Intelligent CONtent management System
Presentation of the IST ICONS[*] project

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Abstract

The ICONS (Intelligent CONtent management System) project objectives and contribution to the current state of the knowledge management field is presented. The project represents an on-going international research effort funded by the European IST research programme. An important aspect of the project is the fact that its inception and the technological platform are based on the industrial software development, the OfficeObjects® Portal project, performed at Rodan Systems S.A.. The OfficeObjects® Portal product is currently commercially available and boasts 6 large scale application within the first 6 months of market distribution.

1 Introduction

As organizations are moving to flatter, networked structures, the ability to share and leverage knowledge across the enterprise, as well as with other associated organisations, becomes increasingly critical in a stride to achieve the competitive advantage. **Action line II.1.2 (Corporate knowledge management)** pertains to development and demonstration of tools for representing, capturing, accumulating and transferring distributed knowledge.
Many organisations see knowledge management as a way to capture the tacit knowledge that exists in the heads of employees and transfer it to the so-called “organisation memory”. In other words they try to capitalise on the employee competencies so that the organisation increases its intellectual capital. The ICONS projects, although recognises and addresses the need for management of dispersed knowledge that exists within the organisation so that it can be of value to the organisation itself, **has a strong emphasis on the reverse movement of knowledge: from the organisation memory to the employees**. Action line II.1.2 as well as Key Action II as a whole, in addition to addressing to addressing specifically **knowledge management**, has too a clear emphasis on improving working conditions of employees by introducing new ways of working and increasing flexibility with respect to time and location constraints. The Key Action also pays special respect to the adaptation of corporate infrastructures to individual needs and training. The ICONS project is contributing exactly to these points: a primary objective of the ICONS project is to build tools that provide context-sensitive information and knowledge to the employees, therefore addressing on-the-job training needs, best practice support for employees, competence building, as well as support for younger, first-time employees.
The ICONS project will help to implement the concept of the “smart workspace” by delivering knowledge guidelines and experiences in an active, timely, context-specific manner to employees’ desktops. This is a clear priority of **Key Action II** as it supports *actions that contribute to the EU’s competitive strength areas such as (...) knowledge modelling and enterprise management.*
The ICONS project aims to capitalise on the significant amount of work that has been done in the Artificial Intelligence (AI) and Knowledge Management (KM) fields, and on the significant experience in integrating and semantic representation of the pre-existing heterogeneous information resources. The ICONS project aims therefore to contribute to the strengthening of the European position in the above-mentioned fields.
The ICONS project has been selected as out of 71 proposed research projects submitted in the April 2001 IST RDT project call as on of the 7 funded projects with the project budget exceeding 3 mln Euro. The project is to be completed within 24 months and the principal results will be presented as a working ICONS system prototype and a pilot knowledge management system application. The technological platform serving as the starting point of the ICONS prototype development is the OfficeObjects® Portal system, which is the proprietary software product of Rodan Systems S.A.

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The project consortium comprises Rodan Systems S.A. (Dr Witold Staniszkis – the project coordinator), University of Paris Dauphine (Prof. Witold Litwin), University of Ulster (prof. David A. Bell), University of Calabria (Professors Nicola Leone and Pasquale Rullo), The Polish Academy of Sciences (Prof. Kazimierz Subieta), as well as industrial partners Sema Belgium and InfoVide.

2 The ICONS project objectives

Turning information into knowledge has been one of the principal goals of advanced information systems developed in all realms of social and economic life of modern societies. Terms like "knowledge management", "knowledge engineering" and "knowledge bases" became ubiquitous in corporate board rooms as well as IT departments. Easy access to information enabled by the explosion of Internet technologies has created new problems related to exponentially growing wealth of information sources flooding the information system users.
Many advanced information systems are focused on knowledge bases comprising large collections of facts, rules, and heuristics pertaining to a specific application domain. Such knowledge bases are typically divided into two principal parts, namely the content base comprising repositories of mutlimedia information objects and ontologies representing formal knowledge pertaining to the corresponding application domain.
Our aim is to develop a prototype of an Intelligent CONtent management System (ICONS) supporting a uniform, knowledge-based access to distributed information resources available in the form of web pages, pre-existing heterogeneous databases (formatted, text, and multimedia), as well as legacy information processing systems.
The principal objectives of our research and development project are to obtain and present novel results in the areas of **knowledge representation and inference**, **heterogeneous information integration**, and **user-friendly interfaces** based on advanced information architecture techniques. The preliminary architecture of the system is presented in figure 1.

