An Application of Facet Analysis Theory and Concept Maps for Faceted Search in a Domain Ontology: Preliminary Studies

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Netto, Cristiane Mendes, Gercina Ângela Borém de Oliveira Lima and Ivo Pierozzi Júnior. 2016. "An Application of Facet Analysis Theory and Concept Maps for Faceted Search in a Domain Ontology: Preliminary Studies." *Knowledge Organization* 43: 254-264. 22 references.

Abstract: This paper presents partial results of a research project still in development that aims to study the theory of faceted analysis and concept maps for faceted search in a domain ontology. The research shows a solution that enables abstraction levels for users in order to retrieve information in the domain area represented in ontology. The problem is considered a challenge, because of the formal computational structure of semantic description of ontology that does not present itself as feasible from the point of view of its users' cognition. This paper exposes the results using a web tool prototype for faceted navigation in a sample of ontology that was created for the organization of the domain knowledge, regarding the impact of agriculture and climatic changes on water resources. The results show the feasibility of navigation and information retrieval in the ontology using the web faceted prototype. It is believed that through this study a computational solution that can be developed is able to facilitate the creation of the conceptual model for faceted and concept map navigation around the area represented by ontology so human learning on the domain can be assessed, as well as the recovery and sharing of information on user groups.

Received: 23 March 2016; Revised: 28 March 2016; Accepted: 29 March 2016

Keywords: information, ontology, domain knowledge, concept maps, facet analysis

1.0 Introduction

One of the objectives of knowledge organization is to create a shared vision of a domain for a given user community. Thus, in the context of a group of people working together within the same domain, it follows that the organization of concepts and the information in a knowledge organization system (KOS) is essential for developing an effective job. Considering this need and the possibility of using technology to support the organization of knowledge, domain ontologies have been presented as an alternative to explain formally shared concepts and the relationships within a particular subject area. As presented by Sales et al. (2008), an important element of ontologies is the knowledge representation in a semantic context, which can provide a greater processing intelligence to the computer due to the representations of relations that are explicit in a formal language. In consequence, the results of information retrieval can be better presented to users.

However, from the point of view of navigation and human cognition, the structure is extremely complex. It lacks an interface that allows abstraction levels for information retrieval that encourages users who do not master these technologies. It is easy to access, to retrieve and to learn the diverse content of a domain, represented by the ontology. This problem was identified in the real context of the Brazilian Agricultural Research Corporation and it is a challenge that lacks an efficient solution. This work presents the partial results of a developing research project, which aims to study the theory of faceted analysis and concept maps for representing information on domain ontologies. In this case study, the OntoAgroHidro was analyzed. This domain ontology was established in such a way as to organize the field of knowledge concerning the impact of agriculture and climate change on water resources. Its construction was made by experts and the structure contains more than 8,500 domain concepts described in OWL 2, using the Protégé tool.

This study is justified by the theory of faceted analysis and it was supported by the results of Pontes and Lima (2012) and Maculan (2011); there they show a conceptual model on the digital context based on this theory providing a more efficient representation and recovery for users. In addition, the positive results presented by Lima (2004), with the theory of faceted analysis it, were used to create a conceptual model of the hypertext document and, also concept map theory was used to create a structural navigation. From studies of the theoretical framework and the literature review during the methodological development of this work, the Facetlog prototype developed by Silva (2013) was discovered; this is a tool designed to represent OntoAgroHidro ontology in a web interface faceted navigation. To this representation was added arbitrarily a sample of the ontology and a mapping model for the structure of this prototype was created.

Initially, the results demonstrated the feasibility of navigation and information retrieval in the ontology through the web faceted prototype. It is believed that it is possible to develop a computational solution that can facilitate the creation of the conceptual model for navigating facets and conceptual maps across the area represented by OntoAgroHidro. Accordingly, such solutions allow assessment of human learning in the field as well as the recovery of and information sharing among users. The article is organized as follows: section two describes the methodology; section three presents the theoretical foundations; section four reports about the OntoAgroHidro ontology; section five exposes the results of the study; then, the final considerations are presented.

2.0 Methodology

This work utilizes exploratory, descriptive and case study methods. According to Gil (1991), the first aims to provide greater familiarity with the problem in order to make it more explicit involving the improvement of ideas or the discovery of intuitions. The descriptive research aims to describe the characteristics of a given population or phenomenon for then establishing relationships between variables. The case study arises from the use of OntoAgroHidro within its real context. The nature of the research is applied, which, according to Marconi and Lakatos (2003), is characterized by practical interest, i.e., that the results are applied immediately to solve problems that occur in reality.

