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Semantically Driven Presentation of Context-Relevant Learning Material

Alexander Streicher+ and Wolfgang Roller

Fraunhofer IOSB, Karlsruhe, Germany

Abstract. In this paper we present our work on a new approach for an intuitive presentation of semantic relationships for the results of a semantic search algorithm. The underlying semantic search retrieves the most relevant learning material according to the context of the user. It provides the user with qualified learning material which is intelligently retrieved based on the current working situation. To ease the understanding how the presented result list has been generated a new presentation form is introduced. The preliminary results of our work are shown in a prototype implementation used for radar image interpretation. The aim is to optimally assist the image interpreters by offering relevant help and learning material.

Keywords: E-Learning, Semantic Visualization, Semantic Retrieval, Image Interpretation

1. Introduction

Specialists in complex working environments face the challenge to be always up-to-date with their knowledge. They have to keep up with the often rapid development in their field of work. Assistance systems can aid them in their working tasks whereas e-learning systems can offer task-related information and learning material. With a combination of assistance and e-learning systems employees are capable of adapting to new scenarios and challenges as well as to solve new problems and to refresh and update their knowledge. In some areas employees must continuously update their knowledge because of the transient character of their field of work. This renders the learning process as lifelong learning instead of a one-time learning at school or in a qualification program. Assistance systems and e-learning systems can help the user to deal with situations when experience and background knowledge are not sufficient to solve new and unexpected problems. In this paper we present an approach how to present context relevant information of an interlinked assistance and e-learning system. The application scenario is e-learning for image interpretation.

The work of an image interpreter perfectly fits the description of a complex working environment. Image interpreters not only must be able recognise various complex objects but they also require background knowledge for the correct and sound interpretation of the images. Different sensor and imaging parameters, a high variety in appearance of objects around the globe and time pressure create a challenging and demanding working environment. One of the most demanding tasks is the analysis of complex facilities, such as airfields, harbours and industrial installations, because they require immense technical background knowledge and deep understanding of the processes in such facilities. An additional difficulty arises with the use of complex imaging sensors, for instance radar image sensors. One manifestation of such a radar sensor is the Synthetic Aperture Radar (SAR) sensor. SAR is an imaging technology based on reflections of microwave pulses emitted by a radar sensor. Due to the complex imaging geometry and the very different reflection properties of objects in the microwave band, special training and substantial experience are required in order to be able to identify objects in this kind of images.

+ <firstname.lastname@iosb.fraunhofer.de>

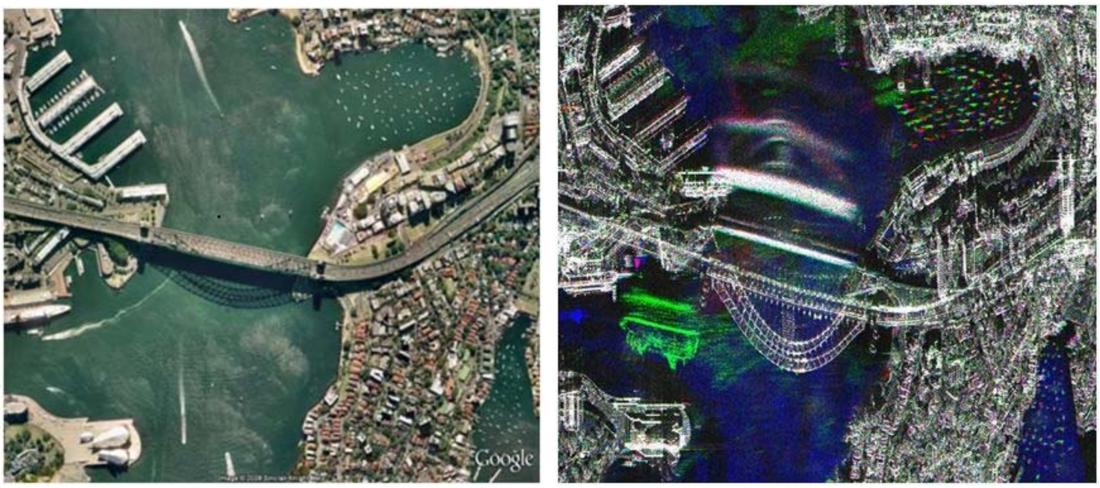

Fig. 1: Images of the sydney harbour bridge. Optical image (left) and radar image (right). The radar image shows the specific SAR radar effects (e.g. flipped down buildings, ghosting effects etc.)

