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Approaching the Digital Libraries in Perspective of Semantic Operability

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Abstract

The emerging use of semantic interoperability in digital library services is the hot topic since 2-3 decades. The paper discusses in terms of contexts and the information life-cycle; the role of semantic services. It discusses the Application and Relation of knowledge organization systems (KOS) with library. The paper discusses ontologies as well as the Role of Semantic Services and Semantic Description of Web Services. It highlights the processes to Enhance Semantic Interoperability and Current Developments. It highlights the Levels of Semantic Interoperability in Digital Library Environments and Data structures. Web Service Modeling Framework (WSMF) is also explained.

Keyword: Semantic interoperability; Digital Library Environments; Ontologies; Data structures.

Introduction

Digital libraries should enable any citizen to access all human knowledge any time and anywhere, in a friendly, multi-modal, efficient and effective way, by overcoming barriers of distance, language, and culture and by using multiple Internet-connected devices. What the experiences show that the overall objective of semantic interoperability is to support complex and advanced, context-sensitive query processing over heterogeneous information resources. Semantic interoperability is an essential technology in realizing the digital library goal. Semantic interoperability is based on conceptual understanding of the shared information, data and knowledge interpretation, ontologies and agents, reconciliation methods and modelling of processes. Interoperability is the ability of two or more systems to exchange information and to use the information that has been exchanged. None can deny the relationship between Knowledge Extraction and Semantic Interoperability. Semantic interoperability is characterised by the capability of different information systems to communicate information consistent with the intended meaning of the encoded information (as intended by the creators or maintainers of the information system). It involves:

- The processing of the shared information so that it is consistent with the intended meaning
- the encoding of queries and presentation of information so that it conforms with the intended meaning regardless of the source of information.

The semantic interoperability is important in digital library information systems. This includes various components:

a. Improving the precision of search,
b. Enabling advanced search,
c. Facilitating reasoning over document collections and knowledge bases,
d. Integration of heterogeneous resources, and
e. Its relevance in the information life-cycle management process.

It is considered as:

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a. "The ability of multiple systems, using different hardware and software platforms, data structures, and interfaces, to exchange and share data" (NISO 2004).[1]

b. "The ability of two or more systems or components to exchange information and use the exchanged information without special effort on either system" (ALCTS 2004).[2]

The recent developments also throw light on some theoretical issues such as clarification and selection of relevant terminology, standardisation and interpretation and the differing levels of semantic interoperability in digital library environments. It is wiseful to include:

a. The information structure;

b. Language and identifiable semantics.

Defining

Interoperability is therefore a major issue that affects all types of digital information systems, but has gained prominence with the widespread adoption of the Web. It provides the potential for automating many of the tasks that are currently performed manually.

Ouksel and Sheth (2004) identify four types of heterogeneity which correspond to four types of potential interoperability (Ouksel and Sheth 2004).[3]

The overall ambience can be structured as following:

- System: incompatibilities between hardware and operating systems.
- Syntactic: differences in encodings and representation.
- Structural: variances in data-models, data structures and schemas.
- Semantic: inconsistencies in terminology and meanings.

As far as digital libraries are concerned, interoperability is becoming a paramount issue. It is evident that the Internet unites digital library systems of differing types, run by separate organizations. Federated digital library systems, in the form of co-operating autonomous systems are emerging in a bid to make distributed collections of heterogeneous resources appear to be a single, virtually integrated collection. The benefits to users include:

a. Query processing over larger,

b. More comprehensive sets of resources, and

c. Easier to use interfaces that hide systems, syntax and structural differences in the underlying systems.

Semantic interoperability can function as a catalyst in the field of digital libraries for the purpose of developing the next generation digital library technologies. Semantic interoperability will be crucial to the next generation of digital library technologies, which in turn will be strongly influenced by semantic web technologies. Semantic interoperability is importance in terms of contexts and the information life-cycle.