The following steps describe the methodological approach used to develop this work:

- Bibliographic research: A theoretical research study was undertaken on the theory of facet analysis, concept maps and ontologies, in addition to a study of related work where we attempted to analyze the use of these ideas in organizational applications of information. The survey was conducted on the CAPES Portal (Digital Library of Scientific Journals) and Google Scholar, and was supplemented by theses and dissertations from the libraries of various institutions.
- Study of Ontology OntoAgroHidro: Seeking to understand the domain being modeled, the ontology construction process was studied, likewise, the structure, relationships and entities represented in the Protégé tool. During this stage, there was continuous contact with professional domain experts who worked on the creation of the ontology a well as visualization tools used to understand the ontology structures.
- Study and choice of interface: To assess how the representation of OntoAgroHidro could be made into facets

and conceptual maps, some tools were studied. By presenting a web interface for faceted navigation, the prototype Facetlog, developed by Silva (2013), was chosen for this study.

– Conceptual modeling: Within this step, we sought to identify how the ontology of structures could be abstracted and mapped to the web faceted navigation tool Facetlog.
– Testing and analysis of results: From the model created, testing and evaluation of navigation and information retrieval were analyzed.

3.0 Theoretical foundations

This section presents the theoretical foundations of the issues underlying the proposed development of this work.

3.1 Faceted analysis theory

Facet analysis theory has its origin in the work of an Indian mathematician who became a librarian, Shialy Rammarita Ranganathan (1892-1972), whose idea was originally published in the 1930s. He is considered one of the scholars who contributed greatly to the theory of librarianship in the twentieth century (Lima 2004), especially in the area of subject classification. Facet theory (Duarte and Cerqueira 2007) is a type of classification that can identify the common characteristics of various categories of a subject organized into parts that are denominated as facets; it involves two different, but complementary, processes: subject analysis in facets and elements synthesis, and therefore, it is applicable to any area of knowledge. Barbosa (1972, 174) defines faceted classification as a system that brings together structured terms on the basis of the analysis of a subject to identify its aspects, that is, all of the different aspects contained therein. Facet analysis coordinates concepts, meaning that a subject's complexity can be represented by the synthesis of more than one facet, each indicating different concepts.

As shown by Lima (2004), to develop a faceted classification required examining the literature of a subject with the purpose of identifying its concepts and terms, then, establishing its features and facets. After bringing together and defining the terminology of the subject, the terms are analyzed and divided into facets. In this process, the subject is fragmented into facets and represented by selecting five basic categories of elements: personality, matter, energy, space and time, known by the acronym PMEST. The personality category is the characteristic that distinguishes the subject. The matter category is the physical material of which a subject can be composed. The energy category can be understood as an action that occurs with respect to the subject, while the space category is the geographic component of the location of a subject. The time category is the period associated with a subject.

Ranganathan's main categories had been studied attentively in the 1950s by a group of London researchers who formed the Classification Research Group (CRG). From the ideas that had been suggested by Ranganathan, this group proposed changes to some aspects of the theory, considering it too restrictive. Among these changes, the CRG expanded from five PMEST categories to ten: final product types, parts, materials, properties, processes, operations, agents, space, time and forms of presentation. Table 1, as presented by Maculan (2011), shows that the categories identified by the CRG seem to accommodate the categories that had been indicated by Ranganathan, but more targeted and subdivided.

Ranganathan	CRG
Personality	Final Product Types
Matter	Parts
	Materials
	Properties
	Forms of Presentation
Energy	Processes
	Operations
	Agents
Space	Space
Time	Time

Table 1. Comparison between categories of Ranganathan and CRG.

As Maculan (2011) explained, both Ranganathan and the CRG proposed to segment an issue within a particular domain. Thus, in Ranganathan's view, each domain has the personality category, which is its subject or object; matter, which is the breakdown of that subject or object in different attributes or characteristics (materials, properties, quality); energy, which are the actions, activities or processes in relation to the subject or object investigated; space, which is the setting of the subject or object, such as its geographical location; and time, which is usually the date or historical context of the period studied object, or even the year of production of such knowledge. The categories space and time are the same, and, therefore they do not cause controversy, but the others deserve more study. Drawing a parallel to the other categories indicated by Ranganathan and the CRG, the categories are reconsidered: personality and "types of final product" which is the theme we investigate; matter as parts, materials, property, which is the theme of targeted research; and energy as

