



Ontologies:

Technologies for domain modeling, knowledge re-purposing and knowledge sharing

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Contents

- ❑ Complexity
- ❑ Computational thinking
- ❑ Knowledge Representation
- ❑ Ontologies
- ❑ Linked Open Data
- ❑ Application: Research Data Management



The century of complexity

I think the next [21st] century will be the century of complexity. We have already discovered the basic laws that govern matter and understand all the normal situations. We don't know how the laws fit together, and what happens under extreme conditions. But I expect we will find a complete unified theory sometime this century. There is no limit to the complexity that we can build using those basic laws.

Stephen W. Hawking, interview in San Jose Mercury News 23 Jan 2000

[Answer to question: Some say that while the twentieth century was the century of physics, we are now entering the century of biology. What do you think of this?]

Complexity and computers

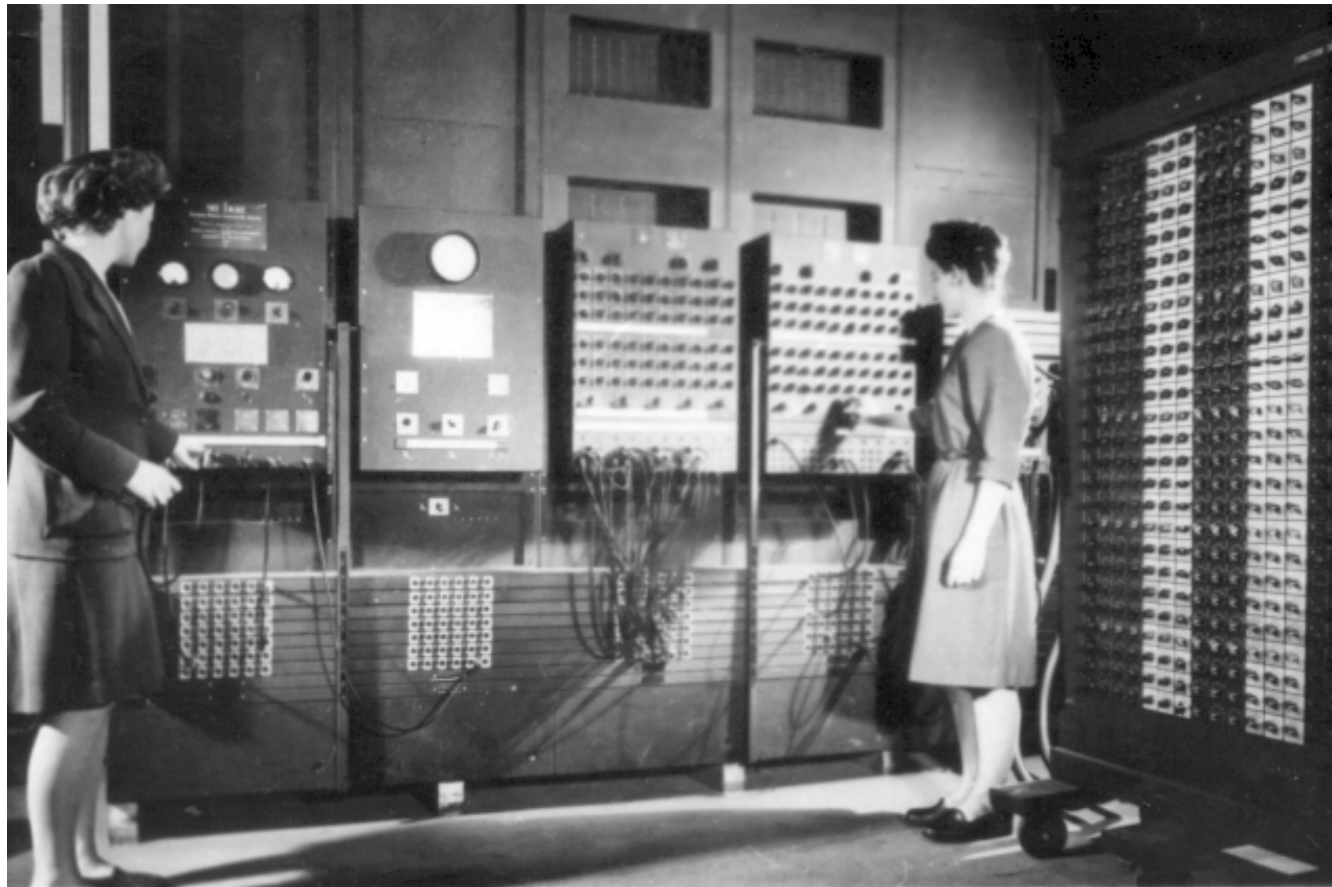


Human Computers

NACA High
Speed Flight
Station
"Computer
Room" (1949)

Source:
Wikimedia
Commons

Complexity and computers



Jean Jennings
Bartik (left) and
Frances Bilas
Spence (right)
preparing for
the public
unveiling of
ENIAC,
February 1946.