KOS and Interoperability

The current researches are going on to investigate the methods and processes that are currently being used to improve semantic interoperability. It requires examining the standardization of meta data schemas, mediation and data warehousing, while the second covers methods which are being applied to KOS, their concepts, terms and relationships. To consider some of the prerequisites to enabling and enhancing semantic interoperability, include:

a. Standards and consensus building;

b. The role of foundational and core ontologies;

c. Knowledge organization systems (KOS);

d. The role of semantic services;

e. Architecture and infrastructure and access and rights issues.

Merging into the library

The emerging use of semantic interoperability in digital library services is the hot topic since 2-3 decades. The current scenario reflects that the resource environment became greatly expanded: besides library catalogues and abstract and index databases, digitized collections, licensed collections, remote preprint archives, institutional repositories, e-reserves, virtual reference, new scholarly resources, learning objects, web-based information and publications, subject gateways etc. became available and needed to be integrated in one seamless information space for the user. It leads to how library services such as: searching, browsing and navigation; information tracking; user interfaces; and automatic indexing and classification are being enhanced and implemented to provide advanced user services. There should be focus on identifying gaps and areas that would benefit from further research and attention. Information discovery here requires to be able to navigate across many sources by subject, by name, by place, by resource type or by educational level, with as little custom work, as little pre-coordinated agreement and as little terminological investigation as possible (Dempsey, ARLIS 2004).[4]

The provision of this semantic information and the mapping or merging process determines the degree of semantic coherence in a given service. Consequently, there are different levels of semantic coherence or interoperability. An aspect of semantic interoperability between two or more sets of data is a situation where the meaning of the entities or elements, their relationships and values can be established and where some kind of semantically controlled mapping or merging of data is carried out or enabled. Bergamaschi *et al* identify two major problems in sharing and exchanging information in a semantically consistent way (Bergamaschi *et al* 1999)[5]:

- How to determine if sources contain semantically related information, that is, information which is related to the same or similar concept(s).
- How to handle semantic heterogeneity to support integration of information and uniform query interfaces.

Some of the critical issues in this area relate to providing adequate contextual information, meta data and the development of suitable ontologies. Achieving terminology transparency has been the focus of attention of many mediated systems (Bergamaschi *et al* 1999)[5] that provide a reconciled view of underlying data sources through a mediated vocabulary, which also acts as the terminology for formulating user queries.

Meta data vocabularies and ontologies are seen as ways of providing semantic context in determining the relevance of resources. Ontologies are usually developed in order to define the meaning of concepts and terms used in a specific domain. The choosing and sharing of vocabulary elements coherently and consistently across applications is know as *ontological commitment* (Guarino *et al* 1994) and is a good basis for semantic interoperability in independent and disparate systems.[6]

Contexts

Semantic interoperability is not only important in the “traditional” contexts of subject indexing and subject access to databases and documents, or when integrating heterogeneous information sources for the purpose of information discovery. It seems relevant in most of the stages of the so-called information life cycle. Interoperability is an important issue in all information systems and services. Data and information cannot be handled properly without syntactic interoperability with regard to its formats, encodings, properties, values, and data types etc., not merged nor exchanged. The meaning of the used language, terminology and meta data values cannot be negotiated or correctly understood without semantic interoperability.

According to Dempsey, Interoperability is an important economic issue (Dempsey, ARLIS 2004).[4] It is necessary to be able to extract a maximum value from investment in metadata, content and services by ensuring that they are sharable, reusable and re-combinable. The improved services will allow users to focus on the productive use of resources rather than on the messy mechanics of interaction.

A solution, a semantically well integrated digital library service, could be tried to be implemented as either a more or less centralised integrated and interoperable information service or as a "recombinant" library (Dempsey 2003)[7] based on distributed and independent services and sources (e.g. based on a Web Services architecture): highly specialised presentation, application and content services, supported by common services would be made to cooperate.