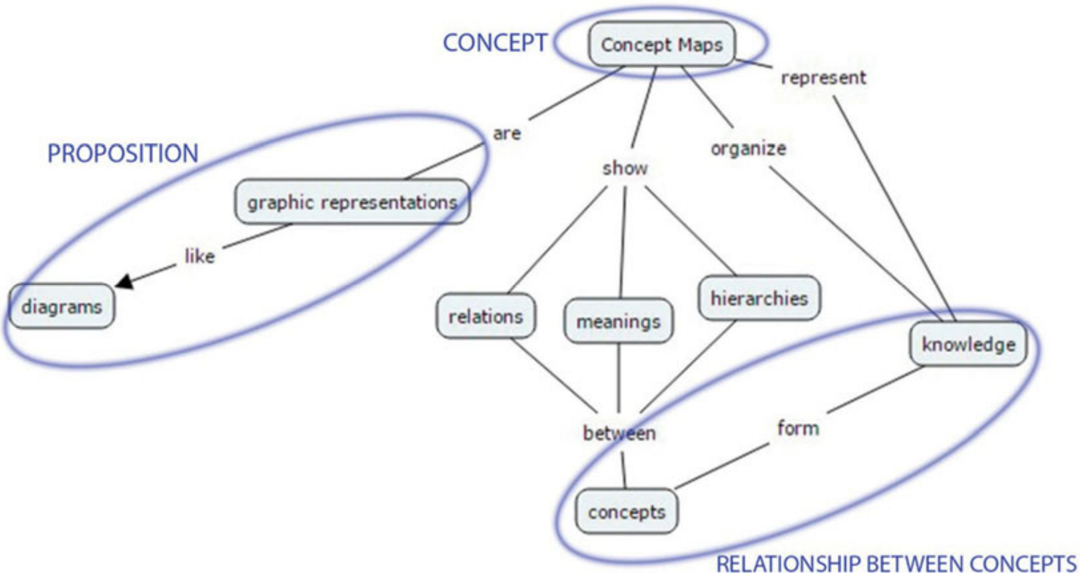

Figure 1. A concept map representing the concept of conceptual map.

processes, operations, agents, since it indicates the means of implementation and variables in action. Therefore, it is noted that even the larger number of categories can be considered specifications of the categories represented by PMEST, conceived previously by Ranganathan.

Among the advantages of facet analysis theory, Costa (2012) presents the possibility of a set of information being organized in several ways. The organization of a magazine, for example, can be performed by subjects: news, sports, culture, health, beauty, among others. This set can be called faceted classification, as each subject is a dimension in the structure that organizes the information. This type of classification allows the user to search for information from various terms and can relate them, which is characterized as one of the advantages of faceted classification; it accommodates different search strategies and conceptual models. In the development of this work we sought to understand the principles of organization of knowledge by faceted analysis, representation of concepts described in the domain ontology.

3.2 Conceptual maps

Theory concerning concept maps was developed in the 1970s by the researcher Joseph Novak, from the theory of meaningful learning of David Ausubel. Novak and Kanas (2008) introduced the concept map as a graphical tool for organizing and representing knowledge. The definition by Moreira (2010) says that concept maps can be understood as two-dimensional diagrams showing hierarchical relationships between concepts of a body of knowledge and they derive their existence from the conceptual structure of this body.

Concept maps represent the concepts usually within circles, and the relationships between the concepts, which are indicated by connecting lines. The concept-relationship-concept sets form propositions that are meaningful statements about objects or events involved. The proposals define the semantic units or map cognition units. In the structure of the conceptual map, it can also represent cross-links identifying relationships between concepts in two different areas of the map. Figure 1 shows a conceptual map representing these ideas (Souza 2006). In this illustration, an important feature of the concept map is that the concepts are represented in a hierarchical way that means, the most inclusive or generics are located at the top of the map and the most specific concepts at the bottom. Thereby, the map's vertical axis defines a hierarchical structure for conceptualizations.

As shown by Lima (2004), concept maps can have the following advantages: 1) they define a central idea through the subject's position in the center of the page; 2) they give a clear indication of the relative importance of each idea; 3) the links between the key ideas are easily found; 4) all basic information can be viewed on a single page; 5) as a result, recall and review are more efficient; 6) new information can be inserted without disturbing the information structure ; 7) the information in different formats and different points of view can be easily accessed; 8) the complexity of the relationships between ideas can be easily understood; and, 9) it is easy to use them to verify contradictions, paradoxes and flaws in the material organized.

