CONCEPTUAL MODELING IN SPECIALIZED KNOWLEDGE RESOURCES

Pamela Faber, Antonio San Martín

***Abstract**: Conceptual modeling is the activity of formally describing aspects of the physical and social world around us 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.*

In this respect, the design and creation of terminological databases for a specialized knowledge domain is extremely complex since, ideally, the data should be interconnected in a semantic network by means of an explicit set of semantic relations. Nevertheless, despite the acknowledged importance of conceptual organization in terminological resources [Puuronen, 1995], [Meyer et al., 1997], [Pozzi, 1999], [Pilke, 2001], conceptual organization does not appear to have an important role in their design. It is a fact that astonishingly few specialized knowledge resources available on Internet contain information regarding the location of concepts in larger knowledge configurations [Faber et al., 2006].

Such knowledge resources do not take into account the dynamic nature of categorization, concept storage and retrieval, and cognitive processing [Louwerse and Jeuniaux, 2010], [Aziz-Zadeh and Damasio, 2008], [Patterson et al., 2007], [Gallese and Lakoff, 2005]. Recent theories of cognition reflect the assumption that cognition is typically grounded in multiple ways, e.g. simulations, situated action, and even bodily states. This means that a specialized knowledge resource that facilitates knowledge acquisition should thus provide conceptual contexts or situations in which a concept is conceived as part of a process or event. Since knowledge acquisition and understanding requires simulation, this signifies that horizontal relations defining goal, purpose, affordance, and result of the manipulation and use of an object are just as important, if not more so, than vertical generic-specific and part-whole relations.

Within the context of recent theories of cognition, this paper examines the frame-based conceptual modeling principles underlying EcoLexicon, a multilingual knowledge base of environmental concepts (http://ecolexicon.ugr.es/) [Faber et al., 2005, 2006, 2007].

***Keywords**: conceptual modeling, terminological knowledge base, cognition, specialized knowledge representation*

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1. Introduction

Conceptual modeling is the activity of formally describing aspects of the physical and social world around us 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.

2. Terminology, user needs and terminological knowledge bases

Terminology and specialized knowledge representation is basic to knowledge acquisition processes such as specialized translation and communication. Given that terms are the linguistic designations of specialized knowledge concepts, it goes without saying that they are inextricably linked to their representation, activation, transmission, and acquisition of specialized knowledge. According to [Sandrini, 2000: 1], concepts are at the center of all types of knowledge, and constitute the key elements of the knowledge space of a subject area. A knowledge space is made up of relations among concepts of a predefined domain, and is represented by statements. Concept systems are evidently a core element in conceptual knowledge representation and acquisition.

As is well-known, a major focus in both applied and theoretical Terminology and Specialized Communication has always been conceptual organization. In fact, a great deal has been written on the topic [Budin, 1994], [Puuronen, 1995], [Meyer and Mackintosh, 1996], [Meyer et al., 1997], [Pozzi, 1999], [Pilke, 2001], [Feliu, 2004], [Tebé, 2005], [Faber et al., 2007], [León 2009], *inter alia*. Given the fact that terms are specialized knowledge units that designate our conceptualization of objects, qualities, states, and processes in a specialized domain and are key to understanding, any theory of conceptual modeling and knowledge representation should aspire to psychological and neurological adequacy. Conceptualization processes as well as the organization of semantic information in the brain should underlie any theoretical assumptions concerning the access, retrieval, and acquisition of specialized knowledge as well as the design of specialized knowledge resources. However, quite often, this is not the case.

It is a fact that conceptual organization (of any sort), despite its acknowledged importance, does not appear to have an important role in the elaboration of specialized knowledge resources. Astonishingly few resources are conceptually organized, and even those that are based on meaning merely provide an overview of a specialized field, solely based on the IS_A or TYPE_OF conceptual relation. This overview usually consists of graphical representations of concepts in the form of tree or bracket diagrams. However, even this type of organization is a fairly rare occurrence since the great majority of terminological resources available on Internet contain little or no information regarding the location of specialized knowledge concepts in larger knowledge configurations [Faber et al., 2006].