Knowledge management approach

Advanced Knowledge Technologies Interdisciplinary Research comprises six challenges, and serves as a means to classify knowledge services and technologies. They are:

- Acquisition,
- Modelling,
- Reuse,
- Retrieval,
- Publishing and
- Maintenance.

Library and information science approach

As described in G. Hodge (Hodge 2000) focus on digital archiving based on an information life cycle approach, it concentrates on[8,9]:

- Creation,
- Acquisition,
- Cataloguing and identification,
- Storage,
- Preservation and
- Access.

While in the KM approach, when discussing acquisition, their focus is on harvesting of ontologies from unstructured and semi-structured sources. In modeling, they deal with modelling life cycles, and the coordination between Web services, as well as with mapping and merging of ontologies. Reuse refers to reuse of Web services via brokering systems and their experiments in mediating between problem solvers via partially shared ontologies. In the retrieval stage they focus on the transition from informal to formal media. In the publishing stage they demonstrate how formally expressed knowledge may be made more personal. The maintenance stage refers in their case to tools that respond to changes of language use in an organization over time.

Creation is the act of producing the information product in the Library and Information Science Approach. Acquisition is related to collection development, and the two represent the stage in which the created object becomes part of the archive or the collection. Identification provides a unique key for finding the object and linking that object to other related objects. Cataloguing is important for organization and access. Storage is a passive stage in the life cycle, although G. Hodge [8,9] reminds us that storage media and formats have changed over time, which caused some information to be lost maybe forever. Preservation refers to preserving the content as well as the look and feel of the object. Access needs to be ensured and enabling it comes as a result of the previous stages.

Approaches as found in LIS contexts

Traditionally, the principle options for improved semantic interoperability have been described as (Nicholson, D., Wake, S., & Currier, S.) (2001)[10]:

a. Integration of existing KOS,
b. Mapping between KOS, or
c. Creation of a new KOS.

The recent developments indicate the multiplicity of possible solutions in a large but rather unsystematic matrix of nine main options and numerous second level options and combinations with capability enhancements such as:

- Adding thesaural structure,
- Building new scheme-specific micro-thesauri,

- Mapping to existing domain-specific micro-thesauri,
- Adding mappings to local terms,
- Ensuring multilingual capability,
- Allowing community control,
- Machine-assisted processing,
- AI-assisted processing,
- Providing user training,
- Providing flexible facilities to aid users,
- Facilitating user mind maps,
- Ensuring consistent application of indexing terms via training and/or monitoring,
- Providing user assistance for optimal retrieval, terminologies interoperability agency.

Here are both KOS and indexing enhancements, involvement of several KOS, processing enhancements, and search and user support measures listed. Different actors could apply one or several options in combinations and sequences of actions (e.g. adopting a mapping service in the short term and compiling a single scheme in the long term) are possible. Regarding the decision process for a given service, Zeng and Chan (2004) summarize [11]:

"The choice of a basic approach plus any combination of the possibilities mentioned above may bring various end-products and require different amounts of time and resources. Any method and combinations with other processes may have pros and cons. When a particular method is employed, it is necessary to conduct a comprehensive investigation in order to identify potential problems."

Constituents of semantic interoperability in digital library environments

There is a fundamental problem: in order to retrieve information related to one specific subject, information from multiple sources, including background knowledge, must be virtually or physically integrated. Integration affects:

1. Meta data structure and its intended meaning, such as Creator, Reference.
2. The meaning of terminology and related background knowledge.
3. The use of names and identifiers for concepts and real world items in data fields.

Semantic interoperability means the capability of different information systems to communicate information consistent with the intended meaning. Information integration is only one possible result of a successful communication. Other forms are querying, information extraction, information transformation, in particular from legacy systems to new ones.