U. S. Army Photo



Computational Thinking

- Computational thinking changes other fields
 - Machine Learning to Statistics
 - Computational Biology to Biology
 - Computational Game Theory to Economics
 - Nanocomputing to Chemistry
 - Quantum Computing to Physics
- Computation changes the way scientists **think**

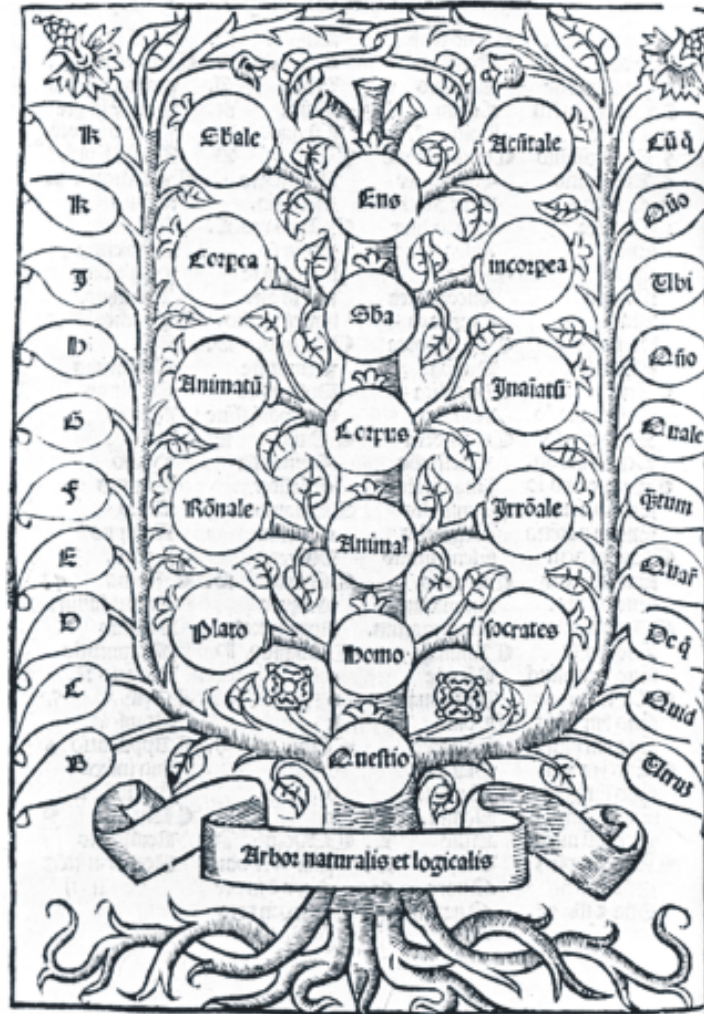


Computational Thinking

- *Computational thinking involves solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science.*
- *Thinking like a computer scientist means more than being able to program a computer. It requires thinking at multiple levels of abstraction.*

Jeannette M. Wing. 2006. Computational thinking.
Commun. ACM 49, 3 (March 200 6), 33-35.

Knowledge Representation



- Introduced in Artificial Intelligence
- Underlies any automatic information processing task



Knowledge Representation

Knowledge representation is a multidisciplinary subject that applies theories and techniques from three other fields:

- ☐ *Logic provides the formal structure and rules of inference.*
- ☐ *Ontology defines the kinds of things that exist in the application domain.*
- ☐ *Computation supports the applications that distinguish knowledge representation from pure philosophy.*

John F. Sowa, *Knowledge Representation: Logical, Philosophical, and Computational Foundations*, Brooks Cole Publishing Co., Pacific Grove, CA, 2000



Semantic Web: the Web of data

The ultimate goal of the Web of data is to enable computers to do more useful work and to develop systems that can support trusted interactions over the network. The term “Semantic Web” refers to W3C’s vision of the Web of linked data. Semantic Web technologies enable people to create data stores on the Web, build vocabularies, and write rules for handling data. Linked data are empowered by technologies such as RDF, SPARQL, OWL, and SKOS.

<http://www.w3.org/standards/semanticweb/>



Semantic Web: the Web of data

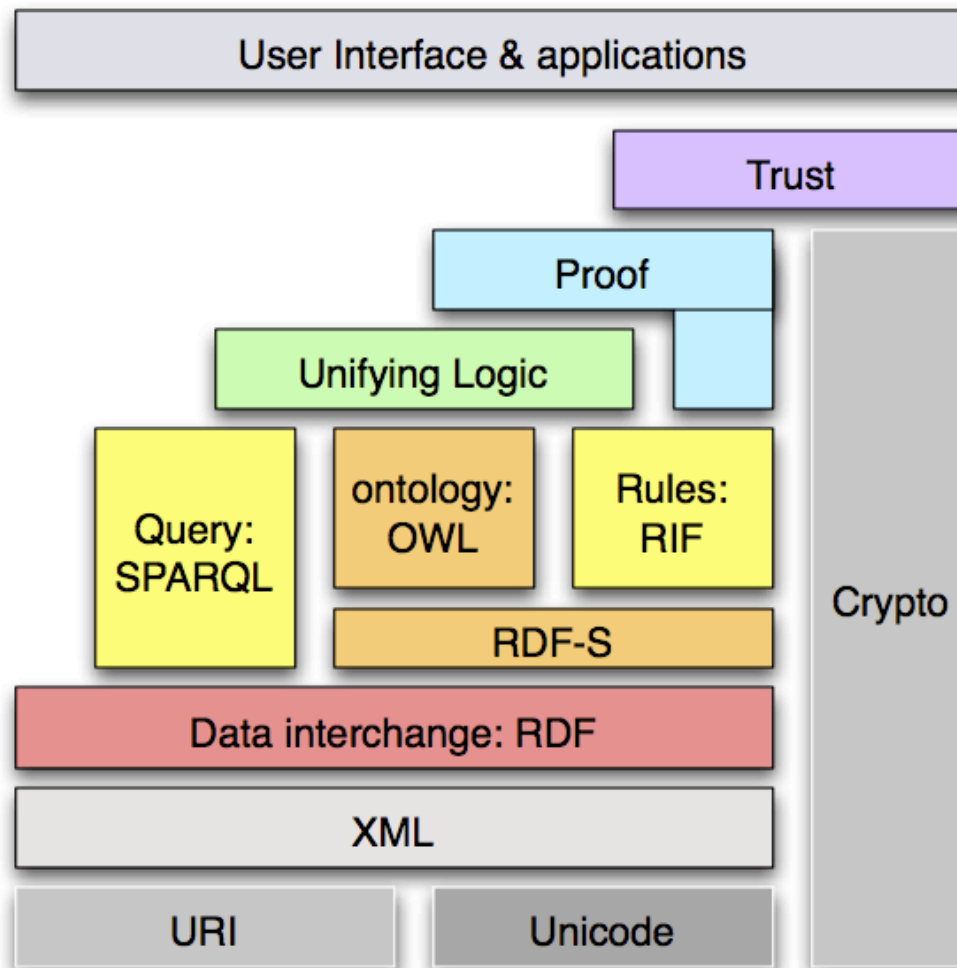
The Semantic Web is not a separate Web but an extension of the current one, in which information is given well-defined meaning, better enabling computers and people to work in cooperation.