According to Tavares (2007), although concept maps can transmit factual information, as well as texts, these organizational graphics are more effective, because the graphics help readers to build complex inferences and to integrate the information provided. They also have the potential to improve accessibility and usability of materials during a search in such a way that they present visual-spatial markers that can guide a selection or categorization. There is empirical evidence on the effectiveness of searches, which demonstrates that people can locate more information when they are presented in the forms of maps.

Depending on need and interest, the conceptual structure of a map can be represented in different ways, in order to show the concepts. Among the most common representations are web-like maps, in which the focus is placed in the center, hierarchical maps, and flowcharts. As for the arrangement of presentation, the maps can be in three-dimensional format, hyperbolic, etc. There are several tools that can be used to design concept maps. CmapTools software, developed at the IHMC (Institute for Human and Machine Cognition), is software which presents a potential solution to assist in the exploitation of documents, giving support to visualization and to the process of acquisition, organization, representation, location and use of documented knowledge. Cmap also gives support to information and knowledge in digital environments. In this work it was necessary to understand the definition of concept maps with the purpose of studying the representation of the concepts described in the field of knowledge.

3.3 Ontologies

As shown by Almeida (2013), the term ontology has been used differently in many scientific fields. In the context of information science, ontologies can be considered a mechanism of knowledge representation as a means of observing the knowledge of a given domain. Guizzard et al. (2008) show that in the context of concept modeling, the term ontology is used in accordance with the definition given in philosophy, which is the reference to a formal system of categories that can be used to articulate concepts and models in specific areas of knowledge. According to Campos (2010), a concept is an abstraction, a simplified view of the world that represents itself in order to help understanding, sharing or consensus in an area of knowledge. Although, in information science there are other representation of information in shared databases, such as thesauri, ontologies provide a meta-level and extremely powerful resource that has the possibility of offering inference to support the handling of explicit knowledge in an ontology.

In conformity with Almeida and Bax (2003), ontologies do not always have the same structure, but they can have features and basic components, which are in most of them. So, the basic components are presented as: classes (organized in a taxonomy), relations (representing the type of interaction between the concepts of a domain), axioms (used to model true sentences) and instances (used to represent specific elements—the data themselves). With respect to the benefits related to the use of ontologies in the specification of a domain, Guizzardi (2000) provides:

- Communication*:* Ontologies are useful for assisting communication between people about certain knowledge because they help in the reasoning and understanding of this domain. This relationship helps in reaching consensus, interaction and elicitation of knowledge about technical terms in a professional community.
- Formalization: Formalization is related to the specification of the ontology for eliminating contradictions, inconsistencies and ambiguity in the representation of knowledge. Furthermore, this specification can be tested, verified and validated.
- Knowledge representation and reuse: Ontologies are constituted by a vocabulary of consensus that can represent domain knowledge at its highest level of abstraction, aggregating a potential of reuse.

There are several classifications of types of ontologies. Guarino (1998) proposes a classification based on their contents, with top-level ontologies, which describe general concepts such as space, time, event, and others that are independent of a particular domain. On the other hand, domain ontologies and task ontologies respectively describe the vocabulary of a domain and tasks or processes. Application ontologies describe concepts that are dependent on both domain and task. In this work, the OntoAgroHidro ontology study is classified as a domain ontology.

4.0 OntoAgroHidro: a domain ontology

OntroAgroHidro is a domain ontology created from the interest of a group of expert researchers from the field of water resources, climate change and land use within the EMBRAPA (Brazilian Agricultural Research Corporation). The study regarding the need to reconcile the development of agricultural production with the sustainable use of water and land can be considered of global importance. Furthermore, the need to have a solution for sharing and integrating information between the various institutions and researchers triggered the efforts to create a domain ontology.

The OntoAgroHidro building process is reported by Bonacin et al. (2013), which present the reuse strategies

