

CONTEXT-AWARE RETRIEVAL OF LEARNING UNITS

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ABSTRACT

Complex working environments call for flexible employees willing to continuously increase their knowledge and to adapt to new processes. As a consequence a lot of time has to be spent on the search for appropriate information and learning material. We present a new approach for semantic retrieval of learning units considering the working context. Basis is an ontology with attached binding weights and semantic spreading activation to get a context-aware ranking of suitable learning units. The gained semantic search results may fit better to the learner's actual situation than e.g. a pure full-text search, because the underlying ontology-based retrieval is aware of relations in the search domain and uses this knowledge in a way aligned to the learning process as well as to the specific domain. The results are shown in a prototype implementation for Synthetic Aperture Radar (SAR) image interpretation.

KEYWORDS

e-learning, ontology, retrieval, semantic spreading activation, image interpretation

1. INTRODUCTION

Lifelong learning is no longer a flowery phrase, for most people it is reality. Especially at work it is no longer possible to think of a completely trained employee who knows everything when starting a new task. Complex systems and complicated workflows demand flexible employees who are willing to enhance their knowledge and to deal with new challenges. E-learning technologies can assist these employees.

The work of an image interpreter, especially in the domain of aerial reconnaissance, perfectly fits the description above. The image interpreter must recognize objects (such as vehicles, buildings, roads, etc.) and interpret their meaning based on aerial images. Different sensor and imaging parameters, a high variety in appearance of objects around the globe and time pressure create a challenging working environment. One of the most demanding tasks is the analysis of complex facilities (such as airfields, harbors and industrial installations) based on Synthetic Aperture Radar (SAR) images. Similar conditions also apply for image interpreters in the medical domain who have to adapt to individual problems and various interactions given by nature. In histology for example the images of thin slices of tissue are analyzed to provide diagnostic information. The diagnostic result is then directly related to the quality of the image interpretation.

To ease the identification and classification process assistance systems are developed which help the user to classify objects in an image. Although these systems can offer a wide variety of tools, e.g. for image processing, image annotations or automatic classification [Bauer2008, Cootes2001], the human-factor in the interpretation process still remains the essential element of correct and sound interpretation.

As the user constantly interacts with the assistance system during the interpretation process, the system is well aware of the current state of the task. 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 learning units of an e-learning system, as soon as he reaches the limits of his current knowledge and experience. To achieve this, we present a new approach for semantic retrieval of learning units depending on the current task context. Our approach is based on an ontology with attached binding weights and semantic spreading activation [Crestani1997]. It provides the user with qualified learning material, intelligently retrieved based on the current working situation. This is in contrast to previous systems where the retrieval of learning material is solely based on text retrieval methods, thus considering a limited search space only.

The preliminary results of our work are shown in a prototype implementation for SAR image interpretation. The goal is to optimally assist the image interpreter in his work by offering appropriate learning units for search objects in an image.

Related Work

In this paper an ontology-based spreading activation retrieval algorithm is presented which enables the e-learning system to find learning material tailored to the user model.

Using ontologies in e-learning systems and linking assistance systems is a growing field of research [Amorim2006, Forberger2009]. Ontologies are used to model teaching knowledge [Borst2006] as well as to exploit Semantic Web techniques to enable for instance semantic search [Guha2003] and reasoning [Henze2004]. However, pure semantic search lacks in the context of true information retrieval 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 [Collin1975] is able to yield scores for each accounted concept to enable ranking of results. Spreading activation in information retrieval can be seen in [Cohen1987] and [Crestani1997]. An approach similar to ours but without reference to context-aware e-learning is shown in [Rocha2004], where 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 preceding systems, 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 [Forberger2009]. They give a description of how to interlink an assistance system [Bauer2009] for use in image interpretation of SAR images with an e-learning application.

2. ONTOLOGY

The search space for the presented semantic retrieval is spanned using an ontology based on the principle of the Simple Knowledge Organization System (SKOS) [Miles2005]. SKOS provides an elementary vocabulary to describe basic structures of concept schemes. This structure is easy to handle and if consequently used leads to interoperability between different systems. The SKOS representation is then transformed to F-Logic which allows specification of complex rules and efficient reasoning [Decker1998].