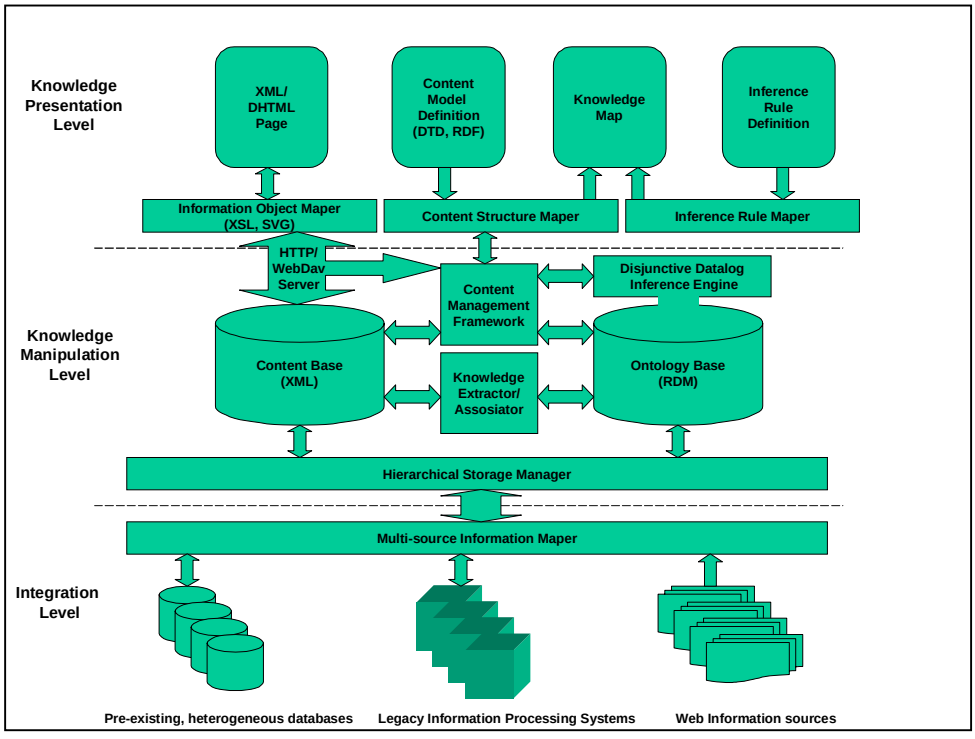

Figure 1. The preliminary architecture of ICONS

The core of the ICONS system is the knowledge manipulation level (KML) comprising the Content Base (CB) and the Ontology Base, as well as the principal functional components, namely the Content Manipulation Framework (CMF), the Disjunctive DATALOG Inference Engine (DDIE) and the Knowledge Extractor/Associator (KEA) engine. The distributed physical data structure is to be