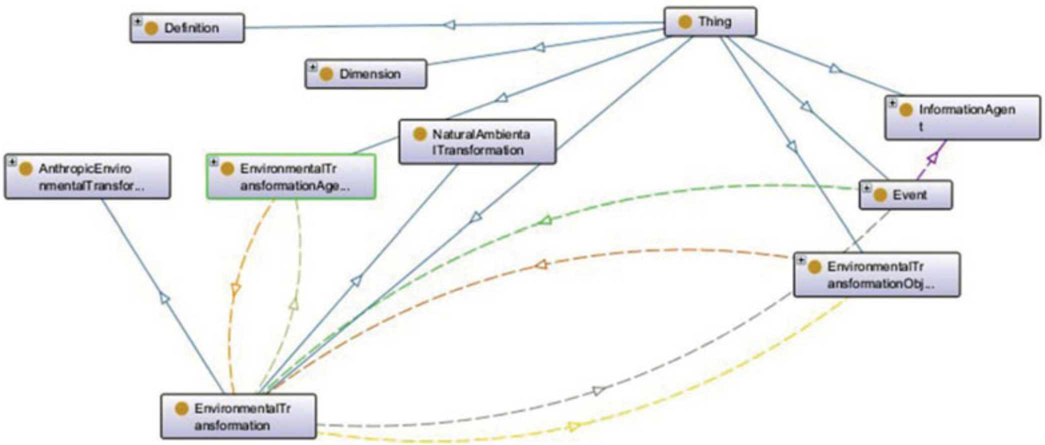

Figure 2. Representation of the main classes of OntoAgroHidro in Protégé tool.

Ranganathan	CRG	Ontologies	Conceptual maps
Personality	Types of final product	Class and subclass	Concept
Matter	Parts Materials Properties Apresentation forms	Whole and Part attributes	Hierarchy relationships
Energy	Processes Operations Agents	Relationships	Propositions/inferences
Space	Space	Origin attribute	Origin Object
Time	Time	Date attribute	Date object

Table 2. Comparative table of a domain representation proposition.

and integration of other existing representations to refine the concepts of ontology. The result of this process was an ontology described in OWL 2.0, the release using the Protégé tool, including about 8,500 domain concepts, including classes and instances. The main concepts presented in OntoAgroHidro are shown in Figure 2, generated by the tool in OntoGraf Protégé. This figure contains the seven main highlighted classes, from which extend descriptions of other subclasses, relationships, properties and instances in OntoAgroHidro.

The environmental transformation class (illustrated at the bottom of Figure 2) is the main class of the ontology and represents phenomena related to changes (physical, chemical, biological, social or economic) in the environment. As shown in Figure 2, this class has a relationship with the event class, object environmental transformation and the environmental transformation agent. The event class is the event that causes environmental changes. The environmental transformation object class represents objects that are affected by the changes. The environmental transformation agent class represents the agents of environmental change. The dimension class describes various aspects of an event. The definition class represents the concepts needed to define the key elements of the domain and related fields. The information agent class is the last class of the first hierarchical level of OntoAgroHidro and represents the agents that produce or contain information on the environmental changes. Bonacin et al. (2016) evaluate the aspects of semantic interoperability and information retrieval in OntoAgroHidro, showing the potential and limitations of this ontology, as well as suggestions for further work to use the ontology.

5.0 Results

As a result of theoretical studies, based on Silva (2013) and Maculan (2011), in Table 2 Ranganathan's proposed categorization is related to that from the CRG as represented in ontologies and concept maps.

The aim of presenting this relationship in Table 2 is not to establish equivalence, but to show that the foundations can be used together as expected purposes. It is

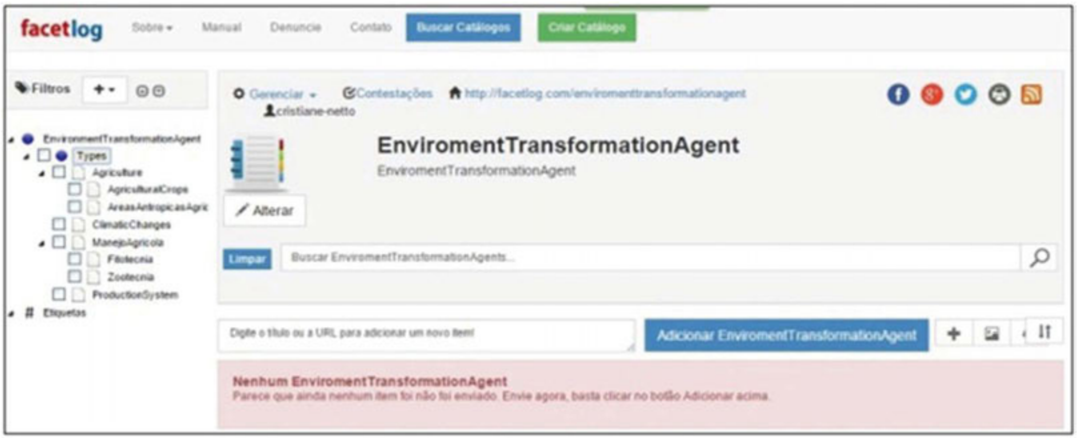

Figure 3. Interface of Facetlog

Ontology	Ontology Set
Root Class	Catalog
Root Class Properties	Facets
Classes or Individuals	Categories
Individuals Properties	Classification
Root Class	Records
Individuals	Items

Figure 4. Ontology mapping for the catalog structure.

