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# Knowledge Discovery in an Agents Environment

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# Overview

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- Ontologies and metadata vocabularies
- A meta-model for metadata vocabularies
- Knowledge repository
- Internal data model
- Architectural components
- Interactive web interface
- Agents interface
- Issues and further work

# Motivation

- **Proliferation** of metadata schemas (developed in closed environments, tower of Babel situation for applications)
- **Disclosure** –adaptations by practitioners and communities of practice not readily and openly available
- **Investigation** of individual terms as well as whole vocabularies for adaptations, local usages and relationships with other vocabularies
- **Interoperability**
  - **Harmonisation** of semantics and usage
  - **Convergence** within specific domains e.g. education, cultural heritage, publishing, rights management etc.
- **Reasoning and inference** -automated querying of metadata vocabularies by software agents to acquire the semantics associated with specific terms

# *Background work at UKOLN*

UKOLN has been involved in several projects in the area of metadata vocabulary repositories or knowledge bases (mainly from the perspective of digital libraries):

**DESIRE II** (1998-2000) –interactive browsing by users

<http://www.ukoln.ac.uk/metadata/desire/>

**SCHEMAS** (2000-2002) –machine processible format

<http://www.ukoln.ac.uk/metadata/schemas/>

**CORES** (2002-2003) –annotation service

<http://www.ukoln.ac.uk/metadata/cores/>

**Agentcities.NET** (2002-2003)-deployment in an agents environment

<http://www.ukoln.ac.uk/metadata/agentcities/>

**DCMI Registry** (on-going) –management of DC vocabulary

<http://dublincore.org/dcregistry/index.html>

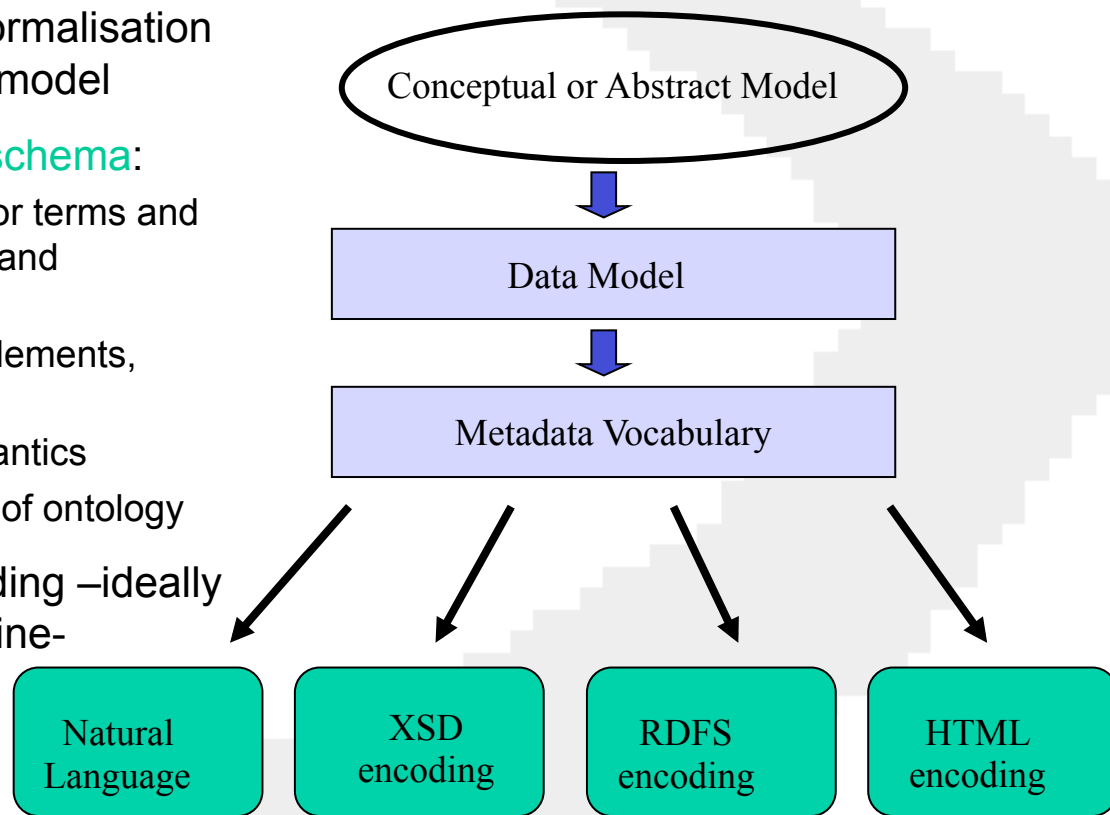
**MEG Registry** (on-going) –UK Education domain