Basis for the search process is a domain ontology that describes the topic of the learning units. In the example case of SAR image interpretation it is an ontology of airfields enriched with simple geometrical aspects. The domain ontology only consists of the one concept *skos:Concept*; all other items are instances of this concept. The relations between instances are defined by the SKOS-relations *broader*, *narrower* (inverse to *broader*) and *related* extended with the self-defined relation *hasPart* to construct a partonomy. Furthermore an identification label as well as synonyms and translations are introduced to offer a broader search space and to provide internationalization. The second part of the ontology model describes the learning units. Each learning unit is an instance of the concept *Document*. The main annotation relations are *hasPrimarySubject*, *hasSubjectTags* and *hasKeyword(integer)*. *hasPrimarySubject* is related to exactly one concept of the domain ontology. The relation *hasSubjectTags* assigns further topics and may link to several concepts – the number is not limited. But in practice it is not reasonable to assign more than ten tags, because a learning unit should be designed to explain the topic precisely and to focus on one topic only. These tags should be items mentioned in the learning unit supporting the main subject. Figure 1 sketches an example ontology based on the described schema including domain and content ontology.

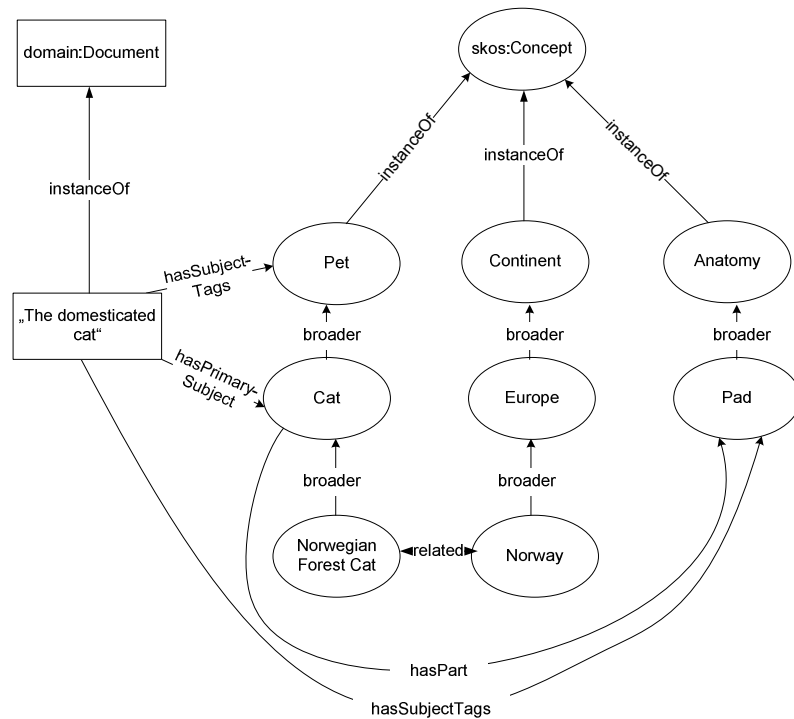


Figure 1: Example of the learning unit “The domesticated cat” as instance of the content ontology linked to concepts of the domain ontology

The relation *hasKeyword(integer)* is not explicitly defined a priori, it is inferred during the reasoning process. The assigned integer value is the calculated binding weight (Section 3.2) for any concept accessible through relations starting from the learning unit by spreading activation. There may be further relations defined by a didactic ontology (e.g. as in [Swertz2004]) describing the didactic dependencies to other units as well as properties like media type. These relations may be used for the visualization of search results but are not essential for retrieval.

3. SEMANTIC RETRIEVAL

The primary objective of the semantic retrieval in the current context of retrieving learning units is to intelligently find those learning units which match best the user’s needs. To find semantically relevant concepts the search process makes use of the ontologies’ semantic net structure and applies the technique of spreading activation.

3.1 Semantic Spreading Activation

The spreading activation mechanism originates in cognitive psychology [Collins1975] to model spontaneous associations when the brain recognizes a word and activates other concepts linked to that term. In information retrieval spreading activation can be applied to expand the search space [Crestani1997, Aswath2005].

The spreading activation process is applied to networks for labeled nodes and weighted edges. When activated, the weight, or “activation energy”, of each activated node is propagated through the network to their linked nodes. In our semantic net we use real valued weights $w \in \mathfrak{R}$, where $0 \leq w \leq 1.0$. The weights can be discounted by multiplication as the activation spreads through the network rendering the neighboring nodes most important and the most distant ones as irrelevant.