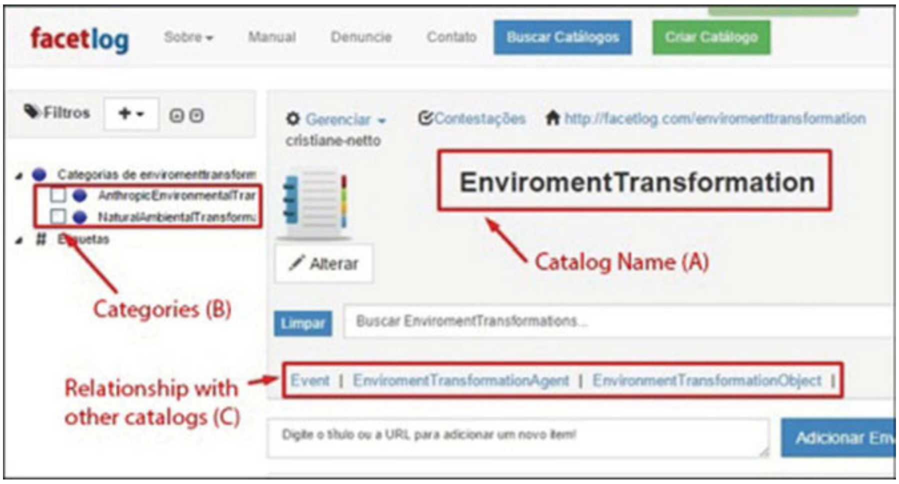

Figure 5. Interface of a catalog in Facetlog tool.

considered that abstractions can be made to improve the understanding of areas, without losing, however, the fundamental properties.

Silva (2013) developed a prototype interface tool that represents the OntoAgroHidro ontology environment in which it is possible to create catalogs that are accessed through a web interface (Figure 3). Another possibility is to search for keywords and navigate through a faceted structure in the web interface. This solution also has collaborative functions so that other users can collaboratively keep creating and indexing the content.

The result of the conceptual modeling of ontology can be synthesized as shown in Figure 4, which has the OntoAgroHidro mapping structure for the model Facetlog catalogs.

This mapping allowed manual creation of a sample representing the ontology tool. Figure 5 shows the interface generated by the environmental transformation catalog.

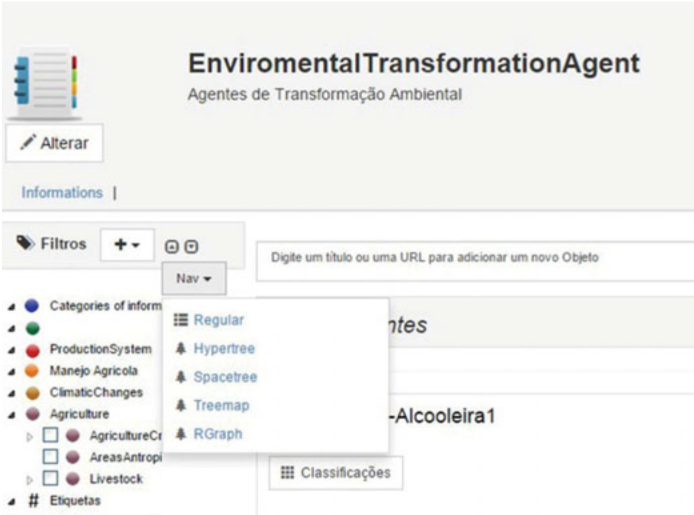

Figure 6. Navigation options for catalog.