Tim Berners-Lee, James Hendler and Ora Lassila. The Semantic Web. Scientific American May 2001.

...A set of formats and languages that find and analyze data on the World Wide Web, allowing consumers and businesses to understand all kinds of useful online information.

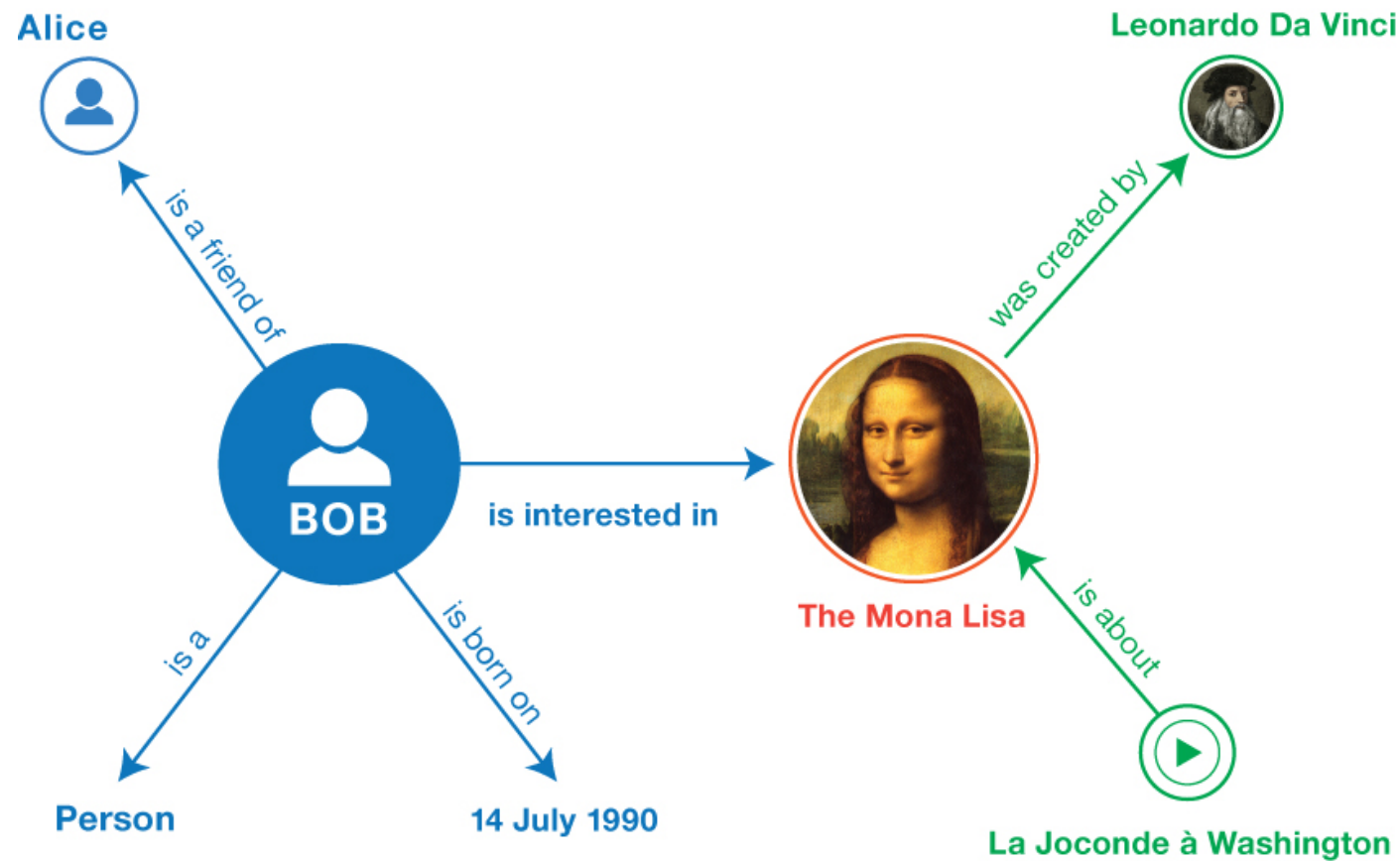
Lee Feigenbaum, Ivan Herman, Tonya Hongsermeier, Eric Neumann and Susie Stephens. The Semantic Web in Action. Scientific American 2007

The Semantic Web technology stack



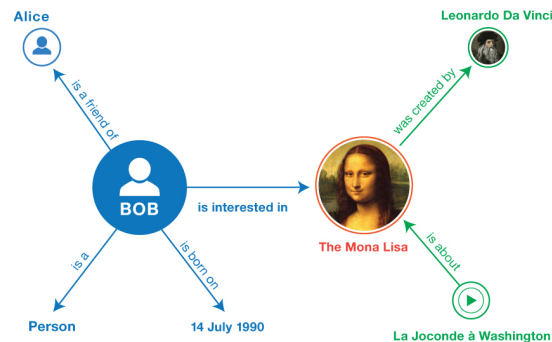
[http://www.w3.org/2006/Talks/1023-sb-W3CTechSemWeb/#\(19\)](http://www.w3.org/2006/Talks/1023-sb-W3CTechSemWeb/#(19))

Resource Description Framework—RDF



<http://www.w3.org/TR/2014/NOTE-rdf11-primer-20140225/>

Resource Description Framework—RDF



<Bob> <is a> <person>.

