ICONS Knowledge Management for Structural Fund Projects
A Case Study

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Introduction

Knowledge representation and manipulation are of paramount importance to users and designers of knowledge management applications. Hence, development of advanced user-oriented knowledge representation features is one of the principal goals of the ICONS (Intelligent CONtent management System) project. We present the principal characteristics of the ICONS multiparadigm knowledge schema serving as the meta-information layer supporting the ICONS knowledge repository. We also briefly discuss an e-Government knowledge management application supporting definition of Structural Fund projects currently under development with the use of the prototype ICONS platform.

Knowledge and Content Management

To provide the context for the ensuing presentation of the multiparadigm Knowledge Schema we briefly present the principal areas of the ICONS content management architecture. A schematic presentation of the principal content management areas and their interactions is shown in Figure 1.

[1] This work has been supported by the ICONS project IST-2001-32429

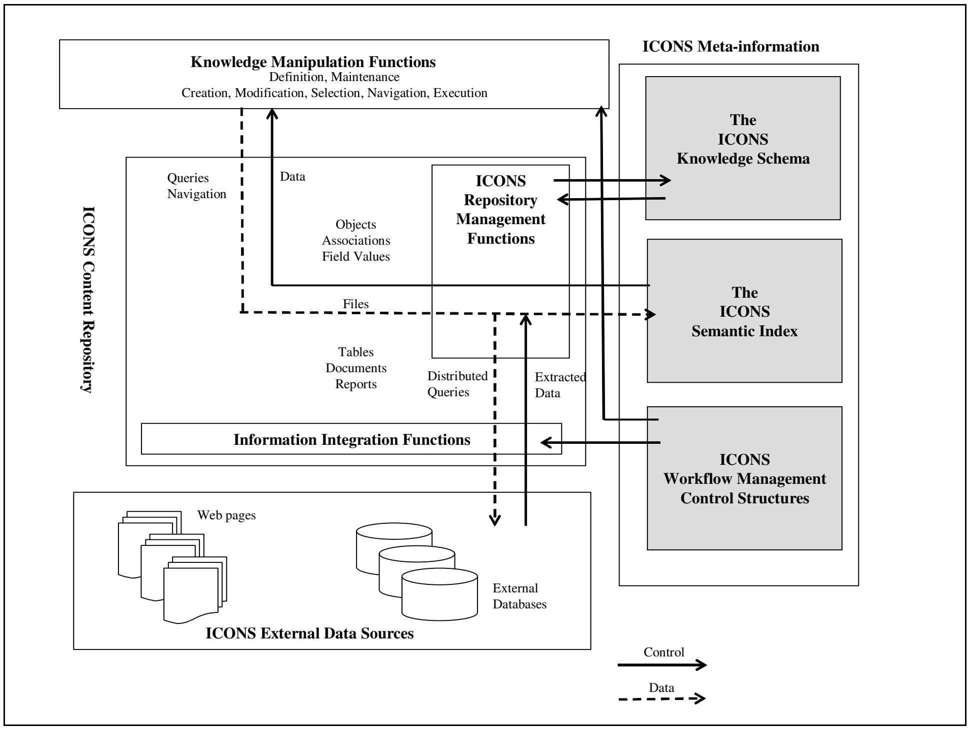

Figure 1. The principal ICONS content management areas.

All of the ICONS architecture components are amply described in the preceding reports, mainly in [ICONS D01 and ICONS D06]. The focus of this report is on the ICONS Knowledge Schema to be used as the platform for multiparadigm knowledge representation.

All Knowledge Manipulation Functions act upon Content Repository objects controlled by the interpreted meta-information stored in the appropriate ICONS control structures. In particular, selection and navigation operations are entirely supported by the Semantic Index facilitating dynamic materialization of categorisation trees and content object associations. The Semantic Index, to be implemented as a relational database with intensive use of the main memory storage functions, will enhance performance of data intensive operations of ICONS. A comprehensive description of the Semantic Index control structures may be found in [ICONS D16].

The External Data Sources are treated as a seamless extension of the ICONS Content Repository covered by the corresponding parts of the Knowledge Schema definition. Declarative specification of the external data materialisation allows for easy knowledge management application development supporting clear external data integration semantics.

The workflow features of ICONS are to be intensively used both for knowledge processes supported by ICONS applications as well as for development of the internal ICONS algorithms in particular in the area of external data integration.

