RELATION. Concepts can be concrete or abstract, simple or complex. In EcoLexicon, abstract concepts include theories, equations, and units for measuring physical entities. They are generally used by experts to describe, evaluate, and simulate reality. In contrast, physical or concrete concepts are those occupying space and occurring over a period of time. They include natural entities, geographic accidents, water bodies, constructions, and the natural and artificial process events in which they can potentially participate.

4.1 Dictionary and text analysis: RESURGENCE

One example of such a natural process event is the environmental concept RESURGENCE, which refers to a stream that flows underground, but which has reappeared at the surface. The English term used to designate this event is *resurgence*, which reflects how a general language term can undergo terminologization and be commandeered into the specialized environmental subdomain of Hydrology.

Resurgence is the nominalization of *resurge*, an English verb that is now rarely used. In general language, *resurgence* (derived from *resurge*) is defined in general language dictionaries in a variety of related ways:

(1) bringing into activity or prominence (*WordNet*)

(2) reappearance and growth of something that was common in the past (*Longman*)

(3) the act of rising again (*Merriam Websters*)

(4) a continuing after interruption (*American Heritage*)

As shall be seen, these general language definitions of RESURGENCE should be the core of the specialized language meaning so that the user can build on previous knowledge to acquire specialized knowledge. The specialized meaning of RESURGENCE should thus be based on an upwards motion event (*rising*) that involves the re-emergence (*reappearance*) of an entity after a lapse of time (*interruption*). This basic meaning of RESURGENCE can be modeled so that it is either a general or specialized description, by varying its subcategorization frame and a predicate-argument structure.

According to Buitelaar et al. (2009), analysis of predicate-argument structure should be an integral part of any proposal for the linguistic grounding of ontologies. Terminological studies normally focus on object concepts, which in most cases are linguistically represented by nominal forms. However, both in the comprehension and structure of specialized discourse across languages, verbs play an important role (L'Homme 2003). This is due to the fact that a considerable part of our knowledge is composed of events and states, many of which are linguistically represented by verbs.

These verbs set the scene for the specialized concepts, which appear on the stage in the form of terms that fill the argument slots of these verbs or semantic predicates. Though there are relatively few specialized language verbs, there are many terms that are nominal forms derived from verbs. The selection restrictions of the arguments generally depend on the area of meaning the predicate belongs to. The nature of the arguments of a predicate is the result of the extension of its meaning to other domains.

Since *resurge* is an intransitive verb with one argument (something *resurges*), when *resurgence* is activated in general language texts, it also has one argument (*resurgence* of something). Concordances retrieved from the BNC corpus showed that in general language, this argument falls into one of the following categories:

Resurgence of	**Argument 1**	
	DEMAND (*for)*	*heroin, insurance, computer package*
	INTEREST (*in)*	*someone's work, fashion, religion, cult*
	TENDENCY (*towards)*	*nonconformism, feminism, power, hostility, rebellion*
	PHYSICAL MANIFESTATION	*disease, symptoms*

TAB. 1 – *Argument structure of Resurgence*

As shown in Table 1, DEMAND, INTEREST, and TENDENCY are all abstract concepts that reappear after not being present during a period of time. Indeed, the only concrete entities related to *resurgence* are *disease* and *symptoms*, which belong to the category of PHYSICAL MANIFESTATION.

This is in direct opposition to the contexts retrieved from the corpus of our research project in which the argument of *resurgence* is a watercourse (*stream*) or a location (*point*) (see Table 2).

The self-purification ability of a **resurgence** stream has been investigated by taking samples along the course of a channeled tract
The point where the stream flows out from under the ground is called the **resurgence**.
The field survey is conducted under conditions that range from moderate to high flow during a wet period so the dominant **resurgence** points are active.
Precise vertical and horizontal locations of the key **resurgence** points and any features that potentially indicate groundwater elevations are surveyed.
Before turning south, cross the moor east to the stream descending in a series of minor waterfalls from the large **resurgence**, where all the streams disappearing in the area on Ingleborough return to daylight.

TAB. 2 – *Activation of Resurgence in specialized texts*

As shown in Table 2, the arguments for *resurgence* in specialized contexts are either the entity that resurges (*stream)* or the location where the stream or water course appears again or resurges from underneath the ground (*point*). This is in accordance with specialized language definitions given for the concept such as the following:

- return of a river that was running underground, back to the surface (http://www.buzzle.com/articles/geography-terms-glossary-of-geography-terms-and-definitions.html)
- re-emergence of groundwater through a karst feature, a part or all of whose waters are derived from surface inflow into ponors at higher levels (*Florida Spring Classification System and Spring Glossary*)
- point where an underground stream reappears at the surface to become a surface stream (*McGraw-Hill Dictionary of Scientific & Technical Terms*)

These definitions can be used to elaborate a new definition that is in consonance with that of related terms in the knowledge base, and which is an extension and specification of the general language definition.