managed by a Hierarchical Storage Manager (HSM) supporting data and process distribution among multiple ICONS servers and invoking services of the Multi-source Information Mapper (MIM).
The **Content Base** stores XML information objects structured and classified according to DTD definitions comprised in the XML schema. The XML information objects may comprise other XML objects, of the same or different class, as well as arbitrary binary elements stored as files in the HSM managed physical storage. The XML objects comply with the classical object-oriented data structure principles, such as object identity, class structural constraints and behaviour. Multiple inheritance is to be supported by the XML schema. The machine-understandable description of the Content Base semantics, complementary to the DTD XML object class specification, is provided by the RDF (Resource Description Facility) metadata. The RDF metadata corresponding to the XML information object classes are to be stored as XML objects. The RDF semantics are sufficiently powerful to describe domain ontologies in a way similar to semantic networks and frames used in AI for knowledge representation. It is envisaged that the conceptual schema of the ICONS repository will be defined with the use of UML. There exists a straightforward mapping between a UML schema and a RDF schema.
The **Ontology Base** is a relational data model representation of the XML class ontologies defined by the corresponding RDF specification semantics. All usual semantic data model (UML) object class relationships will be represented. The corresponding parts of the relational schema will be generated on the basis of the DTD and RDF schemata for a given XML information object class. The domain ontology derived from the RDF semantics are to be extended with the inference rules specified in disjunctive DATALOG. The language is well suited to represent a wide class of knowledge-based problems (including, e.g. planning problems, NP optimisation problems, and abductive reasoning) in a very natural and compact way. Use of the relational model, enhanced with DATALOG capabilities for knowledge representation, provides a powerful efficient platform for advanced query processing.
Important issues in many content management applications, such as e.g. historical document archives, pertain to modelling of time, both from the point of view of the time-varying object relationships and the time representation granularity. The temporal queries and the corresponding time modelling issues will be included in the knowledge representation research.
The **KEA engine** is to support mapping of the designated XML attributes as well as the corresponding RDF definitions onto the relational model to represent the specified conceptual content model semantics. The **Associator** relates the results of advanced query processing to the XML content, in order to facilitate selection and delivery of the pertinent information object instances.
The **Content Management Framework** comprises the advanced query functionality, including support for full-text retrieval and DATALOG, as well as the CB schema definition comprising the DTD, RDF schemata. Extension of the OB schema, generated from the CB schema specification, with DATALOG inference rules is to be supported by the CMF. All corresponding definitions are to be parsed by the Content Structure Maper (CSM). The CSM module is also responsible for generating the graphical knowledge map and for supporting the navigational queries defined on the basis of the knowledge map.
The **Information Object Mapper** controlled by the XSL and SVG specifications is to support information object presentation in the Internet browsers according to the design of information architects. The personification mechanism and rule definition facility are also to be developed within the IOM module.
The **Hierarchical Storage Manager**, implemented on top of a standard object-relational database management system, provides an open platform for physical management of content repositories. The HSM is responsible for addressing all XML information object instances, as well as their binary elements stored as files, regardless whether they are located in the distributed Content Base or within any external information source. The appropriate mappings of objects extracted from external databases, web sites and/or information processing systems are to be supported by the **Multi-source Information Mapper.**
The **Knowledge Presentation Level** provides GUI dialogue model in an Internet browser environment. The principal graphic presentation functionality pertains to presentation of the XML information objects and to graphic display and manipulation of the **knowledge map**. The knowledge map is to facilitate user interaction the Content Management Framework.

The overall approach of the ICONS project is to:
(a) provide effective methods for analysing and modelling,
(b) develop practical tools for exploiting and using,
(c) assess in a pilot system the usefulness of ...

..... intelligent content management systems with advanced knowledge management capabilities integrating internal content repositories with external heterogeneous information sources. To achieve these overall objectives **four streams of technical work can be identified** comprising the above operational goals:

Objective 1: Development of knowledge representation techniques and methodologies for a multimedia content repository.

The following specific research problems must be addressed in order to develop the knowledge representation capabilities of ICONS:

(a) Application of semantic data models (UML) and deductive data base mechanisms as the domain ontology specification tool.
(b) Extraction of knowledge embedded in XML documents and in the associated RDF specifications.
(c) Representing knowledge embedded in the schemata of pre-existing heterogeneous databases and legacy information processing system outputs.
(d) Design and implementation of an efficient, non-procedural content management framework providing content and knowledge model definition and query capabilities.

Results obtained in the above research areas will be embedded in the ICONS prototype and they will be verified in the pilot application environment. The principal research approach is to create synergies by integrating known research results in novel configurations and contexts, as well as extending known results in order to meet the identified new requirements.

Objective 2: Development of user interface design and management tools meeting the requirements of the information architecture methodology

The user interface requirements fall into three distinct areas, namely the user tool set and dialogue model, the content presentation model, and the graphical knowledge presentation and manipulation model. All of the above presentation models must incorporate personification capabilities in order to enable dynamic adjustments to changing user preferences discerned from the system usage patterns.
The information architecture methodologies and techniques are considered to be the prime requirements for design and implementation of the ICONS user interface management functionality. The multi-disciplinary research involves skills of industrial designers, psychologists, and computer scientists.
The ICONS prototype and pilot application work is to provide a realistic test-bed for the proposed user interface management techniques.