<http://www.ukoln.ac.uk/metadata/education/regproj/>



# Ontologies and metadata vocabularies

- Parallel developments in the computer science and digital library worlds
- Conceptual model identifies domain of discourse (knowledge level)
- Data model is a concrete formalisation of a view onto the abstract model
- A metadata **vocabulary** or **schema**:
  - declares a set of concepts or terms and their associated definitions and relationships
  - terms are often known as elements, attributes and qualifiers
  - definitions provide the semantics
  - in effect a light-weight form of ontology
- Implementation is an encoding –ideally human-readable and machine-processible



# *Types of vocabularies*

Vocabularies range from international standards to implementation specific schemas

- Single element sets
- Combinations of vocabularies
- Cross-domain (Dublin Core)
- Specific domains (IEEE LOM/IMS, OAIS, CIDOC CRM, MPEG, INDECS)
- Particular applications or implementations (Open Archives (OAI-PMH), Government Information Locator Service (GILS), MathNet)

# *A meta-model for metadata vocabularies*

- Becoming widely adopted in the DL world
- Encourages **modular** organisation of knowledge
- Distinguishes **where** and **how** terms are defined as opposed to how they are **used** and **adapted** in practice

## **Element sets: declare a unique set of elements and definitions**

- Provides semantic knowledge for reuse
- Ideally, addressed on the Web with a URI
- May be expressed in XSD, RDFS etc.

## **Application profiles: declare which terms are used by a particular application or project**

- may mix-and-match terms from multiple element sets (not other application profiles)
- may specify dependencies e.g. mandate schemes
- may adapt existing definitions for local purposes
- may declare rules for content (usage guidelines)
- may specify whether an term is mandatory, optional or repeatable





# *A knowledge base of vocabularies and ontology server*

- Enables individual terms as well as whole vocabularies to be explored
- Data mining –analysis of patterns of metadata usage
- Potential creation and inference of new information
- Essential for support of ontological engineering process
- An ontology server
  - Agentcities.NET project
  - Deployment grant: Sept 2002-Feb 2003
  - Technical Report: An Ontology Server for Agentcities.NET  
<http://www.agentcities.org/note/00008>

# Repository contents

- Metadata vocabularies or ontologies
- Contextual information relating to vocabularies
- Notion of *Element Sets* and *Application Profiles* as basis for vocabulary encodings
- Specification language currently used is RDF Schemas
- Classes or entities recorded (based on findings in SCHEMAS):
  - Agency
  - Element Set
  - Application Profile
  - Element
  - Element Usage
  - Encoding Scheme
  - Values in controlled vocabularies

# Internal data model

- A model for describing the structure of metadata vocabularies
- A normalisation model which lies above the RDFS layer
- A means for integrating multiple vocabularies into a common knowledge base:
  - **Element Sets** are owned and maintained by **Agencies**
  - **Element Sets** are made up of **Elements**
  - An **Element** is a term defined in order to describe a characteristic or attribute of a resource
  - An **Element Usage** may:
    - **introduce constraints on the value** of an Element by associating it with one or more **Encoding Schemes**
    - **introduce constraints on the obligation** to use an Element (e.g. make its use mandatory) or the occurrence of an Element (e.g. whether it is repeatable)
      - **refine the semantic definition** of an Element to make it narrower or more specific to the local application domain
  - **Encoding Schemes** constrain the value space of **Elements**
  - An **Application Profile** defines a set of **Element Usages** of **Elements** drawn from one or more **Element Sets**



# Information recorded

The repository holds information on each of the following entities and their relationships:

- **Element Sets**: intended scope; area of use; relationship to other Element Sets
- Elements: semantic definitions; recommended usage; relationship to other Elements
- **Application Profiles**: intended scope; area of use; relationship to other Element Sets
- **Usages of Elements**: the Element used; any prescription of Encoding Schemes; other constraints on element use
- **Encoding Schemes**: intended scope; area of use; where an Encoding Scheme takes the form of an enumerated list, the **values** prescribed by that Encoding Scheme may be recorded
- **Agencies**: who owns, creates, maintains Element Sets, Application Profiles and Encoding Schemes

# Architecture

- Centralised

e.g. ISO/IEC 11179 based registries (Environmental Protection Agency, Australian Health Information Knowledgebase), DESIRE Registry, Dublin Core Metadata Initiative(DCMI)

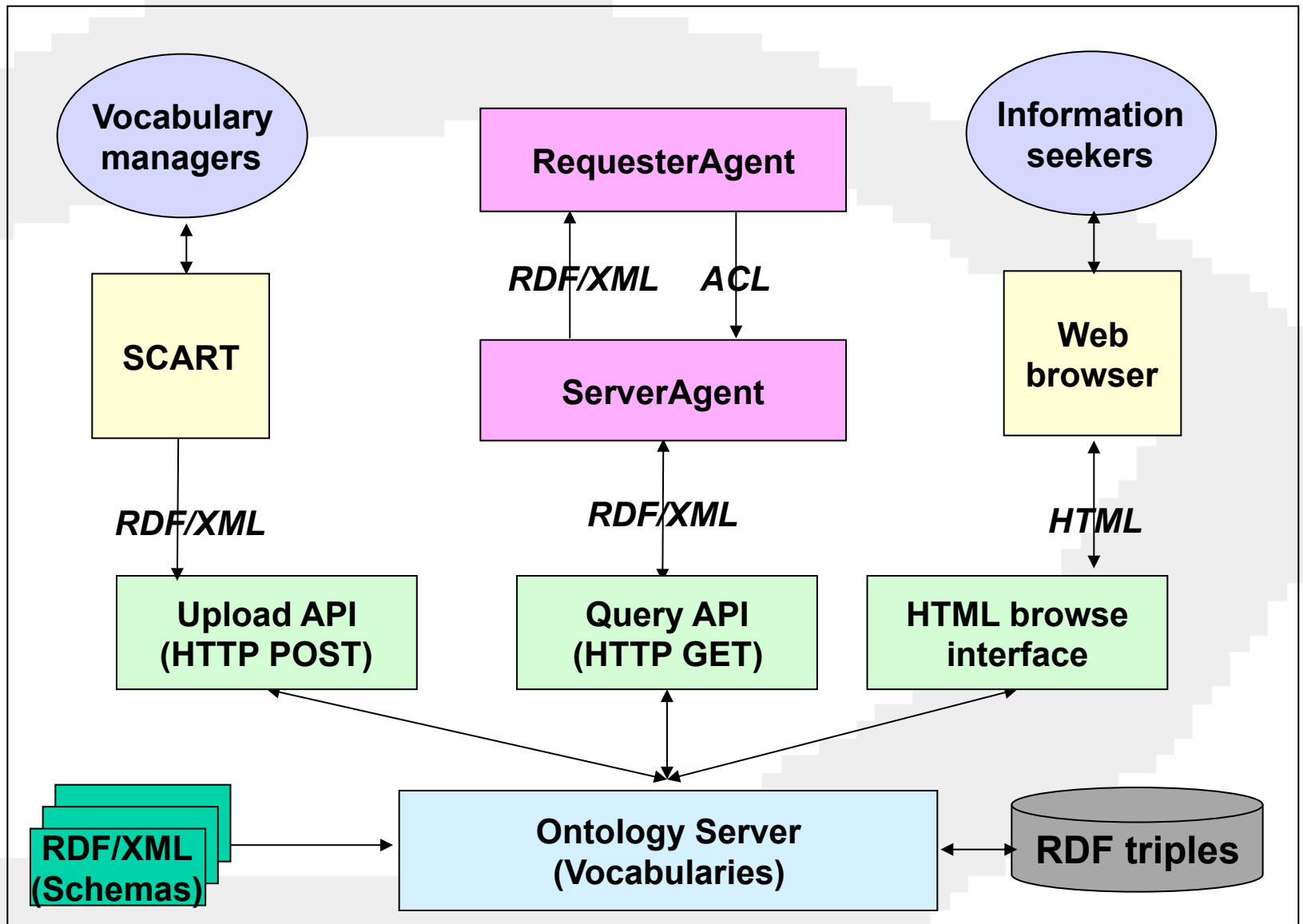
- management of single vocabularies
- multiple language translations
- support standardisation processes