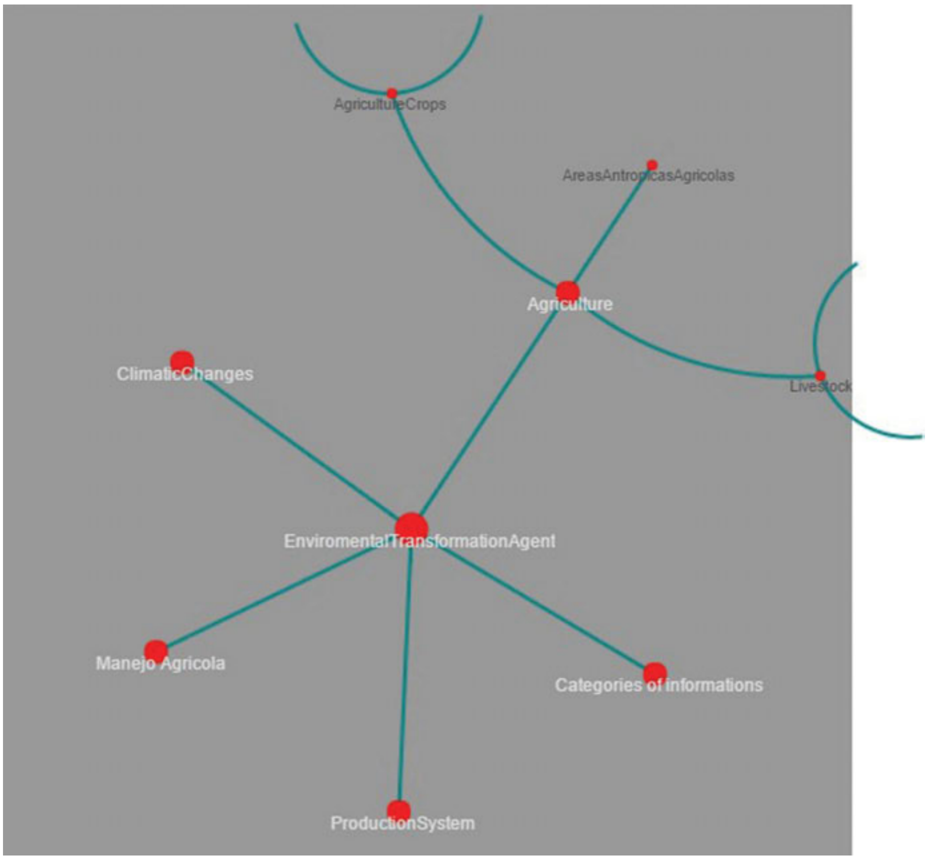

Figure 7. Catalog display interface in hypertrees.

The class chosen in OntoAgroHidro represents the first level of environmental transformation classes and their relationships with classes environmental transformation agent, enviromental transformation object and event. The highlights in this interface refer to the identification of the catalog environment transformation (A); the identification of the categories (B) and relationships (C) of this catalog with others that were also created in the tool.

In a Facetlog tool, test versions evaluate the catalog's representative capacity on maps representing four types: "Hypertree," "Spacetree," "Treemap" and "RGraph." This navigation option is shown in Figure 6, where it has a menu to choose the navigation in the catalog by a visual interface.

Figure 7 shows the catalog environmental transformation agent represented by hyperbolic trees (hyper tree).

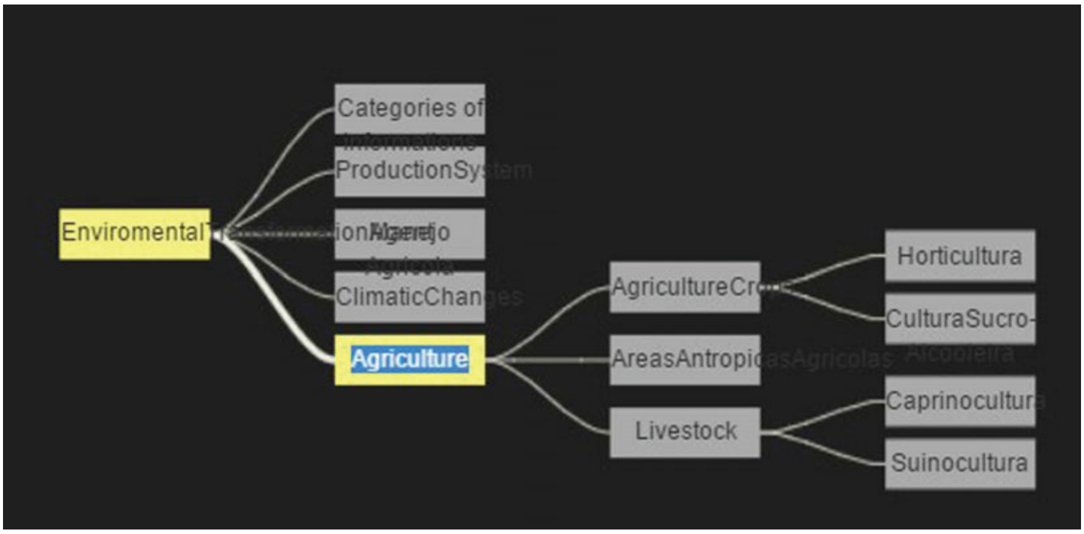

Figure 8. Catalog display interface tree (space tree)

This type of concept map provides an interface where the components decrease and increase in size depending on their distance from the center, and it offers the user an overview of the information and a navigation focused on the context.

