Abstract—This paper presents a model that aims to support the visualization of the knowledge stored in digital repositories through semantic images. In this model images contain representations of the real world that are a priori known by the target group, and which have semantic structures that allow identifying the entities of the domain represented in each region. The proposed model is supported by the framework for knowledge visualization proposed by Burkhard and describes the users’ interactions with the images. The user through the images can retrieve and view the knowledge related to the entities represented in each region. A prototype was developed to demonstrate the feasibility of the model using images in the biomedical field, the Foundational Model of Anatomy and the Unified Medical Language System as domain knowledge and the Scientific Electronic Library Online database as a document repository. The use of images facilitates the dissemination of knowledge, because these compose user’s world view and can easily be related with prior knowledge. Visual representations are processed quickly in the brain and require less effort than the processing of textual information.

Index Terms—knowledge visualization, knowledge retrieval, semantic annotation, ontology.

I. INTRODUCTION

The knowledge dissemination and sharing, are complex tasks for organizations as they often do not know what they have and do not possess systems to efficiently locate and retrieve the knowledge that reside in them [1]. A considerable amount of explicit knowledge is spread across multiple documents within organizations. In many cases, the ability to access efficiently (i.e. retrieval) and reuse this knowledge is limited.

Information visualization systems can be used to explore knowledge, to navigate through large volumes of information and to inspect data to make new discoveries [2], [3]. This kind of system is especially useful when people need some information, but they can not translate these needs in key words to search information [4].

In this context, the knowledge visualization field has been researching how the use of visual elements can help the knowledge dissemination process. The use of images that contain representations of the real world, that are part of the users world view, allows that knowledge presented by these images can be easily related to previous knowledge, thus facilitating knowledge dissemination.

This work presents a model that support knowledge visualization by using semantic images. The goal of the proposed model is to use images to construct a support structure for the knowledge visualization process. These images not only contain a visual representation of the real world, but also semantic annotations that help describe its content. The idea is that when a user views an image be able to quickly recognize which regions have associated knowledge and can to retrieve the documents related to the regions by selecting only the region of interest.

This paper is structured as follows: after this introduction, we present the literature review about knowledge visualization and semantic images annotation. Subsequently, the proposed knowledge visualization model is described. In the following sections, we present the material and methods used for model development and discussion. Finally, the last section, we present the conclusions.

II. LITERATURE REVIEW

A. Knowledge Visualization

The knowledge visualization can be defined as the use of visual representations to improve the transfer of knowledge between at least two persons or group of people [5], [6]. Making knowledge visible so that it can be accessed, discussed, valued, appreciated or managed is a long-standing goal in knowledge management. Because of this the knowledge visualization has recently become the focus of attention in academic and business communities [7].

The benefits provided by the visualization seem to be dependent on the fact that it acts as a frame of reference or as a temporary storage area for the processes of human cognition. Visualization enhances the memory of humans to provide an extensive set of work to analyze and reflect, and thus becomes an external facilitator of cognition [4]. According to Ware [8] there are two main theories in psychology that explain how the vision can be effectively used to realize elements and shapes. At low level, the theory of pre-attentional processing explains that some visual elements can be processed quickly. At the highest level, the Gestalt theory describes some principles used by our brain to understand an image.

The knowledge visualization systems are designed to make use of the skills that humans have to process images.
images are pre-attentive and these are processed before the text [9]. Moreover, the use of images that contain representations of the real world, which are known a priori by the target group and are part of his world view, allows the knowledge presented to abeam of these images can easily be related to prior knowledge of individuals, facilitating learning and memory [5], [9].

Aiming to guide the knowledge visualization application within organizations, Burkhard proposed a framework based on five perspectives that respond to five key questions [5], [6]: What kind of knowledge needs to be viewed? 2) Why should knowledge be visualized? 3) Who is being targeted? 4) In what context should be viewed? and 5) How can knowledge be visualized?

B. Semantic Image Annotation

The annotation can be defined as the process of making explicit the interpretation of the document. Creating metadata by annotating documents is one of the major techniques for putting machine understandable data [10]. Metadata can be attached to a wide range of documents; can be expressed in a wide range of languages and with a wide range of vocabularies [11]; and can be performed manually, automatically or semi-automatic [11]–[13].

Ontologies have been used to annotate documents [10], [11]. Ontological structures may give additional value to semantic annotations allowing inferences and conceptual navigation [10].

The metadata associated with images can be classified as i) independent content metadata, where metadata are related to the image but not described, for example: names of authors, dates, location, etc; ii) content-dependent metadata, where metadata is related to low-level features and/or intermediate level, for example: color, texture, shape; and iii) descriptive content metadata, where metadata is related to semantic content. It has to do with relations of the entities of the image with the real world entities [14].

The descriptive content metadata can be provided at two levels of specificity: i) descriptive content associated with the full image [15], [16] and ii) image segmentation with links to the descriptive content in each segmented region [17], [18].

III. PROPOSED MODEL FOR KNOWLEDGE RETRIEVAL

The proposed model was designed in order to facilitate knowledge visualization using semantic images as support structures. The conceptual model described in the figure 1, consists of four components: the semantic images, document repository, knowledge repository and visualization. To the knowledge linked to the images can be recovered efficiently (i.e., semantic search), both images and documents have been previously enriched with semantic content (letters a and b in figure 1) obtained from the knowledge repository (i.e., ontologies, taxonomies, thesauri).

The process starts when the user has to satisfy some information need. The user selects the image (1 in figure 1) from which the knowledge will be visualized. The selection criterion will depend directly of the user information needs, taking into consideration the concepts represented in each image. For example, if the user need to visualized knowledge associated with the heart, he must select an image in which the heart is represented.

