Navigating Through Earth Observation Knowledge

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Earth observation (EO) from space is a highly specialised technological domain where data and terminology need to be presented to users in an understandable language and customised to meet particular requirements. Most applications that use remote-sensing data require a high level of user expertise – the selection of EO products and their potential for specific applications is not always obvious. In addition, different EO user communities have varying requirements with respect to data, sources and other information when they access EO user services.

To ensure that the required information is obtained efficiently, yet with maximal flexibility, the interface between ESA's EO user services and the wide spectrum of users will have to incorporate some aspects of a knowledge-based system. Intelligence in user systems will be required for occasional users or where help concerning complex subjects is required for a time-efficient and successful session.

EO Knowledge Navigational System

The software system EO Knowledge Navigational System (EKNOS) has now been field-tested in the Remote Sensing Exploitation Department at ESRIN and offers an EO application-related knowledge-based system on the Internet. It includes various data such as descriptions for image products, algorithms, and instrument and ground facility references. The development, supported by the Earth Observation Preparatory Programme (EOPP), is novel to EO user services and reaches far beyond traditional thesaurus-based systems.

EKNOS has been implemented using leading-edge software and database technology. The long-term objective is to gradually build a complete stock of EO facts and relationships making image products and services fully accessible. In the medium-term, the chosen technology will be consolidated. The two essential functions of the system are:
– to enter free search terms with the support of a thesaurus and applying boolean operators
– to navigate within the knowledge base using the techniques of semantic networks.

EO knowledge model and information mining

Existing EO user systems furnish metadata, browse products and documents mostly with limited correlation. Users must make their own judgement about the applicability to a problem, often based on many factors (e.g. compound product characteristics, space/time requirements, accuracies, parameter types, etc.). The purpose of 'intelligent' guiding is to present users with a facility that reflects an intuitive understanding of the EO environment. An EO ontology has been elaborated in the course of this project, modelling the major EO science, engineering and user components. Figure 1 shows a three-plane graph representing the levels which are traversed during a search (by the software) or during navigation (by the user).

The first level contains the user concepts which comprise all the elements that belong to a thematic area – the term 'disaster management' is not typically found in remote sensing, but is linked to particular EO programmes, multi-date analysis and missions. The user concepts appear as free collections of objects that are prepared by an expert, and extracted from knowledge and analysis of past user interactions. The EKNOS system capitalises on previous work done for the CEOS Dossier (http://ceos.esrin.esa.it/) which focuses on application requirements and space capabilities. The term 'concept' means temporary associations which remain on a certain level until they are consolidated and added at the next update to the semantic network (see level 2). This eases the implementation of a scalable system and removes unnecessary system administrator work.

The second level addressed by user concepts in the graph is a conceptual knowledge model. It comprises the relevant object classes and associations. This model represents a picture