SAR is used in a wide variety of application scenarios, e.g. pollution detection, cartography, ice layer and biomass monitoring as well as reconnaissance and surveillance. SAR signatures of objects differ significantly from those in an optical image because of specific SAR effects (for an example see Fig. 1). To ease the interpretation task assistance systems are being developed which help the user to classify objects in an aerial image. Although these systems can offer a wide variety of tools, e.g. for image processing, image annotations or automatic classification [3], the human-factor in the interpretation process still remains the essential element of correct and sound interpretation. The interaction with an assistance system can be utilized to gather information of the context of the user. For example, it collects information on objects which have already been recognized. This knowledge about the current state of the task can be used in order to provide the user with useful help and learning material, e.g. learning units of an e-learning system. The advantage is that the users get help when they need it most, i.e. when they reach the limits of their current knowledge and experience. We present an approach for semantic retrieval of relevant learning units with an intuitive visualization of the semantic relationships. The semantic search provides the user with qualified learning material which is intelligently retrieved based on the current working situation [12] [15]. In contrast to systems where the information retrieval is solely based on text retrieval methods this method finds linked concepts as well.

2. Semantic Search

The search space for the presented semantic retrieval is spanned using an ontology which is based on the *Simple Knowledge Organization System (SKOS)* [13] principle. SKOS provides an elementary vocabulary to describe basic structures of concept schemes. Because of its simplicity a SKOS-based ontology facilitates interoperability (e.g. ontology alignment) since the amount of ontology concepts and properties are well-defined and limited. With the logical basis of the ontology language semantic reasoning gets possible [8]. The technical details of the used semantic retrieval algorithm have been presented in [12].

2.1. Information Model

Basis for the search process is a domain ontology that encompasses concepts of the specific field of work. In the scenario for radar (SAR) image interpretation we chose the domain of airfields. The ontology contains concepts which cover the topic about airfields (e.g. hangar, tower, runway etc.) and it can be enriched with other related ontologies, for example the alignment with an ontology for geometrical aspects. The second part of the semantic model encompasses the learning units. Each learning unit has to be mapped to the concepts of the domain ontology. The mapping is done using a special relation in the ontology which has a binding weight property. This binding weight is computed for each concept accessible through relations starting from the learning unit to the domain ontology. This can be seen as an activation energy which spreads through the semantic network [6]. The calculated binding weights are used as relevance values for the result ranking of learning units, i.e. it determines the position of the learning units in the result list.

2.2. Semantic Search

The primary objective here is to find relevant learning units and to rank the results based on their relevance regarding to the current working situation of the user. The query for the semantic search includes the keywords transmitted from the assistance system. In a first step these keywords are pre-processed with a thesaurus to extend the search space. In a second step, the keywords are mapped to the concepts in the domain ontology. After an automated reasoning process the model contains new relations and inferred concepts. Using spreading activation (semantic priming) the activation energy of each search concept is spread through the semantic network. The importance of each concept is computed by discounting attached binding weights, which have been defined for each relation. The semantic search process and the description of the defined binding weights as well as the mathematical background are detailed in [12].

3. Presentation Of Semantic Search Results

The user acceptance of the semantic retrieval results is directly linked with an appealing and intuitive presentation of the results. The most common presentation style is that of a simple ranking list where the most relevant entries are presented first. However this hides the relationships between the results and the influence of the search keyword concepts. The relationships between the concepts can be made transparent in a way that the user can understand why the first entries are ranked as most important to him. One obvious presentation form of an ontology is the presentation as graphical structure with nodes and edges (Fig. 2).

The common approach is to visualize the structure of the underlying ontology [11] as a cyclic graph, i.e. a network. But for complex ontologies this can be complicated to understand. Even for mid-sized ontologies the amount of nodes (concepts) and edges (relations) can be substantial. We propose to show the user only a subset of the result in a ranking list combined with a projection of the most important relations in a flat view of frequency classes. The frequency classes are the search keywords which were hit most in the search process. The search algorithm expands the search keywords with a thesaurus and an ontology [12] and stores these terms in keyword classes. For the visualization only those classes are shown which have the most influence on the most relevant entries in the result list. Hence there exists a direct mapping between the ranking list and the search keyword classes (frequency classes). This mapping is made transparent to the user. Our hybrid semantic ranking visualization combines the advantages of a simple and intuitive result list with an associative listing of semantic information. On the one hand it shows the ranking as a result list and on the other hand it reveals the semantic relationships and their influences.

Two main questions can arise when the user is presented with the results of the semantic search: (1) ‘Why are the entries ranked in that way?’ (question about the position of the list entries), and (2) ‘What influence had a particular search concept on the position of the list entries, i.e. the learning units?’ (question about the reason of consideration for specific learning units in the result list). To answer these questions two inverse visualization views have been realized and integrated in one user interface. Fig. 3 and Fig. 4 show an example.