Even when concept maps or representations are provided, they rarely respond to user needs or expectations. Our experience as thinkers tells us that the mainstream conceptual tree does not adequately reflect what is in our mind, and that our mental representations are much richer and more flexible than such representations of conceptual structure.

Since knowledge resources should reflect, to the extent possible, conceptual categories and the processes that actually occur in the brain, the question is how an awareness of the nature of mental processes can be applied to the representation of specialized knowledge concepts in order to enhance specialized knowledge acquisition.

3. Theories of cognition

As is well-known, standard theories of cognition are based on abstract, amodal representations of entities, events, and processes stored in semantic memory, which do not take into account the human and contextual factor of processors, their focus of attention, spatiotemporal situation, or context of perception [Barsalou, 2008: 618], [Mahon and Caramazza, 2008: 59]. As it happens, these conventional (though inadequate) theories of cognition are the same theories upon which mainstream conceptual representations (or conceptual trees) in specialized knowledge domains are currently based.

The question is what really happens in our mind when we think about something, and how we acquire permanent knowledge about it. Recently, a set of new theories of cognition have been proposed that provide new insights into conceptualization processes. These theories claim that cognition is situated, and that understanding is equated with sensory and motor simulation. In other words, when we encounter a physical object, we partially capture property information on sensory modalities so that this information can later be reactivated [Damasio and Damasio, 1994].

For example, to represent the concept, PEACH, neural systems for vision, action, touch, taste and emotion partially reenact the perceiver’s experience of a peach. These reenactments or simulations are not the same thing as mental imagery, which is consciously evoked in working memory. Unlike mental imagery, these simulations seem to be relatively automatic processes that lie outside of our awareness [Simmons et al., 2005: 1602].

To date, brain-imaging experiments have largely involved the conceptualization of everyday objects such as cups, hammers, pencils, and food, which, when perceived, trigger simulations of potential actions. For example, the handle of a cup activates a grasping simulation [Tucker and Ellis, 1998, 2001]. Food activates brain areas related to gustatory processing as well as areas in the visual cortex representing object shape [Simmons et al., 2005]. When conceptual knowledge about objects is represented, brain areas represent the shape and color of objects, the motion they exhibit, and the actions that agents perform on them become active to represent these properties conceptually.

Such reenactments not only occur in the presence of the object itself, but also in response to words and other symbols. For precisely this reason, they should be taken into account in Terminology. Although few neuropsychological experiments of this type have ever been performed with specialized concepts, there is no reason to suppose that the brain would work any differently.

For example, when reading about hockey, experts were found to produce motor simulations absent in novices [Holt and Beilock, 2006]. In all likelihood, a similar result would be the obtained if the object were a tide gauge, pluviometer, or anemometer. The expert’s brain would show motor simulations in brain areas that would not be activated in the case of non-experts to whom the object was unfamiliar. The information regarding simulated interaction is thus a vital part of conceptual meaning. The way that object concepts are represented in our brain seems to suggest that current methods and ways of elaborating specialized knowledge representations should be modified in order to take this information into account in order to facilitate knowledge acquisition.

4. Applying situated cognition to specialized knowledge representation

Yet, we may well ask ourselves if such research on cognition, however valuable, can be usefully applied to the creation of specialized knowledge resources. We believe that the answer is yes. First of all, situated conceptualizations reflect the fact that concepts are not processed in isolation, but are typically situated in background situations and events [Barsalou, 2003]. This signifies that context is crucial in knowledge representation. At any given moment in the perception of the entity, people also perceive the space surrounding it, including the agents, objects, and event present in it [Barsalou, 2009: 1283], and this can be applied to specialized knowledge modeling.

For example, EROSION is the wearing away of the earth’s surface, but whether conceptualized as a process or the result of this process, erosion cannot be conceived in isolation. It is induced by an agent (wind, water, or ice) affects a geographic entity (the Earth’s surface) by causing something (solids) to move away. Moreover, any process takes place over a period of time, and can be divided into smaller segments. In this sense, erosion can happen at a specific season of the year, and may take place in a certain direction. All of this information about erosion should be available for potential activation when we think about the concept, and wish to acquire knowledge about it. The meaning of a concept is constructed on-line, and is modulated by context.