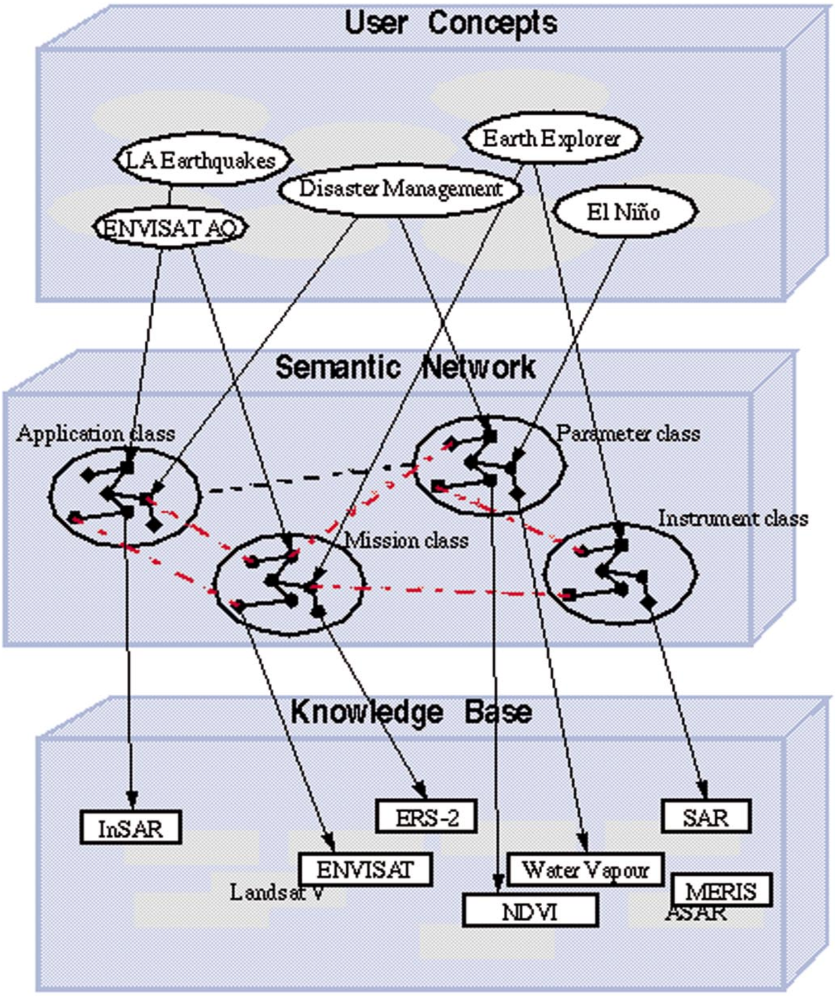

Figure 1. EKNOS three-level concept

of EO-typical objects and shows how they relate to each other. The object classes and associations form the semantic network and are implemented for long-term validity. In most cases, frequent modification of the model is not desirable since this would lead to an increase in system maintenance. (This drawback usually appears in implementations of object-oriented database systems where full advantage is taken of the object-oriented modelling power.) Since object-oriented models cannot be created perfectly, records of user interactions are used to optimise the model. The super-classes, such as 'instrument', contain sub-classes describing in more detail the composition of that class and also allow the introduction of taxonomies. Taxonomies represent structures (e.g. instrument poly-hierarchies as a classification of instruments under multiple criteria) that show how higher classes are specialised (e.g. synthetic- and real-aperture radar). The conceptual model links to the real objects at the instance level which is implemented according to the specific internal/physical model of the database system.

The third level (knowledge base) represents the implementation of instances of each class and taxonomies as defined by the second level. This level also incorporates the rules under which searches and navigation are executed by