<Bob> <is a friend of> <Alice>.

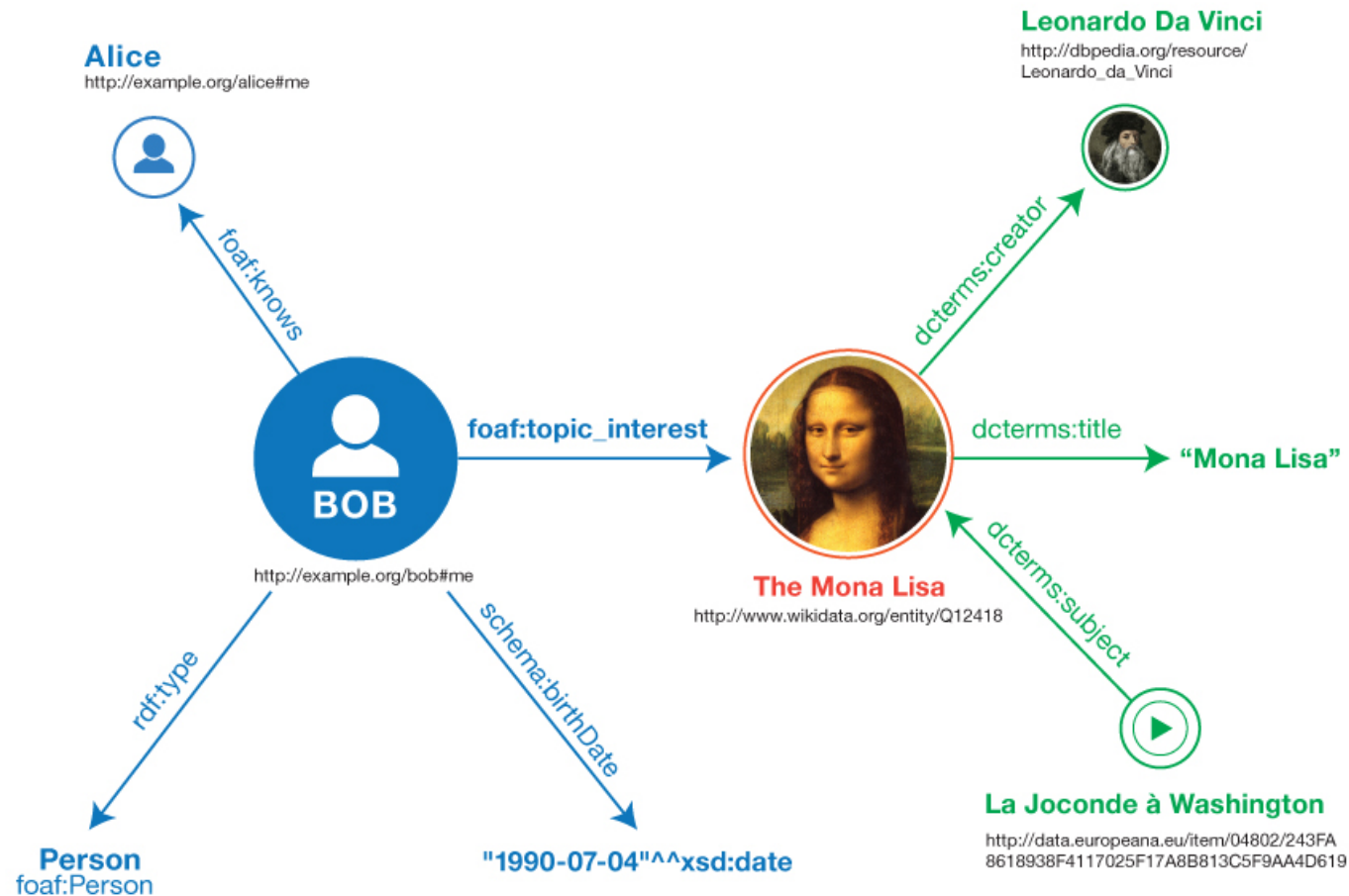
<Bob> <is born on> <the 4th of July 1990>.

<Bob> <is interested in> <the Mona Lisa>.

<the Mona Lisa> <was created by> <Leonardo da Vinci>.