The Multiparadigm Knowledge Schema

The multiparadigm Knowledge Schema to be implemented in ICONS defines the entire information space of the ICONS Knowledge Base. This includes the actual and virtual content structures as well as the corresponding meta-data structures. The structure of the Knowledge Schema is schematically presented in figure 2.

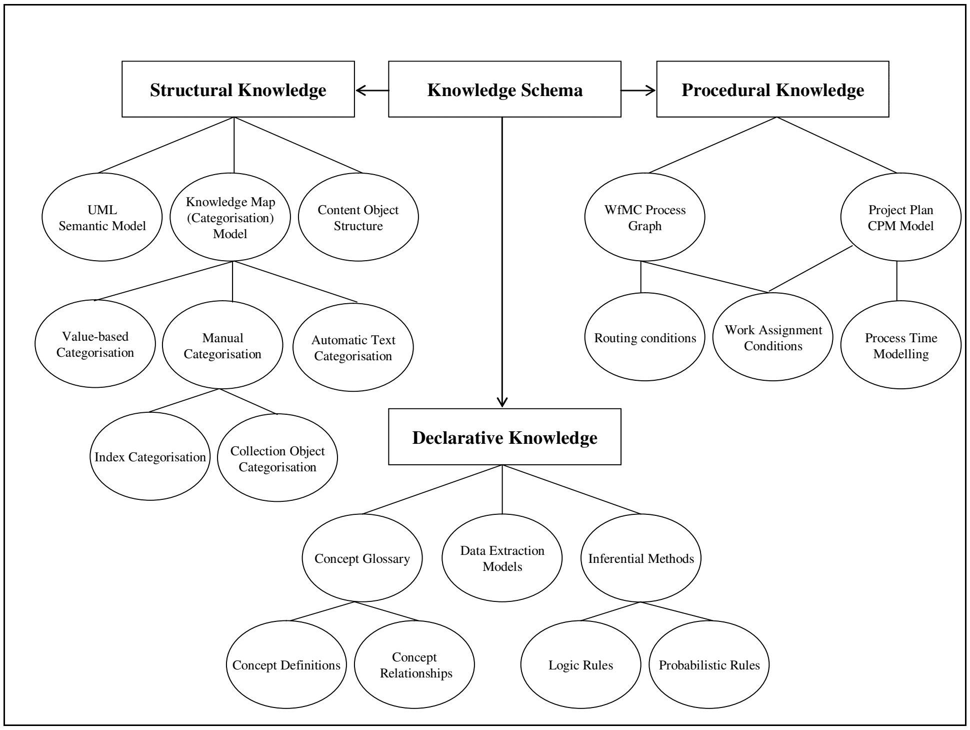

Figure 2. Schematic representation of the multiparadigm Knowledge Schema.

The principal knowledge representation paradigms comprise the Structural Knowledge, the Procedural Knowledge, and the Declarative Knowledge representations. All of the presented knowledge representation formalisms have either been amply defined in other ICONS reports [ICONS D01, ICONS D06], or represent common technological knowledge in the field of content and knowledge management (e.g. the UML Semantic Model, [ICONS D08]). Hence, we provide cursory definitions of the respective representations only in order to introduce sufficient information to understand the Knowledge Schema specification without the need to consult other ICONS reports. Implementation aspects of the Knowledge Schema are described in the ICONS architecture report [ICONS D16].

The Structural Knowledge Representation

The **Structural Knowledge** representations provide meta-information mechanisms for modelling content object class relationships, content object class behaviours, content object class grammars governing the internal object structure, and the object categorisation maps.

The **UML Semantic Model** provides facilities to specify the class relationship structure as well as the class behaviour inheritance structure. The internal object class structures are defined with the use of the respective XML schema specifications.

The **Knowledge Map Model** provides facilities to represent object categorisations and to manage categorisation trees collectively constructing a knowledge map defined within an ICONS knowledge management application. The categorisation trees are compatible with the Topic Map standard [ISO2002, Pepper2000] and the internal ICONS control structures used to define and implement the categorisation trees may serve to generate an external, XML-based representation of a Topic Map to provide interoperability with other knowledge management systems. The object categorisation modes includes the **Value-based Categorisation** providing the principal mechanism for dynamic materialisation of categorisation tree control structures, the **Manual Categorisation** supporting information-bearing relationships between a categorisation tree and the corresponding set of content objects, and the **Automatic Text Categorisation** using ontology-based machine learning techniques for text analysis and classification. The automatic text categorisation algorithm inserts the appropriate ontology term(s) into a predefined content object field(s) to provide required values for the ensuing value-based categorisation. The manual categorisation to be performed by the ICONS user is the principal mechanism for constructing the manually maintained categorisations trees stored in the

Content Repository as static control structures, or for creation of user defined collections of content objects and relationships called the **Collection Objects**.