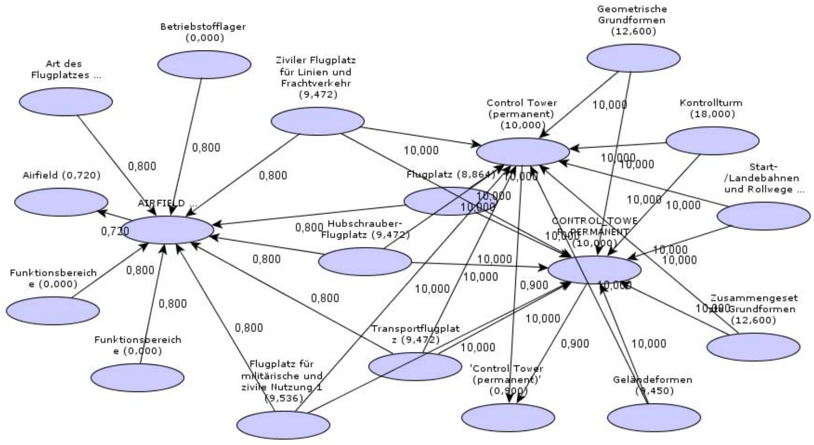

Fig. 2: Visualization of a small subset of the semantic network. Nodes represent ontology concepts and edges relations. Edge labels contain the binding weights (*cf.* section 2).

In Fig. 3 on the left you can see the semantic retrieval results as a normal ranking list. When the user navigates to a list entry the linked concepts for the marked entry are displayed. Histogram indicators encode the global frequencies of each search keyword (on the right in Fig. 3). The number of hits in these frequency classes is directly related to the position of the position of the entry in the result list. This answers question (1). The frequency classes are obtained by clustering the concepts according to their title values. As distance metric text similarity has been used after normalizing the keyword title values by syntactic text editing and linguistic stemming. To offer high affordance only the top ten most relevant results are presented at first.

Fig. 4 shows the inverse scenario. When the user marks a search keyword only those list entries are highlighted for which the keyword had an influence in the semantic spreading activation of the semantic search. This answers question (2), i.e. which influence a particular search keyword had on the result list.

4. Application

The described semantic search and visualization have been implemented in a working prototype for the intelligent interlinking of an assistance and e-learning system in the field of (SAR) image interpretation. In our application scenario the image interpreters interact with an assistance system for infrastructure image interpretation and with an e-learning system which provides help and learning content. As reliable algorithms for automated object recognition in aerial images are hardly available, these systems are often based on interactive approaches [4]. Such an assistance system supports image interpreters to perform a full analysis of a complex object arrangement, for example it helps to decide whether a radar image shows a civilian or military airfield. Singular objects (buildings, roads etc.) are marked by the user in the image and the system makes use of a probabilistic scene model to classify the function of the singular objects as well as the type of the overall facility. The classification results are presented to the user as recommendations.

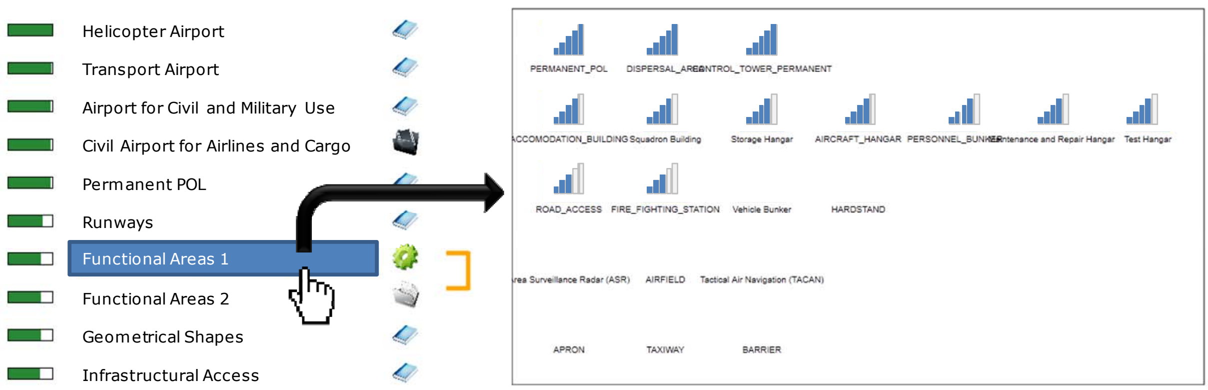

Fig. 3: Visualization of semantic retrieval results. (left) Ranking list, and (right) linked concepts to highlighted list entry sorted in frequency classes.