4.1 Frame-based Terminology and dynamic knowledge representation

Accordingly, a knowledge resource that facilitates knowledge acquisition should not be in the form of a static term base with a list of unrelated data records. It should represent concepts as part of a larger context or situation in which the concept is related to others in a dynamic structure that can streamline the action-environment interface.

Frame-based terminology [Faber et al., 2005, 2006, 2007] uses a modified version of Fillmore's Frames [Fillmore 1982, 1985], [Fillmore and Atkins, 1992] coupled with premises from Cognitive Linguistics to configure specialized domains on the basis of definitional templates and create situated representations for specialized knowledge concepts.

4.1.1 Event representation

In Frame-based Terminology, conceptual networks are based on an underlying domain event as well as a closed inventory of both hierarchical and non-hierarchical semantic relations. We have used these premises to construct an environmental knowledge base called EcoLexicon (http://ecolexicon.ugr.es/). The main focus is on conceptual relations as well as a concept's combinatorial potential, extracted from corpus analysis. This prototypical domain event or action-environment interface [Barsalou, 2003] provides a template applicable to all levels of information structuring.

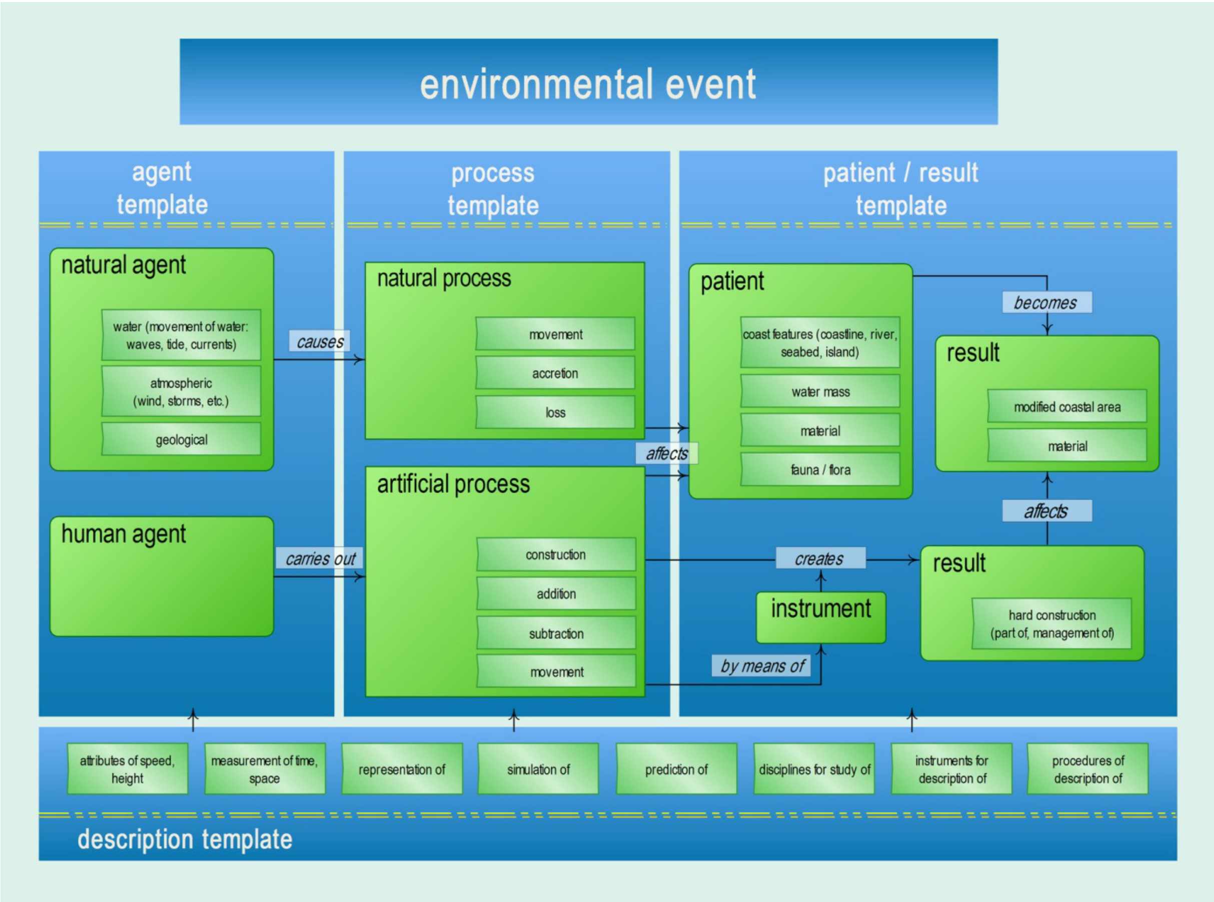

Figure 1. Environmental Event.

In EcoLexicon, knowledge can be accessed from top-level categories to more specific relational structures. The most generic level is the Environmental Event (EE), which provides a frame for the organization of all concepts in the knowledge base. As shown in Figure 1, the EE is conceptualized as a dynamic process that is initiated by an agent (either natural or human). This process affects a patient (an environmental entity), and produces a result. These categories (agent, process, patient, etc.) are the concept roles characteristic of this specialized domain. Additionally, there are peripheral categories which include instruments that are typically used during the EE, as well as a category where the concepts of measurement, analysis, and description of the processes in the main event are included. This event-based representation facilitates knowledge acquisition in text processing since conceptual categories are bound together by event knowledge.

4.1.1.1 extreme event

For example, one of the concepts in EcoLexicon is EXTREME EVENT in its sense of natural disaster. Disasters in the environment include great earthquakes, floods, giant sea waves, hurricanes, tornadoes, etc., and their consequences. The concept of EXTREME EVENT is very complex since it is a natural agent that initiates a process (i.e. earthquakes or volcanic eruptions can produce tsunamis) but it can also be the process itself, which occurs in time and space. This information is represented in EcoLexicon as shown in Figure 2.