The **Content Object Structure** is determined by the corresponding XML Schema providing the grammar for parsing of content objects belonging to a given class as well as for generating default content object electronic forms and XML editor renderings. The content objects are XML text files representing arbitrary trees compatible with the XML schema grammar defined for the corresponding object class. A specimen of a content object XML file structure is presented in figure 3.

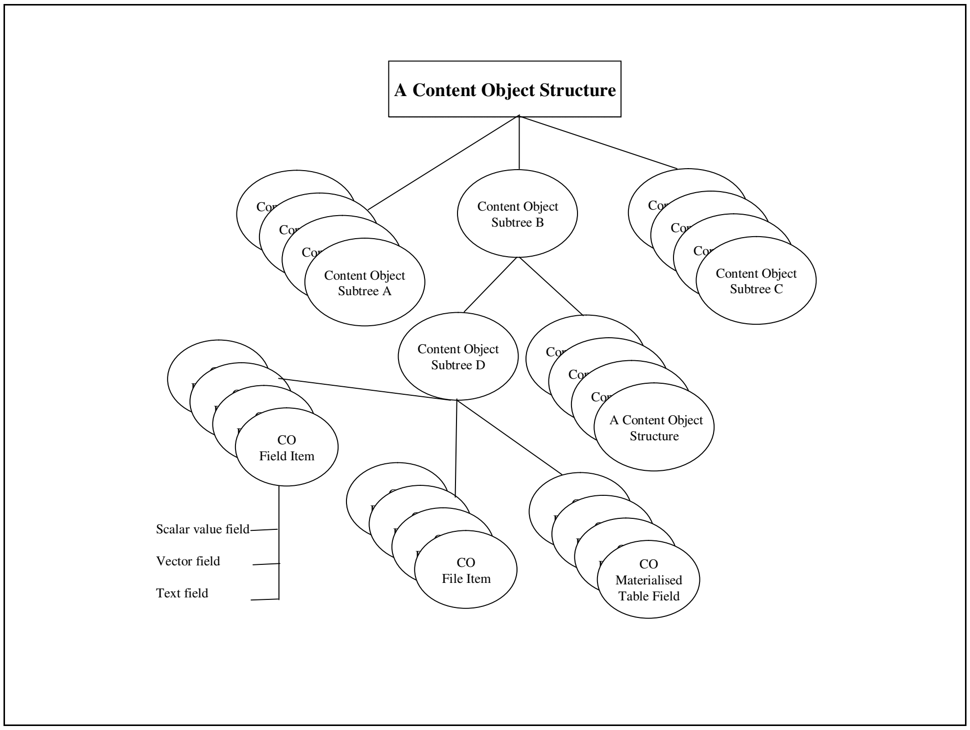

Figure 3. A specimen of a content object XML structure.

The XML representation of a content object comprises recursively defined repeating subtrees, elementary fields such as field items, file items and materialised table fields, as well as other distinct content object classes embedded recursively in a content object structure.

The **CO Field Items** comprise single values of permissible XML schema type, vectors of values representing multi-valued fields, and text fields. Field items annotated with appropriate XML schema attributes to specify their role with respect to the Semantic Index. Mapping to the Structured Knowledge representation to the Semantic Index are defined in the Control Data Structure section of the ICONS architecture report [ICONS D16].

The **CO File Items** comprise binary file objects stored within the Content Repository and rendered to the end-user via the appropriate HCI presentation functions and/or created and interpreted by the corresponding end user environment software tools (e.g. MS Word, MS Excel, Autocad, etc). Approximately 250 standard file types are to be supported by the ICONS Content Repository by the respective rendering functions specified in [ICONS D16].

The **CO Materialised Table Fields** comprise tabular data extracted from external databases and/or semi-structured data sources (e.g. HTML pages or XML files) with the used of external data extraction functions. The extraction rules are specified as declarative knowledge with the use of the QBE-based Data Extraction Models [ICONS D16]. The external data extraction facility is the primary data integration feature available within the ICONS architecture. The semi-structured data extraction functionality is to be developed with the use of the Lixto technology [Baumgartner2001].