Since the non-linguistic information in EcoLexicon is based on the information extracted from texts and dictionaries, the meaning definition of concepts has a central role in the structure of the knowledge base. A meaning definition is encoded as a set of propositions that reflect the relational meaning or associations of concepts with other concepts. For precisely this reason, definitions cannot be randomly added cut-and-paste from another resource, as often occurs in many termbases.

The final text of the meaning definition should be modeled on a template of conceptual relations that reflects its relation with other similar events in the knowledge base. In this case, RESURGENCE would have the same template as other types of upwards and downwards liquid movement in the environment, such as UPWELLING and DOWNWELLING. This template would consist of the relations *type_of, effected_by,* and *takes_place_in.*

4.2 RESURGENCE in EcoLexicon

In EcoLexicon RESURGENCE encodes a process that is initiated by natural forces, occurs in time and space, and may be affected by natural entities. It is thus described as the reappearance [*type_of* MOVEMENT] of a stream or water course [*effector_of* MOVEMENT], whose flow had previously disappeared underground [*location_of* MOVEMENT], but which now has surfaced [*location_of* MOVEMENT]. In this case, this movement is also influenced by the medium through which it moves [*affected_by* SOIL_PROPERTIES]. Figure 2 shows the representation of RESURGENCE in EcoLexicon.

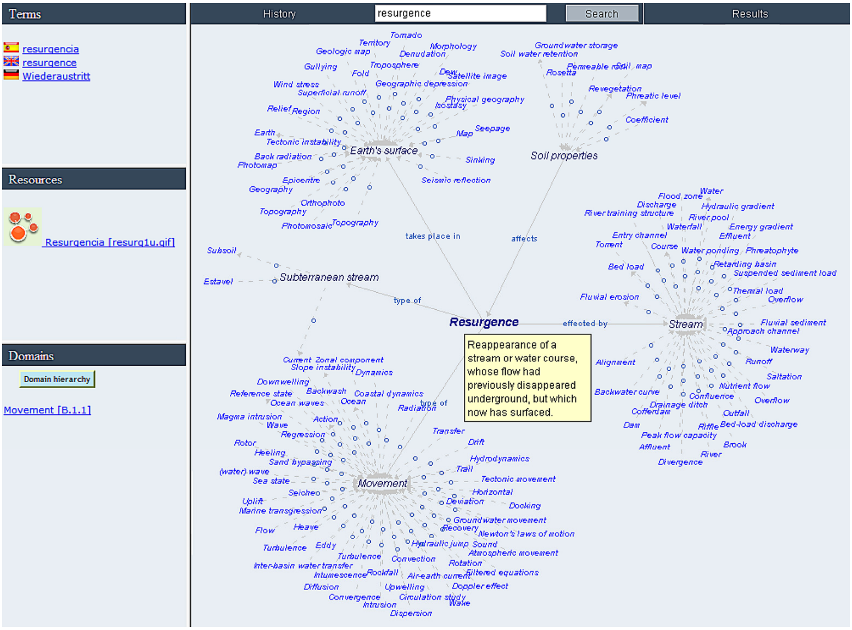

FIG. 2 – *EcoLexicon representation of* RESURGENCE

This semantic network is based on the following basic propositions:

- RESURGENCE *type_of* SUBTERRANEAN STREAM
- RESURGENCE *type_of* MOVEMENT
- RESURGENCE *effected_by* STREAM
- RESURGENCE *takes_place_in* EARTH'S SURFACE
- SOIL PROPERTIES *affect* RESURGENCE

RESURGENCE is thus both movement and the moving entity. It is a type of SUBTERRANEAN_STREAM as well as the flowing upwards movement effected by the stream. This is evident in the nuclear part of the definition, *reappearance*. The reappearance is the result of the stream's upwards movement towards the Earth's surface.

It is often the case in language (and cognition) that an entity begins to exist only when it enters our perception. Many nominal forms thus encode both an event as well as the result of the event. Accordingly, such complex events in EcoLexicon include *erosion, sedimentation, glaciation, flooding, construction,* etc., which are regarded as DOT objects by Pustejovsky (1995, 2005), and lexicalize the event-result polysemy.

When RESURGENCE is recontextualized to focus on SUBTERRANEAN_STREAM, the representation in EcoLexicon is modified and takes the form shown in Figure 3.