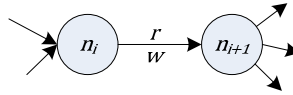


Figure 2: Two nodes in a network connected by relation r with associated weight w

In a recursive fashion the propagation of the binding weights is computed for a node n_i and the linked node n_{i+1} as

$$O(n_{i+1}) = O(n_i) \cdot w[r(n_i, n_{i+1})]$$

$O(n_{i+1})$ denotes the output $O: N \rightarrow \mathfrak{R}$ of the linked node n_{i+1} and $O(n_i)$ the output of the preceding node n_i . Let N be the set of all nodes in the network and R the set of all relations between the nodes. An edge between two connected nodes $n_i, n_{i+1} \in N, i \geq 0$ is defined as a relation $r: N \times N \rightarrow R$. The function $w: R \rightarrow \mathfrak{R}$ yields the binding weight for a single relation $r \in \mathfrak{R}$. The base case for the starting node n_0 is defined as $O(n_0) = 1$. An illustration is given in Figure 2.

Various strategies have been proposed when to stop the propagation process [Rocha2004], e.g. stop when a specific concept is hit (concept type constraint) or when the output's lower limit is hit (distance constraint). Latter is used in this work. The spreading stops when the node output drops below a given threshold T , i.e. $I < T$.

Here, an ontology is used as the semantic network. The concepts are the nodes of the network whereas the properties or relations are the edges. Semantic spreading activation takes into account the meaning of the relations. Thus, in combination with a reasoner, the weights are semantically supplemented by means of their logical correlation. Inference in the ontology can yield to new relations between the nodes and therefore enhancing the search space drastically. As an example see Figure 3 where in addition to the explicitly stated relations (the solid lines) a new relation between LU_1 and C_3 has been inferred (the dashed line) using an ontology reasoner.

3.2 Retrieval

For each relation in the SKOS-based ontology weights are introduced which influence the rank of the found documents in the retrieval result (Table 1). These weights were initially chosen due to the following considerations: the primary subject is what the learning content is about and usually part of the document's heading, thus *hasPrimarySubject* gets the highest binding weight. The subject tags (relation *hasSubjectTags*) are equally directly associated to the unit and should therefore be considered more relevant than any other concept reached by the spreading activation process. Hence the relations between the domain ontology concepts are weighed less than the content ontology relations.

Regarding the domain ontology the relations *broader* and *hasPart* are the ones with the highest weight. Both of them have a close correlation to the origin term. For a specific relevant concept it is often helpful to take the more general concept (relation *broader*) into consideration, too, to get a more complete overview. And, for *hasPart*, if something as a whole is in focus, the parts of it may help to understand it better. Whereas *narrower* - although similar to *hasPart* and inverse to *broader* - may lead to a more specific term that is less helpful to solve the learner's actual problem. For example if the topic of interest is a cat it may be interesting that a cat has something to do with pets (*broader*) as well as the fact that a cat typically has four pads, a tail and long whiskers (*hasPart*). But one cannot automatically assume that the learner needs information exactly about the Norwegian Forrest Cat (*narrower*). The relation *related* can be seen as in between. Relation is not such a strong binding as a partonomy but may be much more helpful than the more specific concept. The initial weights were tested on an excerpt of a learning course and led to the expected results, so that only little modifications were necessary. Table 1 shows the experimentally determined weights.

Table 1. Weights for retrieval

Relation r	Origin	Weight w
domain:hasPrimarySubject	content ontology	1.0
domain:hasSubjectTags	content ontology	0.9
domain:hasPart	domain ontology	0.8
skos:broader	domain ontology	0.8
skos:narrower	domain ontology	0.7
skos:related	domain ontology	0.75

The primary objective of the presented retrieval is to find relevant learning units and to rank the results based on their relevance regarding the current working situation. The algorithm calculates a binding weight for attached concepts for each learning unit depending on how the concepts are related to each other using the weights defined in Table 1. According to the spreading activation principle the terms in the ontology are activated and its activation energy is passed through the network degenerating in accordance with the weights of the relations. The result is a list of learning documents (learning units) where the most semantically relevant documents are ranked first.

