Semantic Retrieval of Learning Material in Image Interpretation

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Complex working environments can lead to situations where the own knowledge is not sufficient to solve a problem. 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. This is also the case for military personnel who has to adapt to new challenges, i.e. constantly learn and update their knowledge. 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. 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. 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 [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 a semantic net (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, which is similar to [Henze2004]. 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 goal is to optimally assist the image interpreter in his work by offering appropriate learning units for search objects in an image. A prototype implementation of such has system has been developed for the field of Synthetic Aperture Radar (SAR) image interpretation.

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 graph structure and applies the technique of 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].
In the semantic net graph with nodes and edges an "activation energy spreads" throughout the network. This energy, or weight, diminishes after each passing of a node, hence rendering neighboring nodes with a higher value, i.e. more important, than distant ones. In the ontology as the semantic network the concepts are seen as the nodes whereas the relations are represented as edges. Because the ontology encodes semantics the spreading activation in this kind of network can be seen as a form of semantic spreading activation. In combination with an inference engine (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.
The algorithm calculates a binding weight for attached concepts for each learning unit depending on how the concepts are related to each other. 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 weighted learning documents (learning units) where the most semantically relevant documents are ranked first.

Application

The presented semantic retrieval algorithm is implemented for the task of semantically interlinking two systems for image interpretation. The first is an assistance system which guides the image interpreter in his task of identifying the objects in an image. The second is an e-learning system which has been customized for training in SAR image interpretation. To help the user in his current working context the two systems are interlinked. To enable a form of intelligent interlinking thus providing the user with context-aware and semantic relevant learning material the semantic retrieval algorithm has been developed. In an implemented prototype an assistance system is interlinked with an e-learning application. Both systems go hand in hand in the education and knowledge transfer of image interpreters, and linking these two systems is an obvious objective.
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 1). 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.

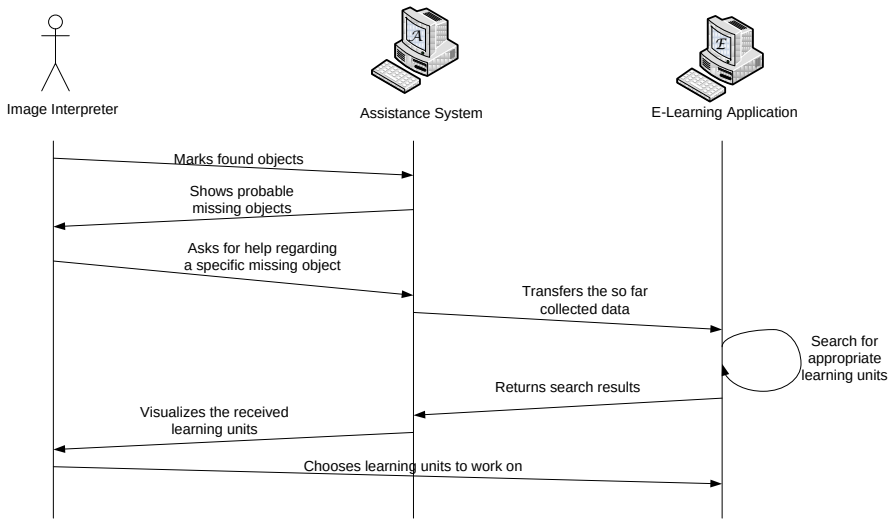

Figure 1: The image interpreter works with the assistance system and asks for help. The assistance system transfers the collected data to the learning system where the context-aware search is performed

Conclusion

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.
The challenge in modelling 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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