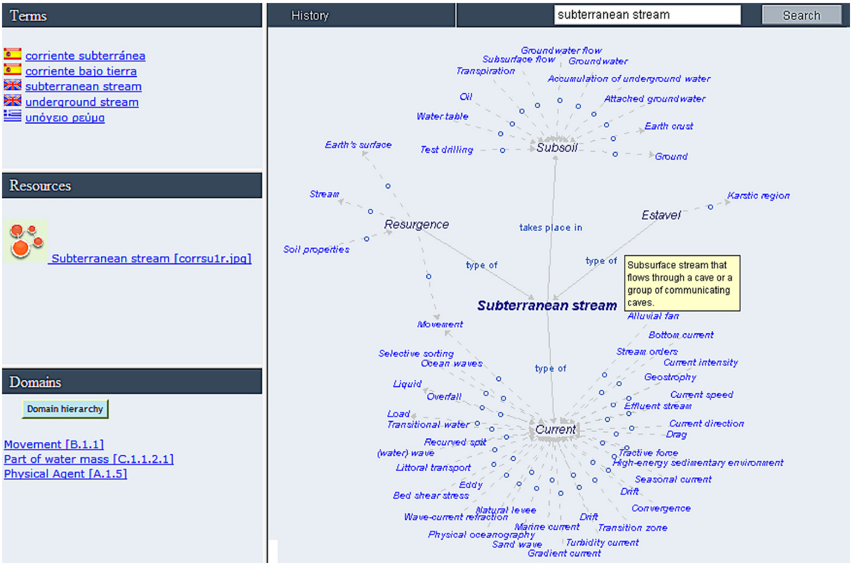

FIG. 3 – *EcoLexicon representation of* SUBTERRANEAN_STREAM

When RESURGENCE recedes into the background, it is thus possible to see its location in the knowledge frame, but with a different contextualization. The focus is thus on its argument, which in this case is SUBTERRANEAN_STREAM, defined as a subsurface stream that flows through a cave or a group of communicating caves.

As a coastal entity, this concept would have another type of template. Such entities should include a description consisting of their representation as an object or objects, relationships to other features, parts and subparts, location in absolute and relative geography, and others, designed for a specific domain of application. A STREAM, for instance, is a flow of water in a watercourse (e.g. channel or bed). A specific instance of this category has a name, course (x, y geometry), mouth, source, tributaries (numbering n), and cities located along its route. Similarly, it is bounded by ridges, flows through valleys, etc. Thus the core set of conceptual relations used to represent it would have more information related to location than movement type.

4.3 RESURGENCE as an extension of general knowledge

As previously shown, the general language meaning of RESURGENCE is not the same as its specialized meaning, which is derived from a greater specification and restriction of its semantic argument within a specialized environmental and hydrological context. However, this does not mean that this general meaning should be ignored and totally disregarded. Rather it should be used as a scaffold from which the specialized meaning can be extended.

The basic information that can be extracted from the general language definitions of RESURGENCE is that it is the *return/rising/reappearance* (nuclear part of the definition) of something (in this case, an environmental entity). One of these general terms should thus constitute the core of the specialized language definition. *Return* is too general and can be ambiguous because it could refer to the trajectory of the stream. *Reappearance* (Longman) is the best candidate because the *rising* movement is already explicit in the general meaning of the verb *surge,* which is part of the morphological structure of the term. *Rising* (Merriam Websters) is also implicit in the fact that the underground stream re-emerges at the ground surface. The continuing after interruption (*American Heritage*) is also encoded in re-emergence.

For this reason, RESURGENCE in EcoLexicon is defined as "reappearance of a stream or watercourse, whose flow had previously disappeared underground, but which now has surfaced". In this way, the description of specialized language concepts can be regarded as an extension of the general language description.

5. Conclusion

This paper has described how concepts are modeled in EcoLexicon, a conceptually-structured terminological knowledge base on the environment. This resource aspires to psychological and explanatory adequacy since its underlying conceptualization and design is geared toward optimal and effective knowledge acquisition in the specialized area. Evidently, in order to be more meaningful, specialized knowledge must be coherently structured, but it should also be explicitly connected to general knowledge structures.

EcoLexicon can be regarded as a linguistic ontology since it is strongly language-dependent and focuses on terms in various languages. Ontologies are important in Terminology since they anchor linguistic representations in one or various languages to the same conceptual representation and help to eliminate conceptual and terminological confusion. It is now widely acknowledged that constructing such a domain model is crucial to the development of knowledge-based systems.

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Résumé

Les ontologies ont été souvent critiquées en raison de la quantité de travail qu’elles nécessitent ou parce qu'elles manquent de flexibilité pour représenter le dynamisme et la complexité de la réalité (Kingston 2008). Néanmoins, même si toute représentation de la réalité demeure imparfaite, les ontologies constituent le modèle computationnel de représentation de la connaissance se rapprochant le plus de la conception cognitive d’un domaine. Il n’est donc pas surprenant de constater qu’elles gagnent en attractivité. Les besoins grandissants en matière de gestion des connaissances et de savoir partagé, aussi bien dans le domaine général que spécialisé, en sont l’explication. EcoLexicon est un thésaurus visuel sur l’environnement, basé sur la sémantique des cadres, qui se nourrit d’une base de données relationnelle. Celle-ci évolue progressivement vers le statut d’ontologie formelle (León et al. 2008; León et Magaña 2010). Cet article décrit les techniques de modélisation conceptuelles employées dans la ressource évoquée et les prémisses théoriques qui en permettent la conceptualisation et la liaison à d’autres structures et ressources de connaissances générales.