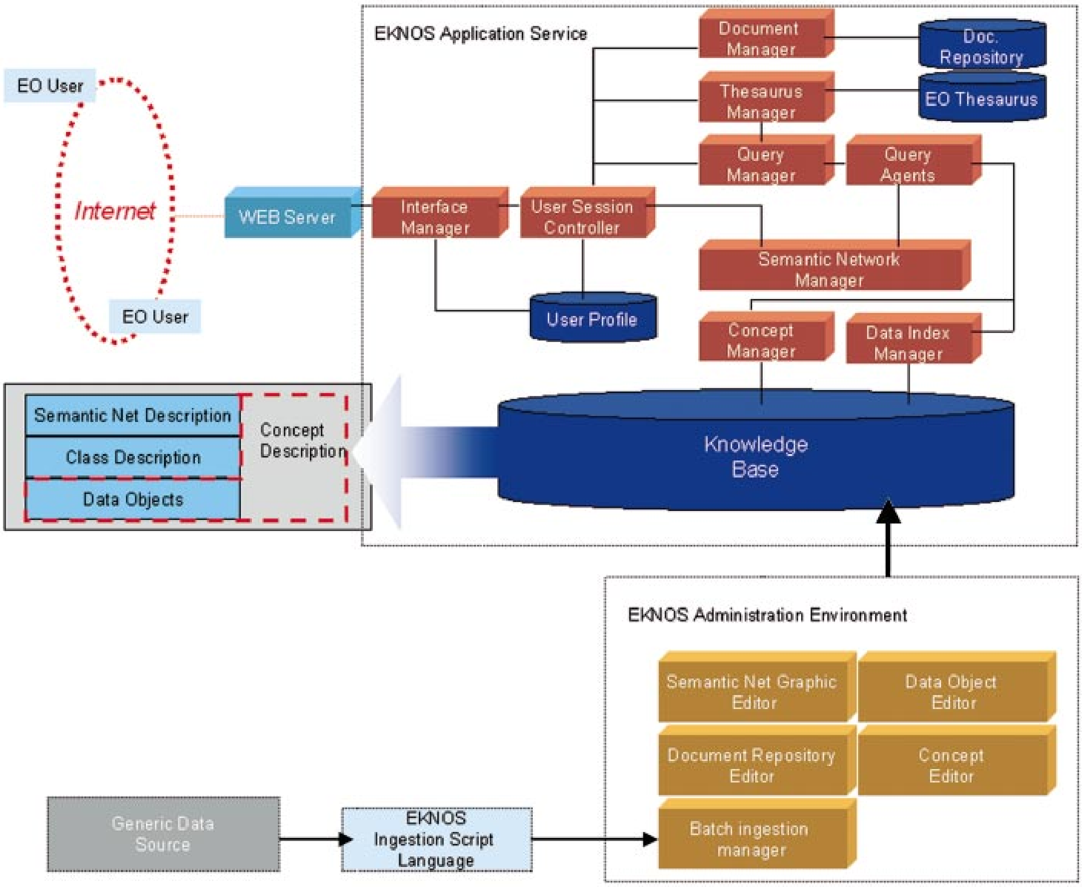

Figure 2. EKNOS architectural concept

assigning individual weights to the object relations. Individual weights can be recorded in multi-dimensional matrices for which the indices belong to classes, concepts, object instances and other criteria to be assigned. This technique can boost the precision and performance since it optimises the traversing of search and navigation paths.

The knowledge-based system concept

With the help of artificial-intelligence information technology, the EKNOS system integrates several elements that contribute to optimal response to a user query. The architecture (Fig. 2) takes advantage of object-oriented database capabilities insofar that they are a natural baseline for the implementation of semantic networks. Other elements are:

- search and inference mechanisms
- thesaurus
- dictionary
- direct link to core documentation management
- knowledge acquisition and maintenance mechanism.

In particular, the usage of a thesaurus and dictionary can help with the pre-processing of a user query through different levels of sophistication. Once a search is executed, the system trades off between the 'precision' of findings and the 'recall' of broader scopes (spreading of activation) based on the selected search strategy and control parameters. The search strategy is driven by user preferences of search depths, search algorithms and target classes. User domains are semi-automatically recognised by EKNOS and the resulting information items are bundled throughout a session and returned to the user. Figures 3 and 4 show examples of the EKNOS graphical user interface for entering queries and displaying the results, respectively.

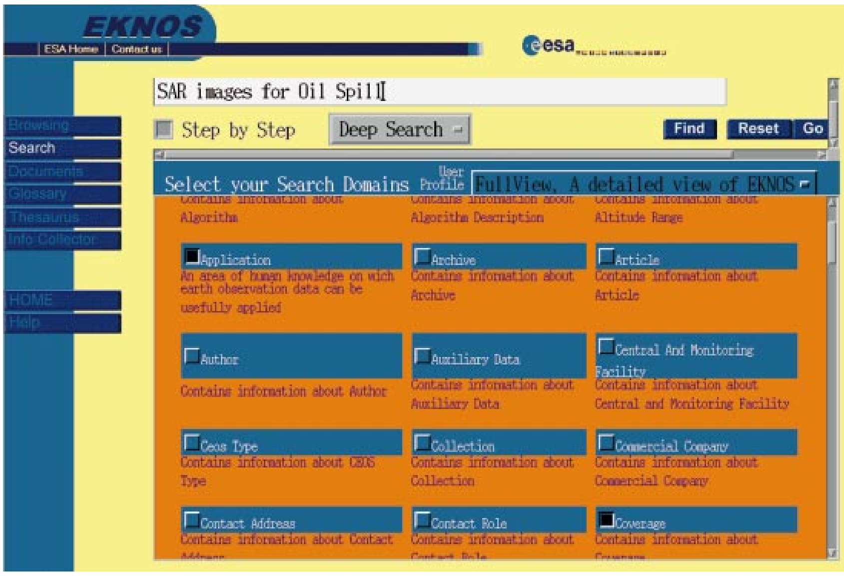

Figure 3. EKNOS graphical user interface: example of query entry

Figure 4. EKNOS graphical user interface: example of instances

Conclusion

The intelligent guiding in EKNOS is achieved using a knowledge model for navigation and querying with the objective of successfully accessing EO data, information and end-user services. The EKNOS project has provided a robust knowledge-based system meeting two objectives for EO applications:

- reduced complexity in accessing EO-application domain information
- largely automated information retrieval.

Earlier implementations of knowledge-based and reasoning techniques had shown the feasibility and benefits of higher-system autonomy for EO user support, which the EKNOS system has now confirmed and demonstrated. It is hoped to complement the 'explicit knowledge' now supplied to EKNOS with the 'tacit knowledge' of experienced EO practitioners in the not too distant future esa