Levels of semantic interoperability in digital library environments

In the current digital library technology, one can clearly distinguish 3 levels of information that are treated in a distinct manner and give rise to distinct methods to address semantic interoperability. These are [12]:

1. Data structures, be it meta data, content data, collection management data, service description data.
2. Categorical data, i.e. data that refer to universals, such as classification, typologies and general subjects. Theoretically, one can regard all numbers to belong to this category.
3. Factual data, i.e. data that refer to particulars, such as people, items, places.

Role of Semantic Services

With the advent of machine-processable data comes the prospect of interoperability, which is increasingly regarded as being important in realising the goal of accessing and reusing data. However, for semantic interoperability to take place requires sharing and consistent use of terminologies, which can only result from a community basing its practices on well informed, published, authoritative information.

It is necessary to ensure that data continues to be interpreted correctly. Without which disastrous consequences will ensue in terms of query processing. Several types of terminology services have emerged in the digital library world, with the aim of supporting semantic reconciliation and thereby enhancing semantic interoperability, they include: registries or repositories of metadata and semantics; metadata schema registries; registries of crosswalks or mappings between vocabularies; and ontology servers as well as other types of terminology services.

It is significant to distinguish between registries and repositories in that a repository is merely concerned with the collection of some corpus of data, whereas a registry has an additional layer, which caters for policy and management issues, as well as providing user level services.

Terminology services play an important role by supporting the following types of functionality:

- Disclosing concepts, terms and semantic relationships.
- Promoting consistent use of vocabularies.
- Publication of semantics.
- Providing examples of use and best practice.
- Making accessible information relating to provenance, currency, authoritativeness, deduction, and reasoning processes (McGuinness and Pinheiro da Silva, 2003).[13]

The types of entities that are used to determine semantic proximity and that support semantic reconciliation include: vocabularies, classifications or taxonomies and thesauri. Semantic interoperability requires domain-level consensus on the structure, concepts and terminology to be used in knowledge representation. Semantic registries serve an informational purpose by collecting together appropriate information and tracking developments in a relevant area. As mentioned earlier, several such services are emerging; they are aimed at collaborative development of metadata vocabularies and their harmonisation at a domain level.

Importance of semantic interoperability

Semantic interoperability issues seem relevant in each of the elements from the following extended list of information life cycle elements:

1. Creation, modification.
2. Publication.
3. Acquisition, selection, storage, system and collection building.
4. Cataloguing (meta data, identification/ naming, registration), indexing, knowledge organisation, knowledge representation, modelling.
5. Integration, brokering, linking, syntactic and semantic interoperability engineering.
6. Mediation (user interfaces, personalisation, reference, recommendation, transfer etc.).
7. Access, search and discovery.
8. Use, shared application/collaboration, scholarly communication, annotation, evaluation, reuse, work environments.
9. Maintenance.
10. Archiving and preservation.

Semantic description of web services

A *Web Service* is a software program that can be accessed via the Internet through its exposed interface (e.g. a query service built on top of the information system of a cultural heritage institution). Web services are identified by their URLs. Web service interface descriptions declare:

a. The operations that can be performed by a web service;
b. The message types exchanged during the interaction with the web service; and
c. The physical location of ports, through which information should be exchanged.

Web services are usually deployed in web servers and can be invoked by any software component (including web services), independently of its implementation (Cabral *et al* 2004).[14]

Web services initially aimed to revolutionize e-Commerce and enterprise-wide integration. These expectations were not met; current standard technologies for web services (e.g. WSDL (Christensen *et al* 2001) provide only syntactic-level functionality descriptions.[15] Web services usually offer little more than a formally defined invocation interface, in the form of human-oriented meta data that describe the service function and the organization that developed it (e.g. through UDDI descriptions (UDDI Consortium 2000).[16] Although applications may invoke web services using a common, extensible communication framework (e.g. SOAP (W3C 2003)[17,18, 19], the lack of machine-understandable semantics makes human intervention necessary for automated service discovery and composition within open systems (Cabral *et al* 2004).[14]

Semantic Web Services (SWS) have been introduced in order to:

a. Augment web services with rich formal descriptions of their capabilities; and
b. Facilitate the automated discovery, composition, dynamic binding, and invocation of services within an open environment.