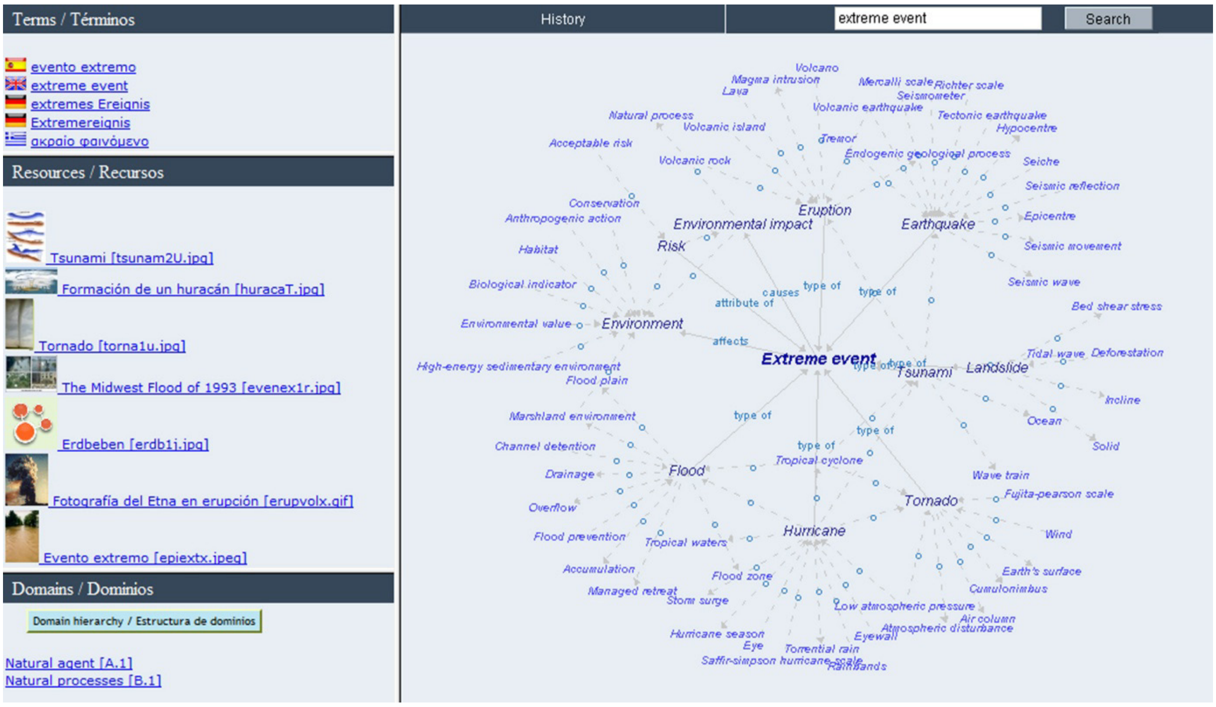

Figure 2. Representation of EXTREME EVENT in EcoLexicon.

As shown in Figure 2, all of the concepts closest to the central concept are connected to it by a series of conceptual relations that are explicitly named (e.g. TYPE-OF, CAUSES, AFFECTS, etc.). Since EXTREME EVENT is a very general concept, the only visual information that can be associated with it is that of its subtypes (HURRICANE, TORNADO, EARTHQUAKE, FLOOD, etc.). The majority of relations at this level are thus TYPE_OF. However, EXTREME EVENT also activates non-hierarchical relations typical of the general event frame. As such, its principal attribute is RISK; it AFFECTS the environment; and CAUSES an environmental impact. As for the TYPE_OF relations, they can be regarded as access routes to more prototypical base-level concepts [Rosch, 1978], which do have a mental image, and can activate specific contexts. This set of subtypes (hurricane, tornado, flood, tsunami, etc.) take the form of constellations, each with their own set of subordinate concepts and conceptual relations, which encode more specific sub-event knowledge and representations.

4.1.1.2. Recontextualization: hurricane

According to [Barsalou, 2005], a given concept produces many different situated conceptualizations, each tailored to different instances in different settings. Thus, context can be said to be a dynamic construct that activates or restricts knowledge. This general event that codifies a natural disaster can thus be recontextualized at any moment to center on any of the more specific subevents. For example, when the EXTREME EVENT representation is recontextualized to focus on HURRICANE, it takes the following form.

