Data Modeling 101

Getting Started with Data Modeling in GLAM

bit.ly/C4LDataModeling101

Your Fearless Facilitators

Hector Correa

Software developer, Brown University Library, @hectorjcorrea

Christina Harlow

Works with metadata somewhere in the world, @cm_harlow

Mark Matienzo

Collaboration & Interoperability Architect, Stanford @anarchivist

Steve Van Tuyl

Digital Repository Librarian at Oregon State, @badgerbouse

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Link to Slides, Notes, Examples, Resources,
and Other Workshop Materials

Communication Channels

- Alert a facilitator if you need help or have questions
- Feedback sticky notes:
  - Red sticky note = have question or need help
  - Sticky note feedback before break
- Code4Lib Slack: **#c4l17-datamodeling** channel
- Information about Code4Lib Slack: **http://goo.gl/forms/p9Ayz93DgG**

Schedule

9:00-9:15	Introduction (Mark Matienzo)
9:15-9:45	Introduction to Data Modeling (Hector Correa)
9:45-10:15	Data Modeling in RDF (Christina Harlow)
10:15-10:30	*Break*
10:30-11:00	Models in context (Steve Van Tuyl/Christina Harlow)
11:00-11:15	Full group: setup for breakout groups
11:15-11:45	Breakout groups: Data Modeling Examples
11:45-12:00	Full group: recap from breakouts and follow-up

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Our Expectations of You

- Follow the Code4Lib Code of Conduct
- Follow the Recurse Center Social Rules (a.k.a. "Hacker School Rules")
- Be ready to learn about data modeling!

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Code4Lib
Code of Conduct

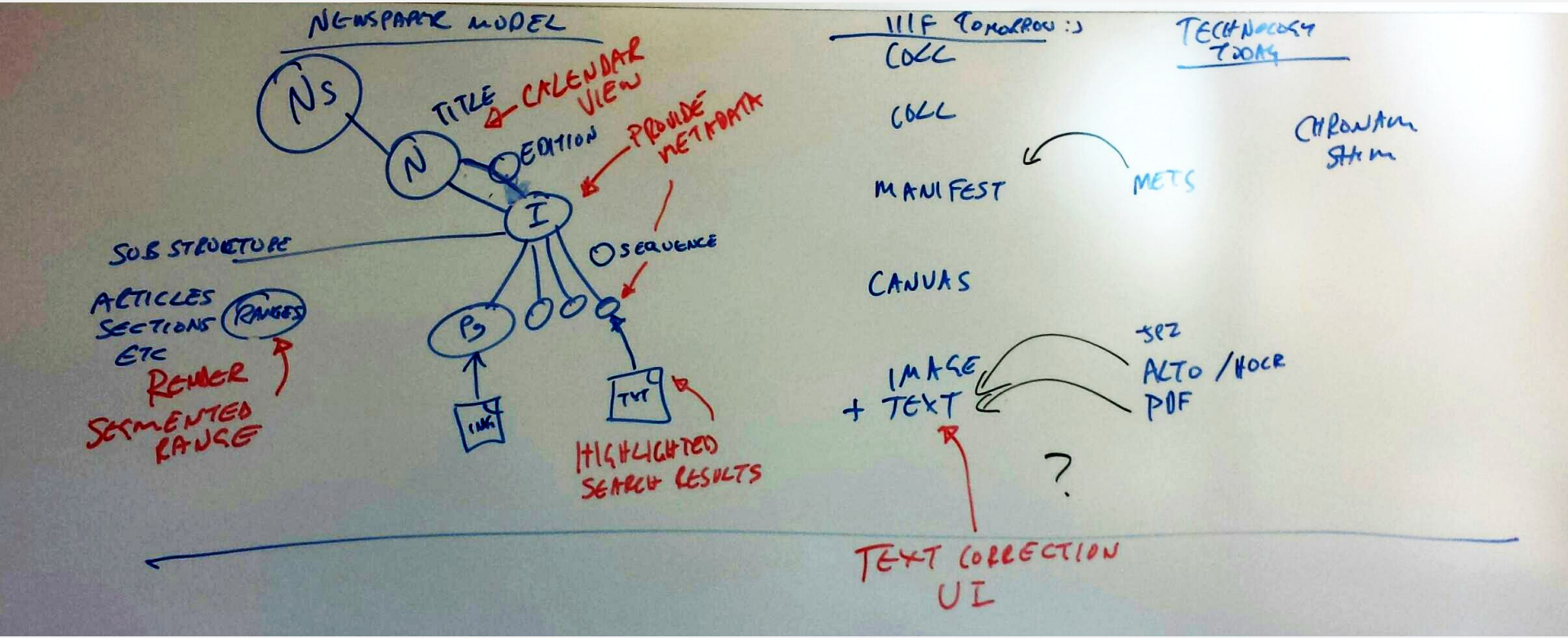
http://2017.code4lib.org/conduct/

Recurse Center Social Rules
(a.k.a. Hacker School Rules)