Once selected the images, the visualization process is executed (2 in figure 1). The visualization process aim to provide users the knowledge stored in document repositories. The results visualization is done over the images, so that users quickly realize the amount of documentation associated with each image region. This is reflected in the image, for example, changing the color of the regions in which concentrates most / least amount of documents or include the number of documents retrieved on each region. From the image, the user can restrict the search space (number 3 in figure 1) and is able to use the metadata provided by document repositories or concepts defined in knowledge artifacts, thus initiating a new visualization process. Next, we briefly describes each component.

A. The Semantic Images

In the model, the images are enriched with semantics structures that allows to represent graphically the domain concepts in which each of its parts is specified in an explicit and formal way. It is defined on three levels (figure 2): the descriptive level aims at identifying and describing the visual representations; the structural level provides information about the internal structure in order to make explicit the region images; the semantic level aims at describing the semantic mappings.

B. Document Repository

In the model, document repositories are characterized by a semantic layer that allows to formalize the information contained in documents. They are defined in four levels: the descriptive level aims at identifying the repository; the metadata level aims at describing the information structure; the content level provides the structures needed to store documents and metadata. The document repository also has a semantic level that aim at linking the semantic content of documents.
Each region was linked to a FMA class incorporating to the aorta. To annotate the images region, we used the FMA vena cava, the inferior vena cava, the right ventricle and the right atrium. Four regions in this image were made explicit: the superior vena cava (equivalent name in Spanish), the inferior vena cava (synonym in English) and Vena cava superior (equivalent name in Spanish). Figure 2 also shows how the region R4 (labeled aorta) is mapped to the UMLS concept C0003483. Using UMLS relations, the model “knows” that Aneurysm is an aorta disease.

In figure 3 we can see the prototype’s main interface. To search for the semantic images the user enters the search terms in the text box in the upper panel (figure 3-A). The tool recovers all the semantic images associated by processing the query terms in both the structural level (i.e., text search for the name of the regions) and in the semantic level (i.e., conceptual search by mappings). When the processing is done on the semantic level, the terms are processed in domain concepts. This transformation allows the query to be executed semantically, making the search language independent. For example, to search for semantic images related to heart, the user can enter search terms such as words like coração (heart in Spanish), or coraço (heart in Portuguese). In all cases, the process returns the same results.

After retrieving the semantic images, it is placed in the center pane (figure 3-B). The user can use it in two ways: to obtain knowledge related to the concepts represented in the regions or to retrieve documents that mention the concepts. Information related to the concept appears in the top right pane (figure 3-C). In this prototype version, this information is presented using the FMA ontology. In this panel the user can view the name, identification and description of the class. Using the button “View additional information”, the user can get additional information such as names in other languages or anatomical entities that constitute it. The concepts mapped in each region can be observed in the right pane in the center (figure 3-D). This information is obtained from the semantic level of the image.

When selecting an region in the image, in addition to presenting to the user information about the concept, also shows the number of documents related to the concepts mapped in each region.

IV. PROTOTYPE MODEL

In order to demonstrate the feasibility of the proposed model, we developed a prototype applied to the biomedical field. The knowledge repository was composed by the Foundational Model of Anatomy ontology (FMA) [20], [21] and the Unified Medical Language System Metathesaurus (UMLS) [22]. As documents repository a copy SciELO (Scientific Electronic Library Online) database was used.

In figure 2 we can see an example of a semantic image. Four regions in this image were made explicit: the superior vena cava, the inferior vena cava, the right ventricle and the aorta. To annotate the images region, we used the FMA. Each region was linked to a FMA class incorporating to the semantic image, all explicit knowledge in the FMA ontology. For example, when linking the R1 region (labeled with veia cava superior) to the class Superior vena cava, the model now “understands” that the region is part of the cardiovascular system (class Cardiovascular system in FMA ontology) which is also known as Anterior vena cava (synonym in English) and Vena cava superior (equivalent name in Spanish).
the integration of these two components. The semantic content allows that the model can to “understand” what are the concepts represented both in images and in the documents thus facilitating conceptual search. One advantage of this is the recovery of knowledge independently of the language of written documents. Due to this “understanding”, the model is able to retrieve documents related to the concepts represented in the images helping the user in the search process. This retrieval mechanism can be seen in the prototype in which to retrieve documents, the user only need select one region of the image without specify the search terms as in traditional retrieval systems.

The idea of the model is that search results are presented in the images changing the color of the regions where it concentrates the largest number of documents. This model behavior is consistent with the visualization tasks defined by Shneiderman [19].

The reason for using images containing representations of the real world is based first on the humans’ skills to process images quickly and secondly in the ease of individuals to relate prior knowledge associated with an image already known.

The proposed model is generic and can be used in any domain that allows the concepts representation by images. It can also be used on any document repository where these can be mapped into knowledge representations (i.e., ontologies or taxonomies).

VI. CONCLUSION

One of the advantages offered by the model is the ease of documents retrieval using only regions of the images. In traditional IR systems, users translate their information needs in search terms, they return a list of items that match the most relevant documents according to the terms informed. In the proposed model users have to translate their information needs also in terms, but these are not used to directly seek the documents, but rather to seek the image to be used in visualization process.

Another model advantage is the component integrations by semantic mappings. The images and information repositories are all integrated by means of semantic information, this allows a single image can be used to view documents in different repositories. For example, the image of the heart, shown in previous sections, can be used to retrieve scientific articles, organizational competencies, projects, clinical studies, indicators, medical imaging, among others. This semantic integration allows to the model to infer new information about a particular concept. When render the heart image, the model can retrieve information related to concepts that are not explicitly defined in the image, but can be inferred, such as certain diseases. In heart image when selecting the aorta, for example, and using the UMLS relations could be recovered documents related to the aneurysm, a disease that affects the aorta.

REFERENCES