The Declarative Knowledge Representation

The **Declarative Knowledge** representations include facilities for modelling domain ontologies pertaining to the specific ICONS application area, features providing for declarative, user-friendly extraction of tabular data from pre-existing relational databases as well as from semi-structured information sources, and rule-based inferential methods supporting the content object behaviour.

The **Inferential Method** declarative specification, either in the form of **Logic Rules** to support crisp reasoning, and in the form of Dempster-Shafer **Probabilistic Rules** to support uncertainty reasoning have been amply dealt with in other ICONS reports [ICONS D01, ICONS D06, ICONS D07]. Consistently with the object-oriented programming paradigm (i.e. object encapsulation) adopted for the Knowledge Schema and the ICONS reports, the inferential methods may only operate on object attributes, the associated concept extensions (i.e. concept dictionaries comprising concept relationships), and on tabular data extracted from external data sources. The inferential methods are an important extension of the object class methods to be developed in Java. The procedural algorithms of Java methods are not considered to constitute declarative knowledge, although they embody an algorithmic representation of application domain knowledge artefacts. Both kinds of object class methods may be inherited within the inheritance structure of the UML Semantic Model.

The **Data Extraction Models** are specified as parametric QBE data extraction models permitting queries with respect to a specific pre-existing database with the use of the native database attribute and table names or with the use of concept names defined in a concept taxonomy used to define the domain ontology. The QBE data extraction models are amply defined in [ICONS D16] within the data integration features section. The semi-structured data extraction is to be supported by the Lixto technology.

We concentrate on modelling domain ontologies with the use of the **Concept Glossary** comprising the **Concept Definitions** and the **Concept Relationships**. The proposed solution is to be fully compatible with the appropriate parts of the Topic Map specification as defined in [ISO2002, Pepper2000].

"Topic maps are a new ISO standard for describing knowledge structures and associating them with information resources. As such they constitute an enabling technology for knowledge management. Dubbed “the GPS of the information universe”, topic maps are also destined to provide powerful new ways of navigating large and interconnected corpora. Here the distinction between individual documents vanishes and the requirement is for indexes to span multiple documents, and in some cases, to cover vast pools of information. In this situation, old-fashioned indexing techniques are pitifully inadequate.” [Pepper2000].

Concepts refer to physical or abstract entities identified in the knowledge management application domain and they may be defined in terms of a concept name, the concept definition and, if required, in terms of enumerated concept value domains (concept dictionaries). The concept relationships typically represent the part-whole, synonymy, homonymy, as well as narrower, broader, or related meanings of associated concepts [Z39.19, ISO1985]. An example may be the glossary of geographic names or administrative institutions pertaining to a given application domain.

The Concept Glossary represents the domain ontology in a similar way that indices and thesauri represent knowledge pertaining to contents of a set of documents. The concept relationships may be exploited in many diverse ways starting from definition of the content object structures and the corresponding Knowledge Map indices, to rewriting concept-based queries and automating integrity control during create and update operations on content objects.

The Procedural Knowledge Representation

Always, in order to achieve a given goal, both data and algorithms to process this data have to be applied. Structural knowledge as well as declarative knowledge are mainly focused on representation of data, its meaning and dependencies. Procedural knowledge complements this knowledge focusing on algorithms or procedures.

In the context of organizations, such algorithms are called processes. Since they are very often connected with some business, they are usually referred to as business processes. A business process defines what units of work, when, and by whom should be performed in order to achieve a given goal, that is to produce a product or to provide a service. Innovate, efficient and flexible business processes help organizations to be competitive and play the leading role on the market.

One of the most popular and effective tools to support processes are workflow management systems (WfM systems). In a WfM system an automated part of a process is represented as a workflow process. WfM systems are also able to execute processes as well as to monitor and analyze their execution. It is especially important from continuous process improvement's point of view.

So far, existing workflow process representations are appropriate to express well-defined and repeatable business processes. One of the famous workflow process representations has been defined by the Workflow Management Coalition and known as the workflow meta-model [WfMC-TC-1003]. This model is provided together with the XML process definition language (XPDL) [WfMC-TC-1025], the WfM application programming interface and Workflow interoperability language (Wf-XML) [WfMC-TC-1023].

Unfortunately, most of the real business processes are not well defined. In addition, it is also needed to represent non-repeatable processes in order to reduce their cost and to monitor their execution (resource assignment, deadlines, etc.). This requirement can be satisfied by defining more flexible workflow representation.

In the ICONS project we extend the WfMC meta-model of some element to make it more flexible. Especially, we introduce a flexible language to define assignment of performers to activities as well as to express complex control flow conditions. We also provide some mechanism to support time management [Eder2001].