- Decentralised

e.g. SCHEMAS, MEG and CORES

- multiple vocabularies
- content and maintenance of vocabularies is decentralised
- evolution of vocabularies is devolved to those committed to their development
- based on a harvesting model

# Architectural components



# *Interactive interface*

- Support for ontological engineering (discovery, disclosure, reuse, harmonisation)
- Disclosure or publication environment for vocabularies
- Enable queries across a range of vocabularies
- Clarify relationships between vocabularies
- Encourage sharing of existing vocabularies to help avoid duplication of effort
- Encourage convergence and harmonisation within single domains
- Promotion of standards to improve potential for cross-domain interoperability
- Web-interface:

<http://agentcities.ukoln.ac.uk/server/>



# Web interface: Entry point

An ontology server for the Agencies.NET project - Microsoft Internet Explorer




File Edit View Favorites Tools Help

Back Forward Stop Refresh Home Search Favorites History Mail Size Print Edit Messenger

Address <http://solo.ukoln.ac.uk/agents/registry/> Go Links >>

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**An ontology server for the Agentcities.NET project**

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**Index**

**Agencies:** [Browse](#) - [Search](#)

**Element Sets:** [Browse](#) - [Search](#)

**Elements:** [Browse](#) - [Search](#)

**Encoding Schemes:** [Browse](#) - [Search](#)

**Application Profiles:** [Browse](#) - [Search](#)

**Element Usages:** [Browse](#) - [Search](#)

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# Web interface: Element sets

An ontology server for the Agentcities.NET project - Element Sets - Microsoft Internet Explorer




File Edit View Favorites Tools Help

Back Forward Stop Refresh Home Search Favorites History Mail Size Print Edit Messenger

Address <http://solo.ukoln.ac.uk/agents/registry/?class=http%3A%2F%2Fwww.ukoln.ac.uk%2Fmetadata%2Feducation%2Fregproj%2Freg%2FElementSet> Go Links >>

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**An ontology server for the Agentcities.NET project**



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**Element Sets**

Name	Version	Agency	
National Curriculum Metadata Element Set, 2.07	2.07	<a href="#">QCA</a>	<a href="#">Detail</a>
RDN Terms		<a href="#">Resource Discovery Network</a>	<a href="#">Detail</a>
The Dublin Core Element Set v1.1	1.1	<a href="#">The Dublin Core Metadata Initiative</a>	<a href="#">Detail</a>
The Dublin Core Terms Element Set		<a href="#">The Dublin Core Metadata Initiative</a>	<a href="#">Detail</a>
The MEG Registry Vocabulary v1.0	1.0	<a href="#">Metadata for Education Group</a>	<a href="#">Detail</a>

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# Web interface: DC audience term

**An ontology server for the Agentcities.NET project**

agentcities ILRT UKOLN

**Element: <http://purl.org/dc/terms/audience>**

<b>ID</b>	<a href="http://purl.org/dc/terms/audience">http://purl.org/dc/terms/audience</a>
<b>Name</b>	Audience
<b>Definition</b>	A class of entity for whom the resource is intended or useful.
<b>Comment</b>	A class of entity may be determined by the creator or the publisher or by a third party.
<b>Data type</b>	
<b>Obligation</b>	
<b>Maximum Occurrence</b>	
<b>Associated Encoding Scheme</b>	
<b>Refines</b>	
<b>Element Set</b>	<a href="#">The Dublin Core Terms Element Set</a> <a href="#">Element Set</a>

**Element Usages**

Name	Application Profile
<a href="#">Audience</a>	<a href="#">The Unqualified Dublin Core Application Profile</a> <a href="#">Detail</a>
<a href="#">Audience</a>	<a href="#">The Qualified Dublin Core Application Profile</a> <a href="#">Detail</a>