Objective 3: Design and implementation of efficient algorithms for management of large, distributed multimedia content repositories

There are two dimensions of the ICONS content distribution. The first pertains to distribution of the system content repository comprising the Content Base and the Ontology Base and the hierarchical storage management processes among the ICON servers. The second concerns integration of external information sources, such as pre-existing heterogeneous databases, legacy information processing systems, and web information resources.
Distribution of the ICON components among the system servers requires efficient load balancing algorithms inter-operational with the selective content and ontology replication mechanism. Research will also concentrate of adaptive data cashing techniques and the multi-criterial data distribution optimisation.
Integration of the external information resources is to be performed with the use of the XML wrapper technology. Wrapper programs producing required XML envelopes for extracted data are to be enriched with RDF specifications resulting from extracting semantics from database schemata, in the case of the external databases, or representing semantics, in the case of the legacy information processing system outputs. The wrapper programs will be generated in the form of Enterprise Java Bean modules comprising the necessary query statements.

Objective 4: Develop an analysis and design methodology for large, knowledge-based content repository systems.

The multimedia content repositories with knowledge representation capabilities require a novel approach to the analysis and design methodology. An application development life-cycle and the associated methods and techniques will be specified and a pilot application of ICONS will be developed. The pilot application is to be the "Best practices of PHARE, SAPARD, and ISPA projects developed within the Newly Associated States" content repository accessible on the Internet. The aim is to present the viability of the proposed methodology and to provide a starting point for the clearly needed knowledge source.

3 The ICONS project contribution to the knowledge management field

The innovative contributions of the ICONS project result from formulating new research results, in particular in the area of knowledge extraction and representation and distribution optimisation algorithms, as well as from integrating new generation technologies (e.g. RDF) into the system features. We discuss the results of the ICONS project in the context of the world-wide state of the art in four technical areas pertaining to the project objectives.

Objective 1: Development of knowledge representation techniques and methodologies for a multimedia content repository.

The knowledge management requirements, in particular the value of domain ontologies and the conceptual reasoning approach have been convincingly presented in [O'Leary1998]. The principal requirement with respect to the knowledge management systems is to provide features supporting representation and extraction (querying) of knowledge embodied in the vast information resources comprised in content repositories.
The prevailing approach to representing knowledge embodied in existing information resources, in particular in the Web information resources, is by using metadata representing the complex information object relationships and in some cases inference rules. The summary and comparative analysis of the knowledge management frameworks is presented in [Holsapple1999].
The knowledge representation approach based on introducing tags in HTML and/or XML objects to represent the content semantics has been presented in [Dieng2000, Ginsburg1999, Shim2000]. Prototype system solutions based on this approach have been presented in [Corby1999, Raborijaona2000]. The disadvantages of the tag-based knowledge representation approach have been discussed in [Martin2000].
Knowledge representation approach based on separately defined semantic schemes, usually based on special-purpose knowledge representation languages, is increasingly gaining importance. An approach based on conceptual graphs has been proposed in [Martin2000]. Representation of procedural knowledge and specified domain knowledge is proposed in [Fensel1998]. Two separate knowledge representation language for procedure (P-Karl) and logic-based inference knowledge (L-Karl) are proposed. The use of logic as a knowledge representation scheme has also been postulated in [Lambrix1999]. Conceptual reasoning and the semantic net approach have been proposed in [Lassila1998, Martin2000]. The prototype system implementations and knowledge management application frameworks have been discussed in [Bassiliades2000, Bouguetaya2000, Chang2001, Goeschka2001, Hammer1997, Knoblock1998, Lawrence2001]. A novel approach of integrating the data mining results into the knowledge representation framework has been discussed in [Buchner2000].
The time representation issues are an important ingredient of the knowledge representation schemes of a wide class of content repositories. The current results in the area of temporal aspects of knowledge management are presented in [Dyreson2000, Gregersen1999].
The Resource Description Framework (RDF) is the emerging semantic interoperability and knowledge management standard for the Web information resources. The RDF standard has been exhaustively discussed in [Decker2000a, Decker2000b, Lassila2000].

The **novelty** of the ICONS project within the realm of this objective is exemplified by the following solution characteristics:

(a) Implementing the RDF standard as the principal knowledge representation scheme.
(b) Integrating RDF semantic net approach with the logic-based knowledge representation and the procedural representation based on the Workflow Management Coalition specification [Workflow1994].
(c) Implementing the domain ontology model with the use of the relational data model enhanced with a DATALOG inference engine.
(d) Integrating the time dimension and temporal query processing into the ICONS knowledge management framework.
(e) The use of the XML wrapper technology for capturing semantic information embedded in pre-existing information sources.
(f) The ICONS architecture based on tight integration of the knowledge management framework with the multimedia, XML-based content repository.