In Figure 8 the "environmental transformation agent" catalog is represented in hierarchical trees (space tree). In this interface, users can have an analytical view of the information catalog and the relationships between content.

A representation of nested rectangles (tree map) is shown in Figure 9. In this interface, hierarchical information is presented with colors and sizes, and can assist users in understanding the organization of information.

In Figure 10, the representation of the catalog is shown in graph presenting the categories of a catalog and also its sub-categories.

The results of the tests performed with the Facetlog tool demonstrated the potential of its resources to be developed as a solution for users who want to browse and search through ontologies. In addition, the collaborative resources can be used for collaborative construction and instantiation of ontologies.

From these early tests, it is possible to implement a prototype based on Facetlog for users in the Brazilian agricultural domain. It is believed that from the knowledge represented in OntoAgroHidro new features can be implemented to obtain a search and a semantic navigation of the information. Furthermore, it is considered relevant to interface searching with users evaluating resources and also aspects of aiding cognition.

6.0 Final considerations

This paper presented a study on the theory of facet analysis and concept maps for representation and information retrieval in digital contexts. As a case study, we analyzed the domain ontology OntoAgroHidro, created by Embrapa. The problem identified is the need for an interface for browsing and information retrieval that provides users with abstractions about the logical properties of an ontology and that favors human cognition about the domain.

As an initial experiment, we evaluated the prototype tool developed by Silva (2013), where a sample ontology was manually mapped to the catalog structure of the Facetlog tool. From the results, it was believed possible to implement a computational solution that can facilitate the creation of the conceptual model for browsing faceted classification and concept maps across the domain represented by OntoAgroHidro, allowing and then facilitating human learning in the domain as well as information sharing. For future work, we intend to implement a solution that can computationally map OWL ontology structure for a structure-based Facetlog. In addition, it is necessary to consider a study with users to evaluate the use of the interface and its potential to contribute to human cognition.

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Figure 9. Catalog display interface into rectangles (treemap).

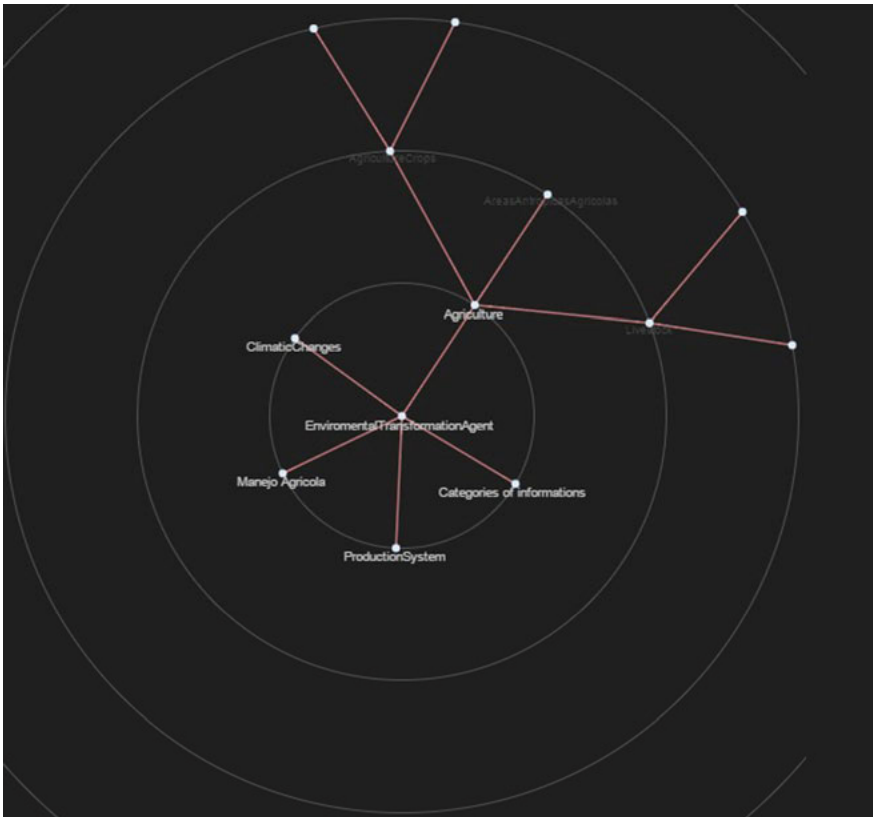

Figure 10. Catalog display interface in graph (RGraph).

https://doi.org/10.5771/0943-7444-2016-4-254

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