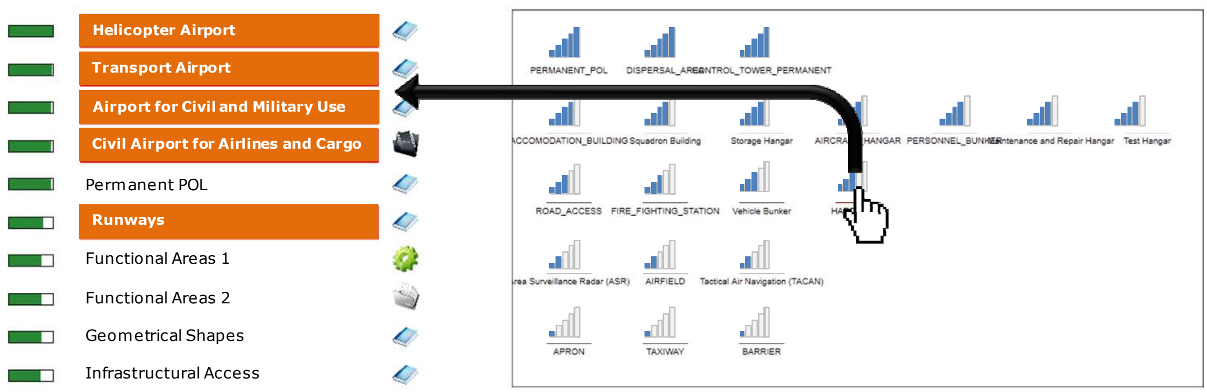

Fig. 4: Inverted view of the semantic retrieval results visualization. (left) Ranking with highlighted entries which are affected by the marked search keyword 'HARDSTAND' (below mouse pointer).

The other involved system is a customized e-learning system [16]. It includes a comprehensive e-learning course about radar image interpretation for reconnaissance as well as knowledge about image interpretation. These two systems have been interlinked by a semantic search algorithm which finds the most relevant help- and learning material according to the user's current working situation [12] [15].

The presented visualization method is the last step in the interlinking process, i.e. when the suggested retrieval results are shown to the user. We implemented our visualization concept in an interactive web-based prototype using freely available, standard-oriented libraries. The GraphML[1]-based, partially serialized ontology-structure of the retrieval results is rendered on the client-side with the JavaScript libraries jQuery[2] and Raphaël[3]. All data in the interlinking process is communicated by web-service interfaces, for example the input data for the semantic search from the assistance system. Because of the usage of standard software with liberal licenses the presented visualization concept and its implementation can be transferred to other application scenarios.

5. Related Work

Using ontologies in e-learning systems and linking assistance systems has been done in [1] and [15]. Ontologies can be used to model teaching knowledge as well as to enable machine-based logical reasoning [10] and semantic search [9]. In the context of true information retrieval pure semantic search lacks in the ability to rank the results which renders the search process as plain data retrieval only. Combined with weights in the semantic network a mechanism based on the spreading activation principle [6] is able to produce scores for each accounted concept to enable a ranking of the results. Spreading activation in information retrieval can be seen in [7]. An approach similar to ours but without reference to context-aware e-learning is shown in [14] in which a search architecture is presented that combines classical search techniques with spreading activation techniques to execute semantic searches in websites. Rather than using keywords as user input for the semantic search it is possible to provide the search terms automatically by a preceding system, e.g. by an assistance system. This can be seen as intelligently interlinking multiple assistance systems. Interlinking of assistance systems and e-learning systems has been presented by [12] and [15]. They give a description of how to interlink an assistance system [3] for use in image interpretation of SAR images with an e-learning application [16].

The visualization of complex graphs is an ongoing and active research topic. One speciality is the visualization of ontologies. Most visualization methods render the ontology graph as planar 2-D view [11], others extend the visualization to 3-D and project the graph onto a sphere [5].

An intuitive visualization method suitably for e-learning applications is presented [2]. They show how to apply cartographic metaphors to learning maps for e-learning systems.

6. Conclusion

In this paper we presented a new concept for the visualization of semantic search results. The semantic search is part of an interlinking system for which a new idea has been presented as how to make the semantic relationships of the most relevant search results transparent to the user. The intuitive concept of a simple ranking list with additional attributes is combined with an extraction of the semantic structure behind the search results. The standard-oriented approach of the ontology schema allows for interoperability to other domains, direct reusability and feasible maintenance. Further research includes the automatic population of the ontology from given content as well as the integration of collaborative ontology engineering methods. Regarding the presentation layer an idea is to combine the presented visualization concept with the concepts of learning maps.

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[3] Raphaël is a free JavaScript library that to create vector graphics on the web, http://raphaeljs.com.

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