As procedural knowledge representation we provide the following languages and models:

- **conceptual model** – this is the WfMC meta-model extended of some elements to flexible workflow processes and to introduce time management. This model is to understand basic concepts of workflow processes. On the basic of this model we will provide an XML process definition language. This language is an extension of XPDL. This model is presented in section The Procedural Knowledge Representation and described in detail in [ICONS D09].
- **process modelling language** – this is a language to represent workflow processes graphically. Both process definition and process instantiation are represented. This language is to support workflow designers in modelling workflow processes as well as workflow participants (or users) in execution process instances. This language is based on UML Activity Chart diagram extended of some elements to represent workflow processes. This model is described in detail in [ICONS D09].
- **storage model** – this is the model to support execution of workflow processes in a distributed workflow environment. It is for the ICONS developers in order to understand services and interfaces of the developed WfM system. This model is an extension of Workflow API specified by the WfM Coalition. This model is described in detail in [ICONS D16], Intelligent Workflow Manager specification.
- **distributed communication model** - this is the model to support execution of workflow processes in a distributed workflow environment. This model is for ICONS partners and other vendors in order to understand how to support execution of workflow processes in a distributed environment. This language is an extension of Wf-XML language. This model is described in detail in [ICONS D16], Distributed Workflow Manager specification.

Knowledge Maps

Knowledge maps provide means to categorise information objects stored in the content repository. They allow assigning objects to categories. The objects may be not only documents but any other knowledge pertaining artifact e.g. localised expertise. The imposed tree-structured hierarchical categories provide a powerful navigation and search device for browsing the content repository along consciously engineered organisational context. Users can drill down into consecutive levels of hierarchy to find more and more pertinent information among fewer and fewer occurrences. The navigation process is especially effective if the knowledge map represents intuitive semantics of the user information requirements. This goes, however, far beyond technical aspects of knowledge maps and must be guaranteed by knowledge engineers responsible for their definition on the application development stage.

Eppler [Eppler2001] provides the most comprehensive view on knowledge maps presenting them mainly as a viable instrument for corporate knowledge management. ICONS although very interested in maps' applicability to corporate knowledge wants additionally to exploit (or not loose) their great potential for content / document management. [Eppler2001] stresses visualisation and contextualisation providing examples of only one level maps. ICONS extends the approach by addressing multilevel hierarchical maps. Thus issues of navigation, search and drill-down studies are innovative. In addition ICONS, as focused on development of the universal prototypes, goes more into technical aspects of building complex maps based on the predefined ICONS Object Content Structure. It is important to notice also that for presentation of non hierarchical relationships based e.g. on UML like constructs ICONS provides a complementary set of services within the Structural Knowledge Graph Manager [ICONS D01, ICONS D16]. Nevertheless the underlying ideas and premises of knowledge / content presentation are valid for both areas.

Eppler assumes (similarly to us) a knowledge map generally consists of two parts: a ground layer which represents the context for the mapping, and the individual elements that are mapped within this context. The ground layer typically consists of the mutual context that all employees can understand and relate to.

According to [Eppler2001] while the basic idea behind a knowledge map – to construct a global architecture of a knowledge domain – might be quite old, the application context, i.e., the corporation, and the format, as an intranet clickable map, are quite new. The reasons why knowledge maps are now viewed as a necessary tool in a corporate context are mainly the scope of (global) expertise that resides within larger companies and the difficulty of accessing this expertise through informal communication. Knowledge maps not only make expertise accessible through visual interfaces, but also provide a common framework or context to which the employees of a company can relate to in their search for (or contribution of) relevant knowledge. One of the most common mistakes in knowledge management projects is that a common context for the employees is not created. Knowledge maps provide this common context in an explicit common visual model.

The process of creating a knowledge map is almost as important as the final product itself. We will see that the technological implementation is only half of the challenge of developing and using knowledge maps in organizational knowledge management. The other even more challenging task consists of gathering the right reference information and combining it in a framework that everybody can relate to. Thus, the mapping process itself can already provide a number of insights into the knowledge assets of a company and its problems in allocating knowledge effectively (a knowledge asset in this context is any explicitly qualified source of knowledge that provides potential benefits for the solution of problems relevant to a company's success).

The following checklist presents guidelines for the knowledge maps assessment. If these criteria are met, a knowledge map may well become one of the killer-applications of a corporate intranet since it provides a quick and comprehensive overview of a company's intellectual assets.