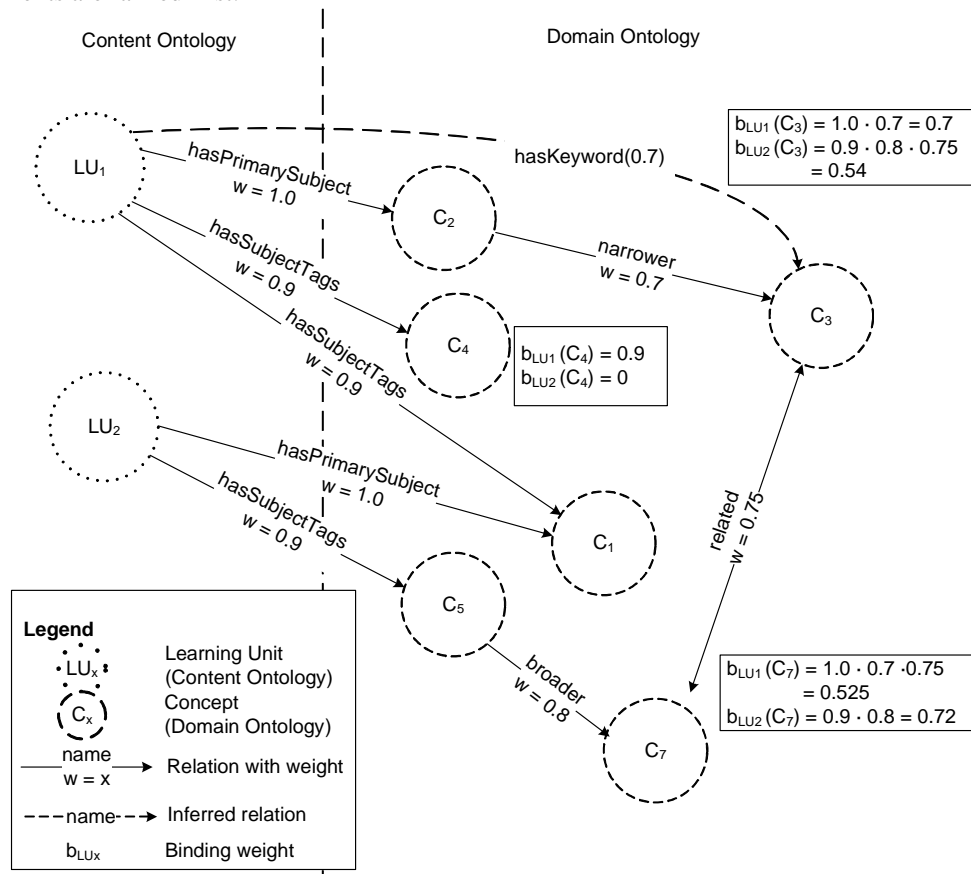


Figure 3: Learning Units are related to the domain ontology concepts. For C₃, C₄ and C₇ the binding weights are calculated

Knowing the learning context it is even possible to use more than one search keyword. $C = \{c_1, \dots, c_m\}$ is the set of concepts of the domain ontology, $S = \{s_1, \dots, s_n\}$ is the set of all search keywords and a subset of C ($S \subseteq C$). $LU = \{LU_1, \dots, LU_m\}$ are the learning units and R is the set of relations. The set of paths

$Paths_{LU_j c_i} = \{P_1, \dots, P_l\}$ are all possible connections from learning unit LU_j to concept c_i regarding the associated relations. The binding weight $B(LU_j, S)$ of a learning unit is calculated as

$$B(LU_j, S) = \sum_{i=1}^n b_{LU_j}(s_i)$$

with $s_i \in S$, and $b_{LU_j}(s_i)$ is the factor of each conducted spreading activation regarding every search keyword. The particular binding weights of each search term are summed up (not multiplied) to guarantee variety in search results. Multiplication would result in excluding learning units where one or more search terms are not linked in any way to that learning unit. To prevent influence of concepts with small binding values on the ranking only concepts with a binding value equal to or greater than 0.4 are considered:

$$b_{LU_j}(s_i) = \begin{cases} \alpha_{LU_j}(s_i), & \alpha_{LU_j}(s_i) \geq 0.4 \\ 0, & \text{else} \end{cases}.$$

Thus $\alpha_{LU_j}(s_i)$ expresses the binding weight of the search keyword s_i according to the learning unit LU_j . It can be calculated evaluating the paths $Paths_{LU_j s_i}$ using spreading activation (Section 3.1), i.e. multiplying the individual relation weights $w(r)$ on the paths. If there are several different paths from the learning unit LU_j to the search term s_i , the maximum value is used:

$$\alpha_{LU_j}(s_i) = \max_{P \in Paths_{LU_j s_i}} \left(\prod_{r \in P} w(r) \right)$$

Figure 3 gives an example for concepts related to a learning unit. Assuming the search inquiry is $S = \{C_3, C_4, C_7\}$ the result for LU_1 is $B(LU_1, S) = 0.7 + 0.9 + 0.525 = 2.125$.

Because of semantic retrieval the system is able to find learning units that are relevant. The domain ontology uses dependencies and relations to describe the domain leading to more specific search results compared to simple full-text search. Knowing the working context it may be useful to additionally weigh the binding of search terms according to their relevance for the search inquiry.