Objective 2: Development of user interface design and management tools meeting the requirements of the information architecture methodology

The user interface aspects of the advanced content management architectures, in particular those based on the internet portal technologies, are of paramount importance. Two principal areas of the user interface design are to be addressed by the ICONS project, namely the area of information architecture dealing principally with the graphic information presentation methods and techniques, and the graphic knowledge representation and manipulation interface.
The information architecture paradigm and applications are exhaustively presented in [Kahn2001]. In particular, the novel techniques in design and graphic representations of Web site maps are discussed. Issues pertaining to the Web site usability comprising the critical appraisal of the current technology are presented in [Becker2001]. The web site interface personalisation requirements are discussed in [Kirda2001, Ramakrishnan2000]
Constructing visual representations of the knowledge domain's ontological structures to help users grasp complex relationships usually focuses on three elements; (i) the identity of individual elements in a large knowledge base, (ii) the relative position of an element within network context, and (iii) explicit relationships between elements. The relevant techniques are exhaustively discussed in [Chen1999] and the corresponding application areas may be studied in [Chen2001, Fairchild1988].

The **novelty** of the ICONS project within the realm of this objective is exemplified by the following solution characteristics:
(a) Integrating advanced results of the emerging information architecture field into the content management system architecture based on the XML/XSL information presentation paradigm.
(b) Development of a graphic knowledge manipulation and extraction editor supporting user queries and domain knowledge navigation.

Objective 3: Design and implementation of efficient algorithms for management of large, distributed multimedia content repositories

Integration of heterogeneous, pre-existing databases has been an active research field in 1980ties and early 1990ties. A collection of papers comprised in [Elmagarmid1999] provides a good insight into the state of the art in the area of multidatabase systems. The current research and development efforts have gone in direction of integrating the Web information resources, as shown in [Goeschka2001, Hammer1997, Knoblock1998], integration of object-oriented and multimedia databases [Chang2001], and extracting database semantics into a global dictionary [Lawrence2001]. Extracting semantic information from text-based information sources has been presented in [Soderland1997].
Integrating information from legacy information processing systems, in particular dealing with results of data mining queries, has been discussed in [Buchner2000].
The prevailing approach is to represent a common schema of integrated information resources as a XML repository and the technique for extracting and representing the underlying semantics is based on construction of wrappers to encapsulate the heterogeneity in accessing the diverse information sources. Wrappers are software modules that can transform data from a less structured representation

into a more structured one. Examples if the wrapper- based solutions may be found in [Hammer1997, Kushmerick1997, Sahuguet1999].

The **novelty** of the ICONS project within the realm of this objective is exemplified by the following solution characteristics:

(a) Extending the current results in the area of XML wrappers to extract rich semantics of heterogeneous information sources into an ontology schema specified in RDF (Resource Description Framework).
(b) Design and prototyping of advanced query optimisation algorithms supporting the use of semantic information.
(c) Design and prototyping of distribution and load balancing algorithms based on access patterns and semantic information.

Objective 4: Develop an analysis and design methodology for large, knowledge-based content repository systems.

Proliferation of the web content management systems in various application realms, in particular those that integrate internal information repositories with the external data sources, is the current trend in the architecture of management information systems. Examples of active development in the areas of government, energy industry, and general B2B systems are presented in [Ambite2001, Bouguettaya2001, Elmagarmid2001, Mecella2001, Shim2000].
Although the current systems are designed according to disciplined life-cycles based on various design methodologies, there exists a clear need to formulate a life-cycle and the underlying methodology for development of large scale, knowledge-based content management systems. Such methodology must be substantiated by at least a pilot development of an application based on an intelligent content management system.

The **novelty** of the ICONS project within the realm of this objective is exemplified by the following solution characteristics:
Specification of a prototype life-cycle and the underlying methodology for design and development of the intelligent content management systems applications.
Demonstrating the viability of the ICONS architecture and application development methodology by developing of a pilot knowledge-based content management application.

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