A Semantic Web Service is a semantically described service. Sophisticated description models are utilized in SWSs, which can be enhanced with ontologies enabling both machine interpretability of the SWS capabilities and integration with domain knowledge. However, *Semantic Service Description frameworks* are needed, which should provide the infrastructure for supporting semantic interoperability among web services.

Current efforts in SWS infrastructure development can be characterized along three orthogonal dimensions (Cabral *et al* 2004)[14]:

- *Usage Activities*, which define the functional requirements that should be supported by a framework for SWSs.
- *Semantic Web Service Architecture*, which describes the components needed for accomplishing the activities defined for SWSs.
- *Service Ontology*, which aggregates all the concept models related to the description of SWSs, and constitutes the knowledge-level model of the information describing and supporting their usage.

The semantic ontology dimension is fundamental in defining SWSs, as it represents both the service capabilities and the restrictions applied to the use of a specific service. The service ontology essentially integrates at the knowledge-level the information that has been defined by web service standards (e.g. UDDI, WSDL, etc.) with related domain knowledge. Three main semantic web service frameworks have been developed (Cabral *et al* 2004)[14]:

1. The *Internet Reasoning Service - IRS-II* (Motta *et al* 2003)[20], a SWS framework that allows applications to semantically describe and execute web services. IRS-II is based on the *UPML (Unified Problem Solving Method Development Language)* framework (Omalyenko *et al* 2003).[21]
2. The *OWL-S* (previously DAML-S) (OWL-S Coalition 2003) framework, which consists of a set of OWL ontologies designed for describing and reasoning over service descriptions.[22] OWL-S allows describing services that can be expressed semantically, and yet grounded within a well-defined data typing formalism. This is achieved utilizing the expressivity of description logics and the practical feasibility found in the emerging web service standards. OWL-S consists of few upper ontologies:

- The *Profile*, which is used to describe services so as to support service discovery (e.g. thesauri, search services etc.). The profile class can be sub-classed and specialized, thus supporting the creation of profile taxonomies capable of describing different classes of services.

- The *Process Model*, which describes the composition (or orchestration) of the flow of control and the execution sequence of one or more services. It is used both for reasoning about possible compositions and controlling the enactment/invocation of a service. Three process classes have been defined:
  - o The *atomic process*, which is a single, black box process description with exposed inputs, outputs, preconditions and effects (IOPEs).
  - o *Simple processes*, which provide a means of describing service or process abstractions.
  - o *Composite processes*, which are hierarchically, defined workflows consisting of atomic, simple and other composite processes.

3. The *Web Service Modeling Framework (WSMF)* [Fensel & Buntler 2002] [23], which provides a model for describing the various aspects related to web services. Its main goal is to fully enable e-commerce by applying Semantic Web technology to web services. WSMF is centred on two complementary principles: (a) a strong de-coupling of the various components that realize an e-commerce application; and (b) a strong mediation service enabling web services to communicate in a scalable manner. Mediation is applied at several levels (i.e. mediation of data structures, mediation of business logics, mediation of message exchange protocols and mediation of dynamic service invocation). WSMF consists of four main elements:

- *Ontologies* that provide the terminology used by other elements.
- *Goal repositories*, where the problems that should be solved by web services are defined.
- *Web Service descriptions* that define various aspects of web services
- *Mediators*, which bypass interoperability problems.
  - o *Domain models*, which describe the domain of an application (e.g. cultural heritage, sports etc.).
  - o *Task models*, which provide a generic description of the task to be solved (e.g. search for resources related to specific concepts), specifying the input (e.g. concepts) and output types (e.g. resources), the goal to be achieved (e.g. location of resources relevant to the concepts specified) and applicable preconditions (e.g. existence of available information sources).
  - o *Problem Solving Methods (PSMs)*, which provide abstract, implementation-independent descriptions of reasoning processes that can be applied to solve tasks in a specific domain.
  - o *Bridges*, which specify mappings between the different model components within an application.