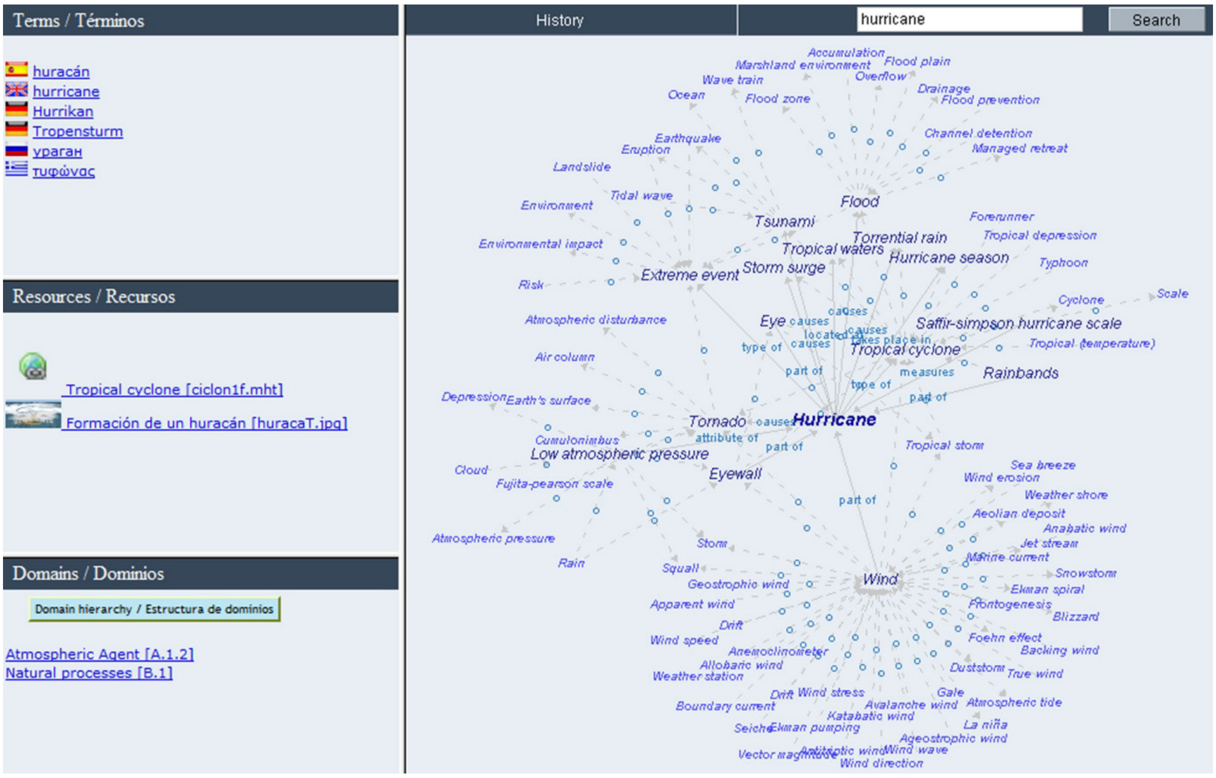

Figure 3. Representation of HURRICANE in Ecolexicon.

This type of recontextualization of EXTREME EVENT still contains a sector of the previous information, but varies the focus of attention so that hurricane is now the center of focus. Besides communicating the fact that hurricane is a type of extreme event, this new representation highlights the fact that wind and flooding are crucial participants in the event. Wind is part of a hurricane, and a hurricane causes floods. Not surprisingly, WIND and FLOOD are concepts that are susceptible to simulation since they can directly affect human life and health. It also mentions the attribute of low atmospheric pressure as well as the scale used for hurricane measurement (Saffir-Simpson hurricane scale), which codifies an important aspect of expert interaction with a hurricane.

4.1.2. Object representation

Object concepts can also be represented dynamically as parts of events. One of the basic characteristics of objects is knowledge of whether and how they can be manipulated. In the case of man-made objects, another important property is their function, or how they can be used. This would mean that an important part of the information in the representation of specialized engineering instruments would evidently involve how they are used by humans, for what purpose, and what is the result of the manipulation.