https://www.recurse.com/manual#sub-sec-social-rules

- No feigning surprise
- No well-actually's
- No back-seat driving
- No subtle -isms
  - More info: https://www.recurse.com/blog/38-subtle-isms-at-hacker-school

Are you ready to data model?



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Reminder

This is an informal workshop - ask questions and let facilitators know how we can help you

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This workshop is an attempt to

- Help build data modeling capacity in the library technology communities
- Help build best practices for data models

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Our goals for this workshop

- Share motivations for data modeling as part of the application development process
- Equip you with knowledge needed to instigate modeling work at your institutions and participate in broader community discussions
- Demonstrate modeling practices and pitfalls
- Give context for data modeling, standards, and interoperability work in various LibTech communities

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However, this workshop is not ...

- A linked data or RDF workshop
- A metadata standards workshop
- A workshop on specific models

... but options exist for learning more about these topics!

Now: your goals for this workshop?

- Why are you attending this workshop?
- What are your goals - immediate or long-term?
- What's your level of comfort and experience with data modeling?

We want to capture your goals, return to them throughout the workshop & going forward - feel free to add to responses to the shared notes.

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Introduction to Data Modeling

What is it & why do it?

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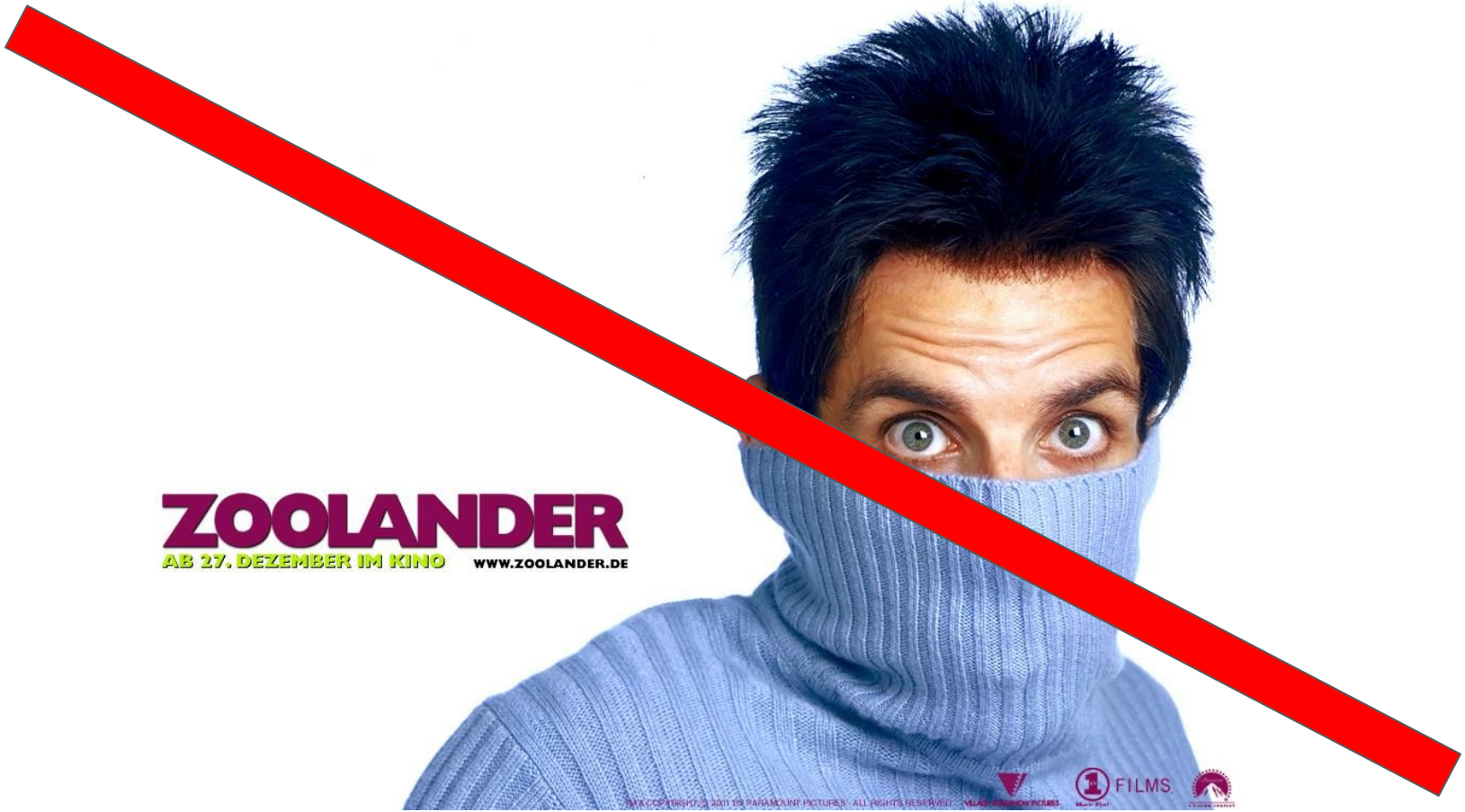
What is a model?