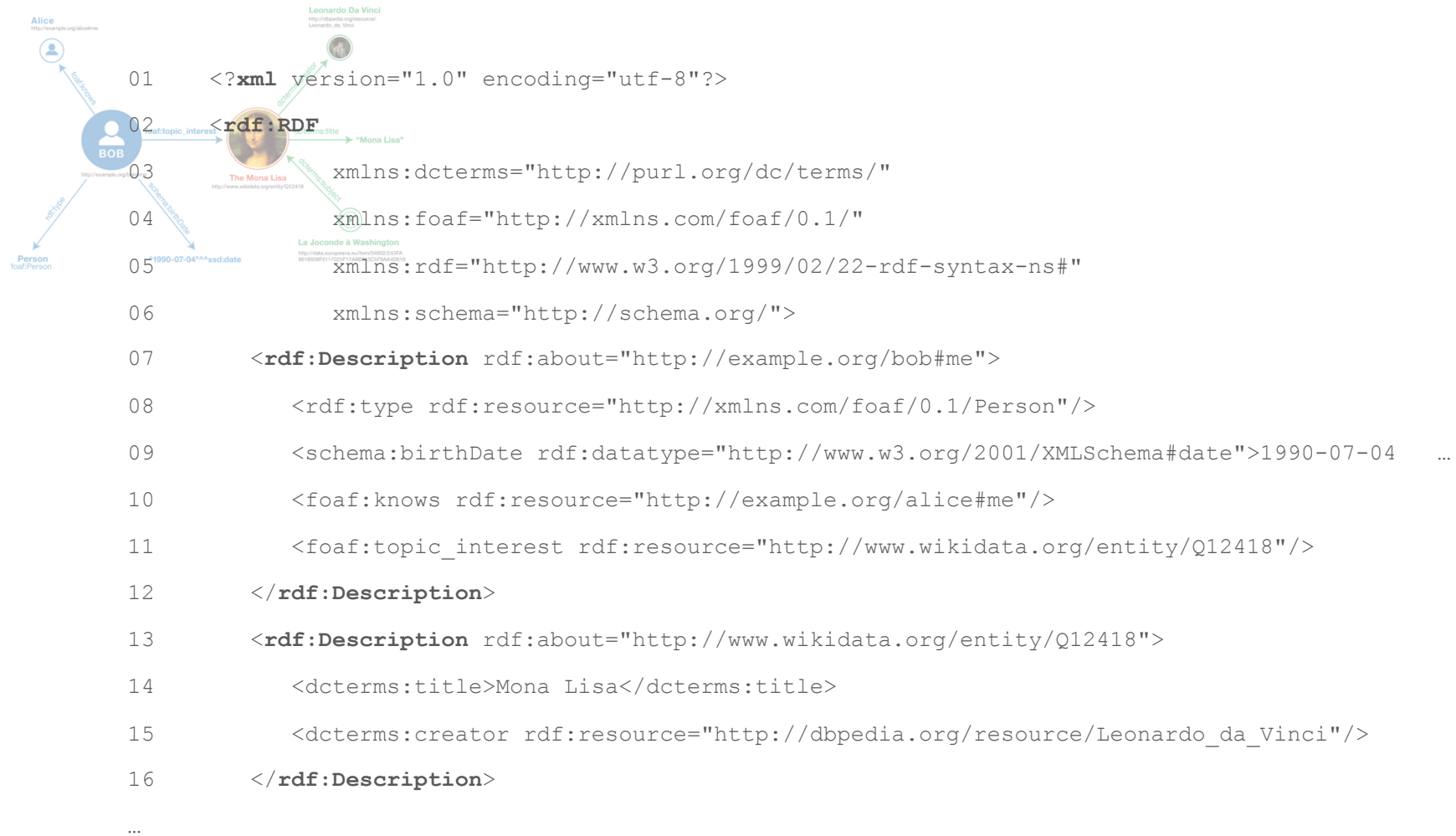
<the video 'La Joconde à Washington'> <is about> <the Mona Lisa>

Resource Description Framework—RDF



<http://www.w3.org/TR/2014/NOTE-rdf11-primer-20140225/#fig4>

RDF in XML



OWL: Classes

The screenshot displays the Protege OWL editor interface. The top toolbar includes buttons for navigation and editing. The main window is divided into several panes:

- Class hierarchy:** A tree view on the left showing the hierarchy of classes. The root is **Thing**, which includes **Accommodation**, **AccommodationRating**, **Activity**, **Contact**, and **Destination**. **Destination** is expanded, showing subclasses: **BackpackersDestination**, **Beach**, **BudgetHotelDestination**, **FamilyDestination** (highlighted), **QuietDestination**, **RetireeDestination**, **RuralArea**, and **UrbanArea**.
- Annotations:** A pane on the right showing the annotations for the selected class, **FamilyDestination**. It includes a **comment** [type: string] with the text: "A destination with at least one accommodation and at least 2 activities."
- Description:** A pane on the right showing the description of the selected class, **FamilyDestination**. It includes an **Equivalent To** section with the expression: **Destination** and (hasAccommodation min 1 Thing) and (hasActivity min 2 Thing).

OWL: Object Properties

The screenshot shows the Protege OWL editor interface. The browser window title is 'tra (http://www.owl-ontologies.com/travel.owl) : [/Users/mcr/Google Drive/_data/inv]'. The address bar shows 'tra (http://www.owl-ontologies.com/travel.owl)'. The top navigation bar includes tabs for 'Annotation Properties', 'Individuals by class', 'OWLViz', 'DL Query', and 'OntoGraf'. Below this, a secondary bar shows 'Active Ontology', 'Entities', 'Classes', and 'Object Properties'. The main panel is titled 'Object property hierarchy: isOfferedAt' and displays a tree structure of object properties. The tree starts with 'topObjectProperty' and lists several properties: 'hasAccommodation', 'hasActivity', 'hasContact', 'hasPart', 'hasRating', and 'isOfferedAt'. The 'isOfferedAt' property is selected. To the right of the tree, there is a 'Usage' tab. Under 'Usage: isOfferedAt', there are checkboxes for 'this' and 'disjoints', both of which are checked. Below these, it says 'Found 5 uses of isOfferedAt'. The usage list shows two main categories: 'hasActivity' and 'isOfferedAt'. Under 'hasActivity', there is one use: 'hasActivity InverseOf isOfferedAt'. Under 'isOfferedAt', there are four uses: 'isOfferedAt Domain Activity', 'ObjectProperty: isOfferedAt', 'isOfferedAt Range Destination', and 'hasActivity InverseOf isOfferedAt'.