4.1.2.1. Recording instrument

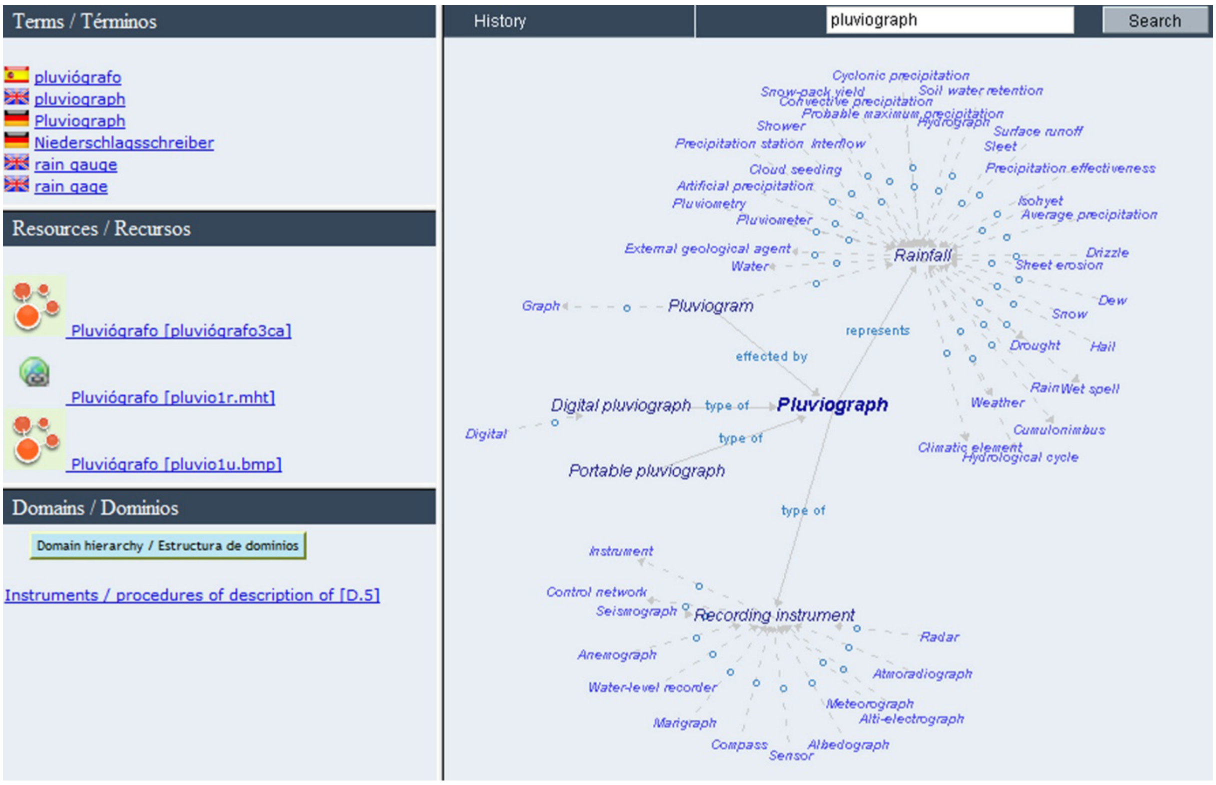

Figure 4. Representation of PLUVIOGRAPH in EcoLexicon.

For example, a RECORDING INSTRUMENT (e.g. marigraph, pluviograph, anemograph, etc.) is a subtype of INSTRUMENT. As a manmade manipulable artifact, a recording instrument has a function (i.e. recording) as well as an object that is recorded (tides, rain, wind, etc.). As a tool, it is strongly susceptible to human interaction, and activates a simulation frame in which much of the perceiver's knowledge of the artifact involves his/her ability to handle it and in some way to extract information from it. For example, Figure 4 shows the representation of PLUVIOGRAPH.

The representation of PLUVIOGRAPH, of course, includes TYPE_OF information. A pluviograph is a recording instrument, and has subtypes, such as digital pluviograph and portable pluviograph. However, it is also part of what might be called a RECORDING EVENT in which a human agent causes the machine to record and generate a representation of something (RAINFALL). The recording instrument used in this event is a pluviograph, which produces (or effects) a PLUVIOGRAM. As can be observed in Figure 4, this process is reflected in the non-hierarchical relations REPRESENTS and EFFECTED_BY.

5. Conclusions

In order to translate specialized texts, translators must acquire sufficient knowledge of conceptual content. Although it is not necessary to have the same depth of knowledge as an expert in the field, there is a minimum threshold that must be met. The knowledge acquisition process can be carried out in cost-effective time if translators have a set of search strategies developed and knowledge resources at their disposal.