1. Functional map quality
- Does the map serve an explicit purpose for a specific target user group?
- Is there an implemented process to update and review the knowledge map periodically?
- Is there a feedback mechanism through which users can suggest improvements to the map?

2. Cognitive map quality
- Can the map be grasped at one glance (not overloaded)?
- Does it offer various levels of detail?
- Does it allow comparing elements visually?
- Are all elements clearly discernible?

3. Technical map quality
- Is the access time sufficient (no time lags)?
- Can the map be used with a browser interface?
- Does the map appear legibly on various screen resolutions?
- Is the map securely protected against unauthorised access?

4. Aesthetic map quality

- Is the map pleasing to the eye (adequate colour and geometric form combinations)?
- Can the map's visual identity be kept when new elements are added (map scalability)?

The Structure Fund Project Knowledge Portal

System Objectives

The current efforts of the NAS country governments concentrate on setting up the management structure and the legal framework matching the EC requirements to ensure sound and transparent evaluation of project proposal, expedient execution of good quality eligible structural fund projects, as well as precise monitoring and benchmarking of the executed projects. The overall objective of the above NAS governments is to ensure compliance with the structural fund regulations and to select projects with most positive impact on the target economic and environmental metrics. The prime concern of most NAS governments, and indeed an important political priority, is to promote the sufficient number of high quality eligible project proposals to ensure the highest possible usage of the structural funds by the countries beneficiaries. Most countries currently develop national level information systems to monitor and report on the structural fund utilisation and performance metrics.

The goal of the Structural Fund Project Knowledge Portal is to support organizations and individuals involved in the SF project proposal development processes to achieve the highest possible number of high quality eligible project proposals meeting the stringent EC criteria.

In view of the past experience of such accessing countries as Spain, Portugal, and Greece, meeting an acceptable threshold of the structural fund usage, in particular during the initial period, is a difficult, if not impossible, task. Even small improvements in project proposal development processes resulting from application of the advanced knowledge management techniques and methodologies will have a substantial economic impact on the regional development of the NAS countries. **Indeed a 1% improvement in the structural fund project proposal acceptance level would mean additional 138 million Euro to be invested in the Polish regional economy alone in years 2004-2006. The figure for all new Member countries for the period 2004-2006 amounts to 30 billion Euro. Hence, the potential value of a 1% improvement of the SF project acceptance rate increases to 300 million Euro.** Considering the varied and rather low level of the regional and local government agencies and organizations involved in the structural fund planning and project development processes, one can reasonably expect a higher improvement rate. Clearly the above figures exemplify a strong economic motivation of the NAS countries to invest in ICT solutions pertaining not only to monitoring of the SF projects but also to improvements of quality and acceptance rate of the SF project proposals.

The secondary goal, consistent with the ICONS knowledge management paradigm, is to provide access to the structural funds benchmarking data to be used in the project proposal development processes to support the planning and cost estimation, as well as the Cost-Benefit and the risk analyses. The feed back loop ranging the project proposal development and the project execution phases represents the Knowledge Management Life-cycle underlying the ICONS knowledge management architecture [ICONS D01].

An important characteristic of the SFP KP system is integration of Communities of Practices involved in the SF project proposal ecosystem. Support and partial automation of expert interactions as well as facilities for documenting, verifying and dissemination of knowledge generated by these processes provides for continuous improvement of the system knowledge services.

System Architecture

The architecture of the SF Project Knowledge Portal (SFP KP) presents the principal system features supporting a system solution compliant with the stated project objectives. A schematic view of the system architecture is presented in figure 4.