tra (http://www.owl-ontologies.com/travel.owl) : [/Users/mcr/Google Drive/_data/inv]

tra (http://www.owl-ontologies.com/travel.owl)

Annotation Properties x Individuals by class x OWLViz x DL Query x OntoGraf

Active Ontology x Entities x Classes x Object Properties

Object property hierarchy: isOfferedAt

- topObjectProperty
 - hasAccommodation
 - hasActivity
 - hasContact
 - hasPart
 - hasRating
 - isOfferedAt

Annotations Usage

Usage: isOfferedAt

Show: ☒ this ☒ disjoints

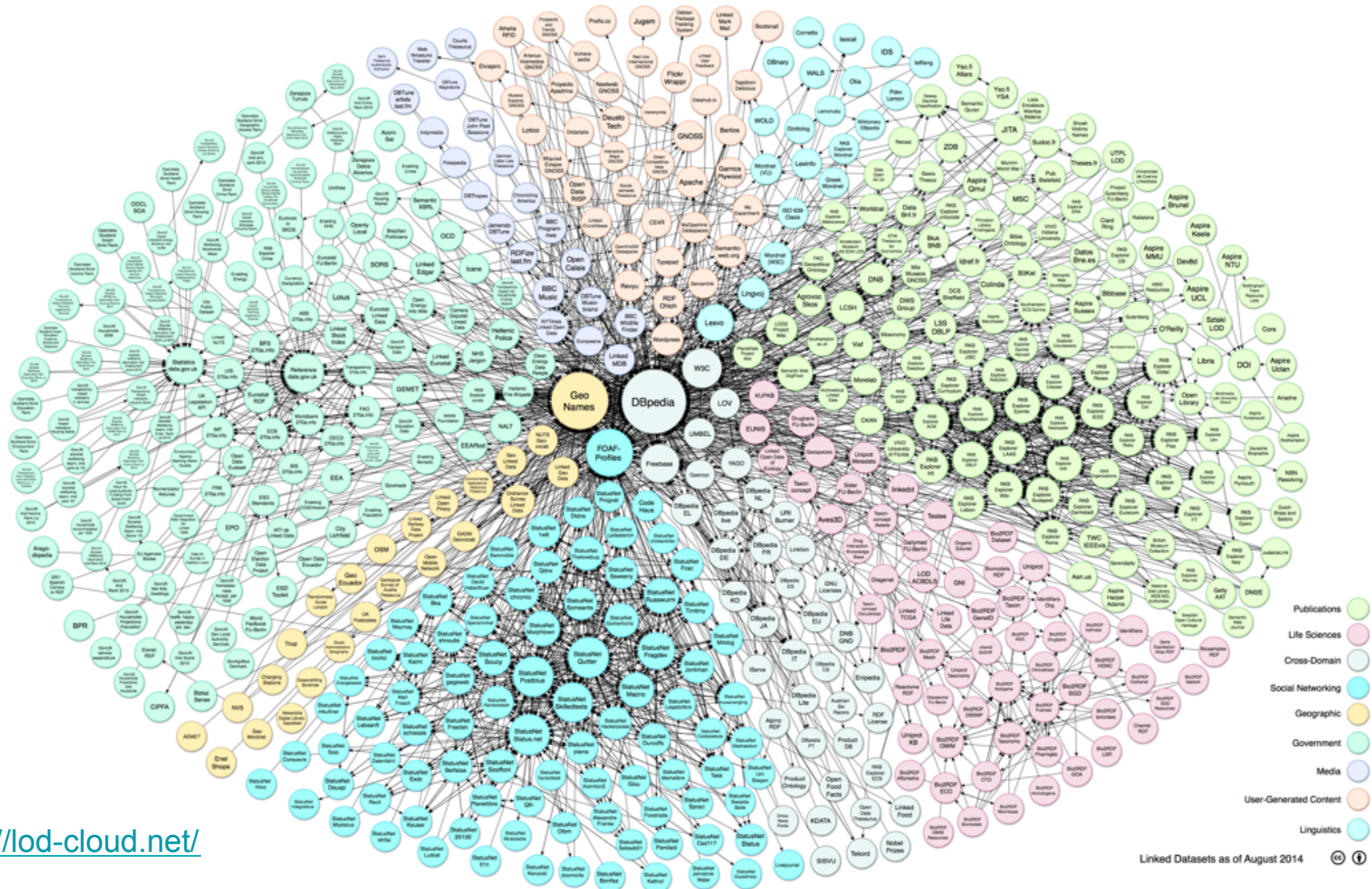
Found 5 uses of isOfferedAt

- hasActivity
 - hasActivity InverseOf isOfferedAt
- isOfferedAt
 - isOfferedAt Domain Activity
 - ObjectProperty: isOfferedAt
 - isOfferedAt Range Destination
 - hasActivity InverseOf isOfferedAt