One of the problems of knowledge acquisition is precisely the lack of translation-oriented terminological resources that reflect the complexity and dynamicity of conceptualization. Although in terminology theory, much emphasis is placed on conceptual representation, reality shows that very few specialized dictionaries or glossaries are concept-based, and those that are based on meaning, only offer static representations based on the IS_A or PART_OF relation.

A truly effective specialized knowledge resource should reflect recent advances in neurocognition which point to the following:

1. No specialized knowledge concept should be activated in isolation, but rather as part of a larger structure or event. A specialized knowledge resource that facilitates knowledge acquisition should thus provide conceptual contexts or situations in which a concept is related to others as part of a process or event.

2. Since knowledge acquisition and understanding requires simulation, this signifies that non-hierarchical relations defining goal, purpose, affordance, and result of the manipulation and use of an object are just as important as hierarchical generic-specific and part-whole relations.

3. Specialized domains are constrained by the nature of their members. This is reflected in clusters of conceptual relations that make up the general representational template, characterizing different categories.

All of these conclusions have been illustrated by examples from EcoLexicon, an environmental knowledge base (available at: http://ecolexicon.ugr.es/). EcoLexicon is a conceptually-organized, frame-based terminological resource that facilitates knowledge acquisition since it presents concepts as part of larger knowledge structures and permits dynamic processes such as the recontextualization of knowledge representations.

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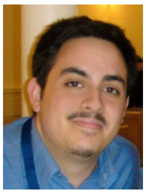

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