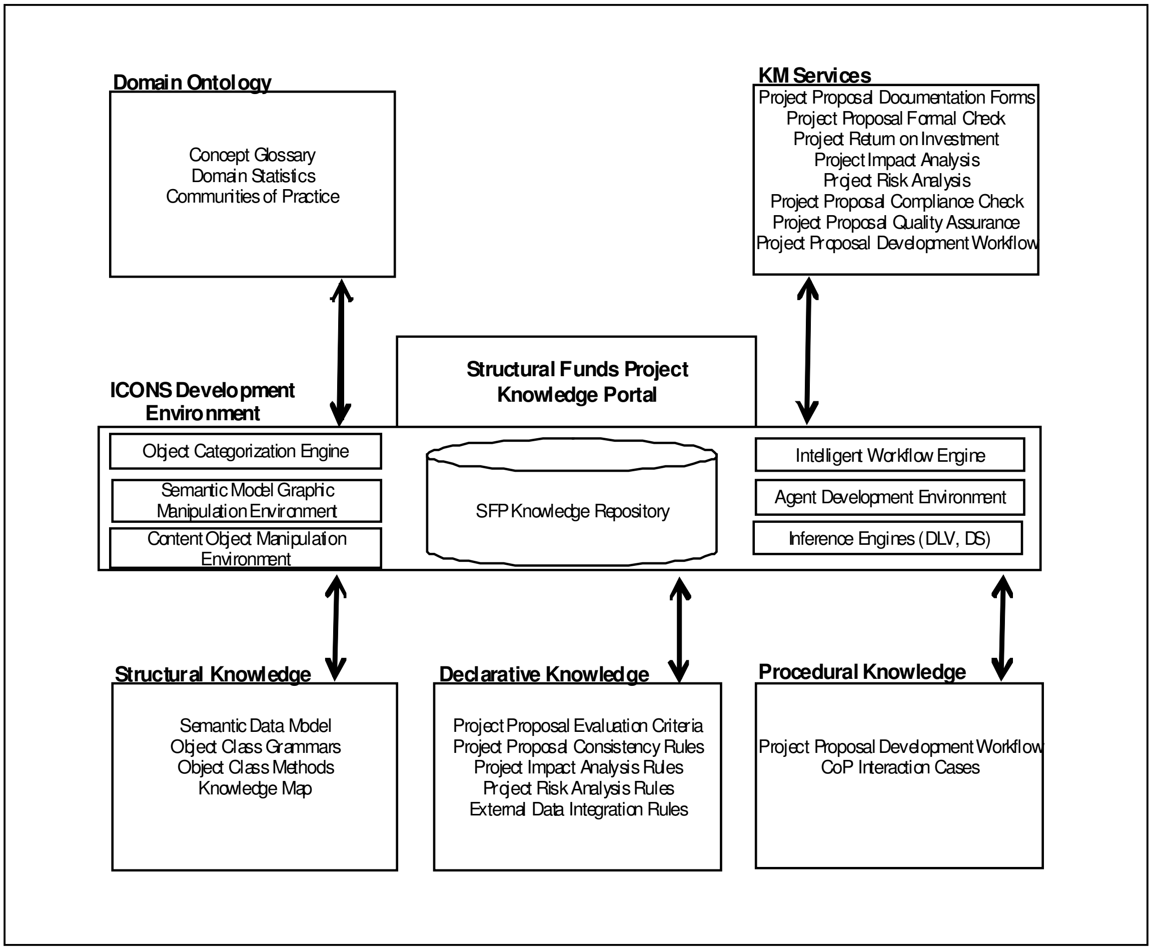

Figure 4. The SF Project Knowledge Portal architecture.

The **Domain Ontology** provides the conceptual foundation for all other areas of the SKP KP system architecture. The principal part, typical for all knowledge management applications, is the **Concept Glossary** defining the SFP domain ontology and providing support for both expert and non-expert use of the underlying knowledge representations and knowledge management services, as well as supporting automatic inference helping users find and merge information. An overview of the use of ontologies in the e-government knowledge management applications may be found in [Hovy2003]. Creation of a coherent domain model for the Structural Fund projects domain is the very first step in the SFP KP system conceptual design. It entails identifying and extracting terms from information sources within the system terms of reference and gradually, with the use of a stepwise refinement procedure, organising those terms into partial ontologies to be finally integrated into the SFP KP ontology represented by the system Concept Glossary. The paramount role of the Concept Glossary in design of the ICONS knowledge management applications is apparent in description of the multiparadigm Knowledge Schema semantics [ICONS D10].
The **SFP KP Domain Statistics** are required to provide the basis for evaluation of macroeconomic information to be used in SFP proposal analysis rules, in particular in automatic analysis of the project impact rules, and the risk modelling rules. Domain statistics are to be organised following the territorial structure used for the structural fund strategic planning and allocation.
The **Communities of Practice** cluster human experts playing key roles in the knowledge management lifecycle of the SFP KP system. The CoP ontology provides information regarding the classification of knowledge and skills required within the system knowledge processes and links into rosters of human experts providing knowledge services and contributing tacit knowledge into the system knowledge repository. The role of human experts in the SFP proposals, both within the initiation and creation processes, as well as within the project proposal quality assurance and evaluation processes, is of paramount importance and the corresponding ontology underlies the automatic management of the CoP interaction models.