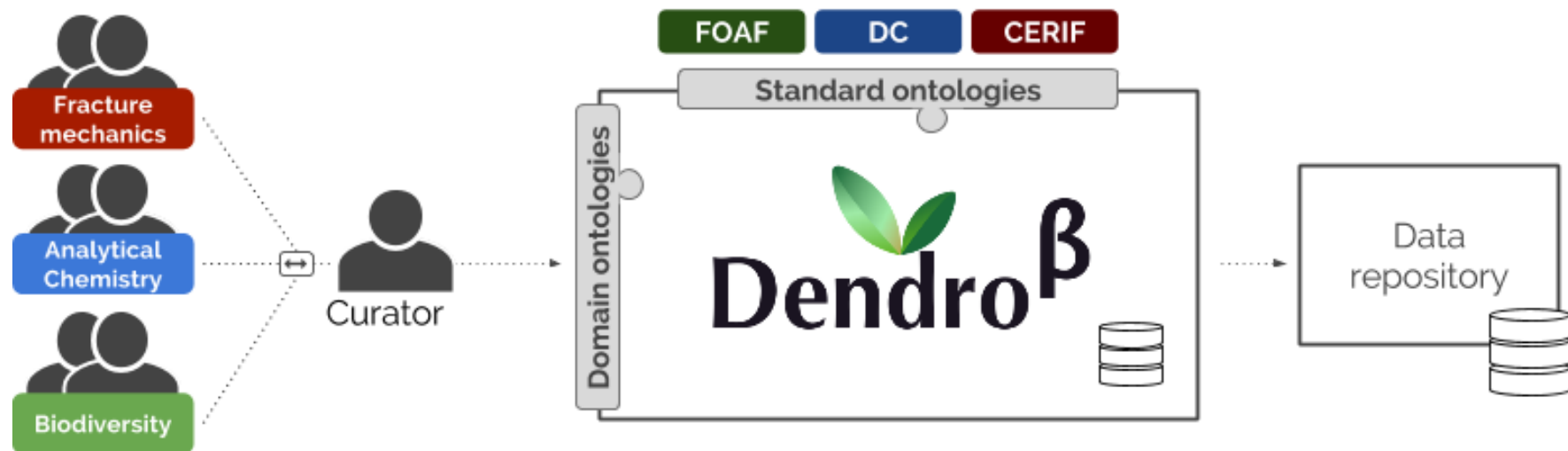
OWL: DataProperties

The screenshot shows the Protege OWL editor interface. The browser window title is 'tra (http://www.owl-ontologies.com/travel.owl) : [/Users/mcr/Goc...'. The address bar shows 'tra (http://www.owl-ontologies.com/travel.owl)'. The top navigation bar includes tabs for 'Annotation Properties', 'Individuals by class', 'OWLViz', 'DL Query', 'Active Ontology', 'Entities', 'Classes', and 'C...'. The main panel is titled 'Data property hierarchy: hasZipCode' and shows a tree structure under 'topDataProperty' with properties: 'hasCity', 'hasEmail', 'hasStreet', and 'hasZipCode'. The 'hasZipCode' property is selected. The right panel shows the 'Usage' tab for 'hasZipCode'. It includes a 'Show:' section with checkboxes for 'this' and 'disjoints', both of which are checked. Below this, it states 'Found 4 uses of hasZipCc'. A tree view shows the following uses: 'hasZipCode Domain: Contact', 'DataProperty: hasZipCode', 'Functional: hasZipCode', and 'hasZipCode Range: int'. At the bottom, the 'Characteristics: hasZipCode' tab is active, showing a checked 'Functional' checkbox and a 'Description' section with 'Equiva' and 'SubPr' visible.