# Agents interface

- Agents interface allows software agents to query, search and navigate metadata vocabularies
  - Enables retrieval of semantics
  - Provides potential for inference and reasoning tasks
- Essential infrastructure for the composition and coordination of automated services over the Web
- Java Agent Development Environment (JADE)
  - Based on FIPA standards for intelligent software agents
  - Communication via an ontology
  - Requests in Agent Communication Language (ACL)
  - Results returned in INFORM slot of return message
- Two examples of *RequesterAgents*
  - GUI
  - Command line

# Agents interface: GUI

The class that you want to Browse or Search

encodingscheme ▼

Show all the resources in this class

Show a specific resource in this class

Resource URI:  Show

Search this class for:

Search Term:  Search

```
<?xml version="1.0" encoding='iso-8859-1'?>
<!DOCTYPE rdf:RDF [
  <ENTITY rdfns 'http://www.w3.org/1999/02/22-rdf-syntax-ns#'>
  <ENTITY rdfsns 'http://www.w3.org/2000/01/rdf-schema#'>
  <ENTITY dcns 'http://purl.org/dc/elements/1.1/'>
  <ENTITY dctermsns 'http://purl.org/dc/terms/'>
  <ENTITY regns 'http://www.ukoln.ac.uk/metadata/education/regproj/reg/'>
]>
<rdf:RDF xml:lang="en"
  xmlns:rdf="&rdfns;"
  xmlns:rdfs="&rdfsns;"
  xmlns:dc="&dcns;"
  xmlns:dcterms="&dctermsns;"
  xmlns:reg="&regns;">
  <rdf:Description rdf:about="http://purl.org/dc/terms/MESH">
    <rdf:type rdf:resource="http://www.w3.org/2000/01/rdf-schema#Class"/>
    <rdfs:label>MeSH</rdfs:label>
    <rdfs:comment>Medical Subject Headings</rdfs:comment>
    <reg:responsibleAgency rdf:resource="http://www.ukoln.ac.uk/metadata/education/regproj/reg/agency/nlm"/>
  </rdf:Description>
</rdf:RDF>
```

Clear



# Example: agent query and result

## Example search for term “audience”:

```
(action
  (agent-identifier :name UKOLNServer@agentcities.ukoln.ac.uk:1099/JADE)
  (ReturnSearchResults (Search :Scope element :SearchTerm audience))
)
```

## Example result in RDF:

```
<rdf:Description rdf:about="http://purl.org/dc/terms/audience">
  <rdf:type rdf:resource="http://www.w3.org/1999/02/22-rdf-syntax-
ns#Property"/>
  <rdfs:label>Audience</rdfs:label>
  <rdfs:comment>A class of entity for whom the resource is intended or
    useful.
</rdfs:comment>
  <reg:useComment>A class of entity may be determined by the creator
    or the publisher or by a third party.
</reg:useComment>
  <reg:isElementOf rdf:resource="http://www.ukoln.ac.uk/metadata/
education/regproj/reg/elementSet/dcterms"/>
</rdf:Description>
```



# *Issues and further work*

- Version tracking: metadata vocabularies evolve over time:
  - Semantics change
  - New terms need to be added or deleted
  - Agency information binds versions together
- Vocabulary Data Models
  - data model implicit in a schema encoding
  - differing data models are a challenge to reconcile!
- Annotation is important for trust, authority, provenance
- Rights management is important for sharing and reuse
- Investigation of interaction with external FIPA agents
- Semantic search and inference of new information

# Conclusions

- Contents of repository are simple forms of ontology as well as contextual information
- Vocabularies need to adhere to meta-model described and use RDFS for encoding
- Need for a service which enables discovery and disclosure of semantics used in applications
- Provides information regarding how terms are defined, how standards are used in practice and how terms and vocabularies are related to each other
- Essential part of infrastructure required to enable exchange and reuse of semantic information
- Support for ontology engineering –semantic interoperability requires domain-level consensus on the structure, concepts and terminology to be used in knowledge representation

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DESIRE Project

SCHEMAS Project

MEG Registry Project

Agentcities.NET Project

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