The **KM Services** represent the functionality of the SFP KP system embedding all knowledge processes support provided within the realm of the SFP proposal and evaluation processes. The knowledge processes supported within respective KM Services utilize knowledge artefacts available within the system knowledge repository represented by the ICONS content objects, and extended with the external information resources integrated with the system as defined in the Knowledge Schema. Results of KM Services performed on the SF project proposals constitute an important body of the SF project related knowledge to be stored and rendered available in the system knowledge repository. An ample specification of the knowledge repository structure, as defined in the ICONS Knowledge Schema, may be found in [ICONS D10, ICONS D16].

The **Project Proposal Documentation Forms** Service is supporting assorted templates and electronic forms required by the European Commission as the project proposal documentation standards. The use of electronic forms and the associated data mapping functions is the precondition for most of the proposed services of the system. In order to incite system users to fill the predefined electronic form appropriate hard copy documentation generation functions are to be developed.

The **Project Proposal Formal Check** Service entails completeness and syntactic validation of project proposal documents, in particular those parts of documents that are developed with the use of electronic forms, and in may to a large extend be performed automatically. The automatic evaluation is to be based on formal consistency rules specified in the appropriate inference method of the corresponding content object class of the system knowledge repository.

The **Project Proposal Cost-Benefit Analysis** Service is to be developed as a set of Cost-Benefit Anaysis models, corresponding to wide project classes identified in the system, to be used by human experts, both proposal developers and proposal reviewers, to assess economic feasibility of the proposed initiative. Accuracy of the Cost-Benefit analyses will depend on the granularity of the project proposal quantitative properties and the corresponding statistical data available (integrated into) via the knowledge repository.

The **Project Proposal Impact Analysis** Service may involve complex mathematical modelling tools and qualitative impact prediction procedures. The role of the system is to provide information underlying the modelling cases as well as to store the results of modelling studies, and to render them available to the interested body of experts. Validated modelling results are prime artefacts of “explicit knowledge” stored and disseminated by the system. Whenever appropriate and technologically feasible, access to the modelling environments is to be provided via the knowledge portal interface.

The **Risk Analysis** Service is to be based on a set of generalised risk models corresponding to the identified SF wide project classes and based on probabilistic reasoning. A machine learning cycle is to be set up, whenever the corresponding project class benchmarking data is available, to feed new evidence into the risk model. This is one of areas where the system use may be extended to provide services beyond the SF project definition and evaluation life-cycle into the project management cycle. However in our case, we shall limit the application work to the initial risk assessment typically performed during the project proposal development stage.

The **Project Proposal Compliance Check** Service entails both automatic proposal evaluation and the manual proposal evaluation. In the first case, respective compliance rules may be used to evaluate the quantitative aspects (properties) of the project proposal versus the stated evaluation criteria and the corresponding domain characteristics provided as the domain statistics. The latter case requires intervention of human experts, preceded by a semi-automatic expert selection and service negotiation process, who should confront the qualitative project proposal aspects with the corresponding evaluation rules and guidelines of the European Commission. Experts will be supported by an appropriate set of electronic evaluation sheets to enforce a uniform and predictable proposal review process.

The **Project Proposal Quality Assurance** Service will support the inherently manual QA processes providing electronic evaluation sheets and appropriate checklist to the human experts performing the manual quality control checks. Project proposal templates and “best practice” hints supported by the electronic forms functionality should also enhance the average quality of the project proposal documentation. Evaluation sheets will be stored in the knowledge repository and corresponding “lessons learned” summary sheets will draw project proposal developers’ attention to frequent documentation development faults.

The **Project Proposal Development Workflow** Service is to provide workflow process classes corresponding to the identified types of the SF project proposal development life-cycles. System users will organise their proposal development work according to the predefined proposal development process invoking required roles, both automatic and/or human expert, and generating knowledge artefacts to be stored in the system knowledge repository. Work assignment may involve human expert selection and service negotiation following a predefined expert interaction model and supported by the ICONS intelligent agent management environment.

The conceptual specification of the above knowledge services to be provided by the system is defined with the use of UML Use Case models.

Contents of the system knowledge repository are organized according to the multiparadigm Knowledge Schema syntactic and semantic rules [ICONS D01, ICONS D10, ICONS D16] and rendered to the system users via the knowledge portal HCI (human-computer interaction) interface based on the advanced graphic models for accessing and manipulation of knowledge. The conceptual view of the system knowledge schema is formally defined with the use of an un-attributed UML CAD model, the UML process models, as well as selected exampled of declarative knowledge specifications.

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