4. APPLICATION

The realization of the described retrieval process is shown in a work in progress with focus on SAR image interpretation. SAR is an imaging technology based on reflections of microwave pulses emitted by the sensor. SAR images can be taken even at night time and under severe weather conditions, which is a significant advantage over optical sensors. However, 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.

4.1 Involved Systems

In order to improve the training of image interpreters, an e-learning system has been customized for this task [Szentcs2008]. To support the image interpreter during the interpretation process, assistance systems for image interpretation are developed. As reliable algorithms for automated object recognition in aerial images are hardly available, these systems are often based on interactive approaches [Bauer2009].

Semantic retrieval enables the image interpretation system to provide the learner with context-adapted learning material. Our implemented prototype interlinks an assistance system with an e-learning application. It combines information provided by the assistance system with existing learning materials.

The 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.

The e-learning application has been developed for education and information transfer in military image interpretation. It provides courses and training content as well as background information for SAR image interpretation.

Both systems go hand in hand in the education and knowledge transfer of image interpreters, and linking these two systems is an obvious objective.

The data structures of the mentioned systems were used to populate the domain ontology. The instances were amongst others collected from several existing data sources, e.g. from the taxonomic data structure of the involved assistance system and from already existing ontologies.

4.2 Intelligent Interlinking Using Semantic Retrieval

If the user, i.e. the image interpreter, is at a loss with his knowledge in a current interpretation task, the system must provide this learner with context-adapted on-demand learning material. When a user needs help for a specific concept the associated term and the probability distributions for all other linked terms are submitted by the assistance system to the e-learning application. The assistance system transfers the so far collected data: already found objects, missing probable objects and of course the actual search object. The e-learning application performs a search on the available learning units which are annotated in the ontology (Figure 4). For each learning unit a binding weight for the received keywords can be calculated. The weights of the relevant keywords are multiplied by a factor related to each keyword source: the actual search term is rated as very important, whereas objects which have already been found get a low factor.

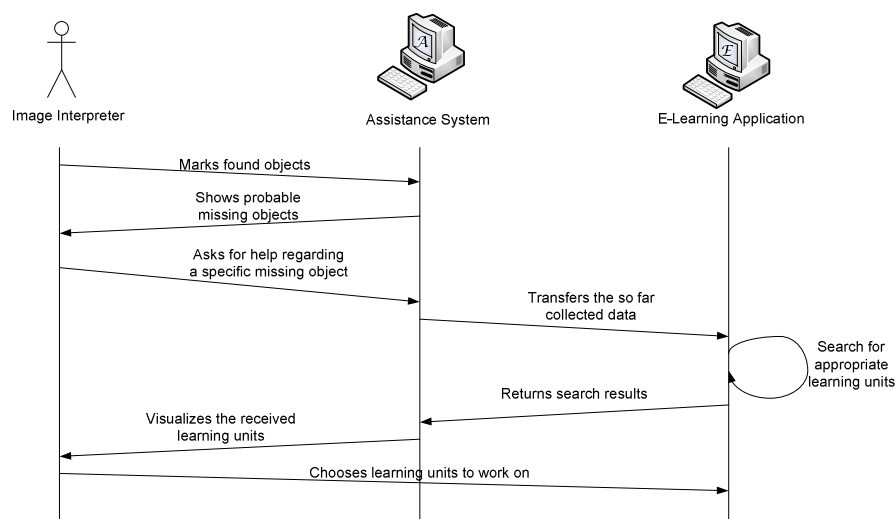


Figure 4: The image interpreter works with the assistance system and asks for help. The assistance system transfers the collected data to the learning system where the context-aware search is performed

5. CONCLUSION AND OUTLOOK

The described retrieval method leads to context-aware support for a learner in his work process. The semantic search results fit better to his actual situation than e.g. a full-text search, because the underlying ontology-based retrieval is aware of relations in the search domain and uses this knowledge in a way aligned to the learning process as well as to the specific domain. The application is not limited to a specific domain - once implemented it can be used in any context if an adequate domain ontology exists. Moreover the SKOS approach allows in many cases interoperability to other domains, direct reusability and feasible maintenance.

As the prototype is still under development the definite weights for relations and different kind of keywords still have to be evaluated. We are currently working on an advanced scenario to compare plain text search to semantic retrieval. Furthermore the retrieval will be tested on complex data to gain more information on the computability of the algorithm considering different reasoners. The challenge in modeling the domain ontology is not simply to copy the content of a learning unit but to provide an overall view on the domain. Ideally the domain ontology already exists before learning material is developed. This may help the e-learning author to structure his work and allows him to match learning units with the domain ontology at once.

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