Linked Open Data

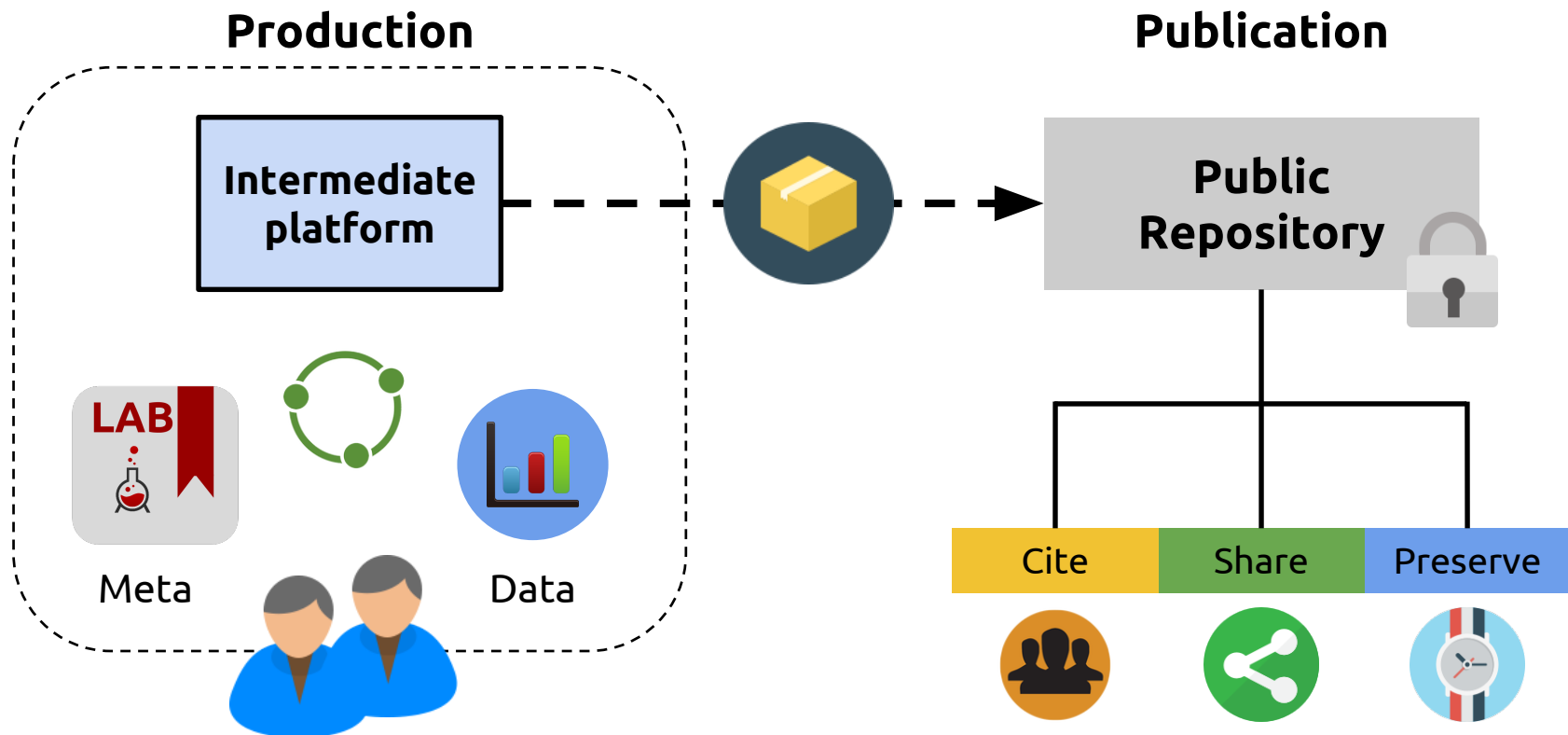


Application: Research Data Management

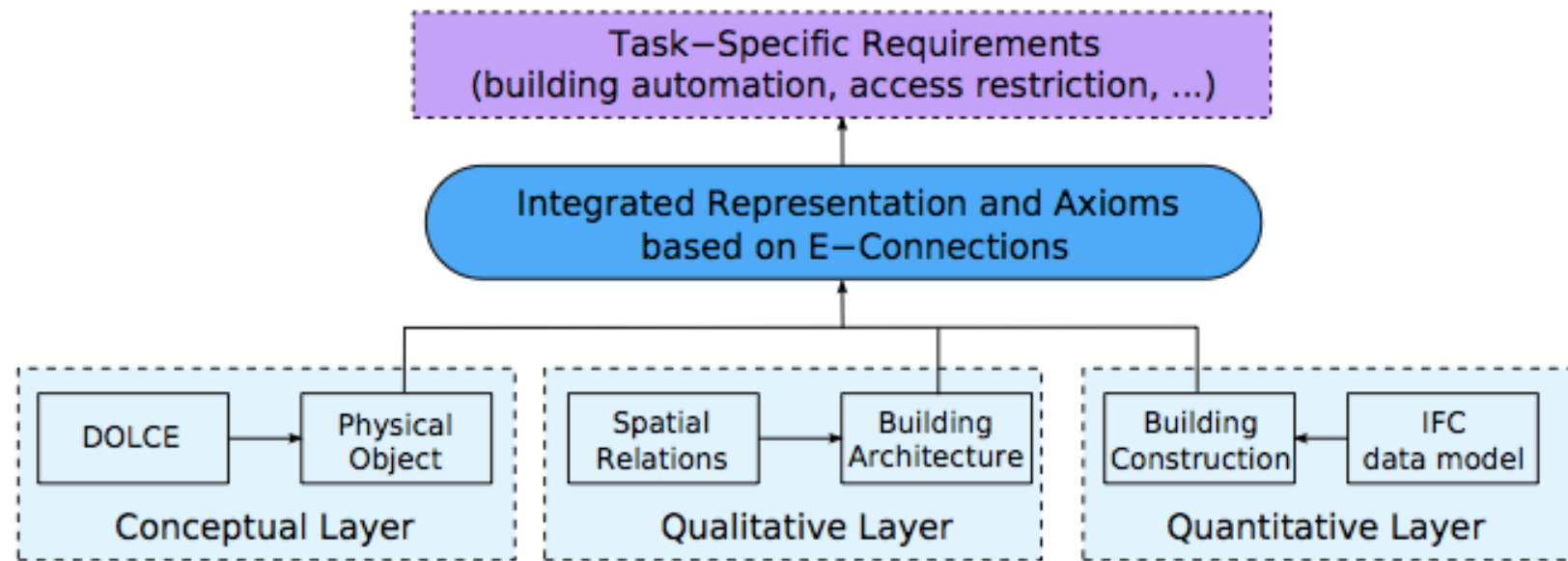


- Reuse existing knowledge: generic ontologies (ex: Dublin Core)
- Add your own: specific ontologies to capture the domain

Repositories and preservation



Ontologies for Architecture



Source: J. Hois, M. Bhatt, O. Kutz. Modular Ontologies for Architectural Design. In Formal Ontologies Meet Industry, 2009



Open World vs Closed World Assumption

- Closed: if it is true, it is known
- Closed: if you cannot prove it, it is false
- Open: it may be true but not known
- Deal with incomplete knowledge

Unique name assumption: associated with CWA



Sources

❑ Computational Thinking

- ❑ Jeannette M. Wing. 2006. Computational thinking. *Commun. ACM* 49, 3 (March 2006), 33-35.
DOI=<http://dx.doi.org/10.1145/1118178.1118215>

❑ Knowledge Representation

- ❑ John F. Sowa, *Knowledge Representation: Logical, Philosophical, and Computational Foundations*, Brooks Cole Publishing Co., Pacific Grove, CA, 2000

❑ Semantic Web

- ❑ <http://www.w3.org/standards/semanticweb/>

❑ Linked Open Data

- ❑ <http://linkeddata.org/>



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