Methods and processes to enhance semantic interoperability

It is important to get an overview of the different methods, processes and techniques in use to enhance semantic interoperability. Standardization and translation approaches need to be covered for all three information levels: data structures, categorical and factual data. The translation approaches are implemented via mapping of source schemata to a global schema. As in database integration techniques, the target schema can be a fixed (employing schema integration and modular approaches) or a constantly adapted schema (requiring continuous mapping, matching and translation).

Activities in Past

Quite a few years back, OntoGov was started EU 6. F.P. STREP project dealing with semantics for life-cyle design of public services, tool development and the creation of a related domain ontology (OntoGov 2004).[24] Activities on a national level included: UK GovTalk and E-GIF which provide interoperability and metadata standards via e.g. a Government Category List, a Government Schemas Working Group and an Interoperability Working Group (GovTalk) [25]; a portal of the Walloon Region applying a semantic web approach for interoperability. Leading terminological efforts for the support of Semantic Interoperability are carried out by Canadian [Canada] and Australian government agencies. Considerable semantic interoperability related efforts are undertaken in the GovStat project for the US Bureau of Labor Statistics (Efron *et al* 2004).[26]

Current developments

1. Service protocols.
2. A platform neutral access protocol, which is not closely linked to specific KOS representation formats.
3. Integrated KOS development tools for distributed usage on the net.
4. Investigate mediation between concept representation in numeric form or in images and in text Research on the specifics of terminology mining.
5. Develop graphical tools; contextualization tools; visualization tools.
6. Interoperability issues when combining terminology efforts with applications such as search engines, Content Management Systems or web publishing software.
7. Investigate the contribution of KOS to knowledge based interactive tools for the Semantic Web.
8. Systematic discussion and common research between relevant communities, e.g. traditional NKOS and Ontology; Semantic Web and Digital Libraries; Library and Information Science, Linguistics, Computer Science, Artificial Intelligence; technical and application/ content standard activities etc.
9. Cooperate with the linguistic and language engineering community.
10. Common developments with the family of ISO TC 37 standards for terminology management, lexicography and computerized terminology.
11. Tools to create, maintain, and deploy data standards.
12. Best practice guidelines how to convert vocabularies into digital services and into a suitable and standardised syntax and exchange format; how to provide term/ concept level metadata.
13. Research the power of query languages developed for XML, RDF, OWL when applied to KOS.
14. Develop semantic registries, vocabulary registries for both human and machine usage.
15. Evaluation and assessment criteria for digital library systems based on achieving semantic interoperability.

Future aspects

The achievement of semantic interoperability is a multi-level issue affecting many functions of information systems. Semantic interoperability is relevant to all aspects of information life-cycle management from creation and integration to archiving and preservation. Any digital library proposing federation, mediation or integration of heterogeneous resources needs to consider issues relating to interoperability, automation and semantic interoperability.

- In addition, these types of systems need to pay careful attention to their user interfaces in order to hide syntax and structural differences in the underlying systems.
- Digital library architectures should make use of standard access and query protocols as far as possible.
- Digital library architectures should cater for interoperation and interaction with

distributed third-party services such as terminology servers rather than building these functions into the system itself.

- Digital library architectures should consider making use of service-oriented architecture (SoA) and semantic web services.

Conclusion

Online technologies facilitate access to resources from anywhere in the world, and make resources available to an international audience. However, this brings with it a need to ensure that interoperability issues are addressed in an international as well as particular country level. Digital libraries have gained acceptance in many scientific and technical disciplines. However, most of these Digital Libraries are implemented in systems and protocols specific to the discipline they support. As such, interoperability between Digital Libraries has yet to be achieved on a large scale.

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