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Source: http://images.fanpop.com/images/image_uploads/Zoolander-ben-stiller-590318_1024_768.jpg

“A model is an abstract description
that hides certain details
while illuminating others"

- Semantic Web for the Working Ontologist : Effective Modeling In Rdfs and Owl.

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“A model is a simplification of reality”

- The Unified Modeling Language User Guide

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What Does a Repository Know?

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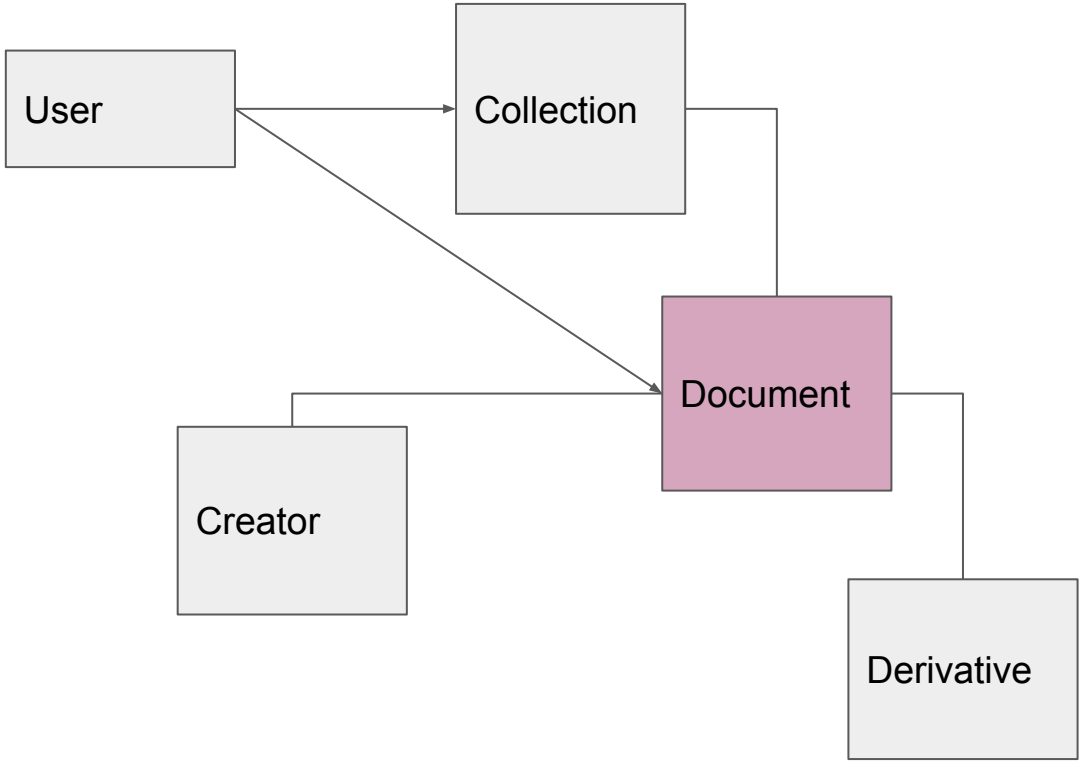

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```
class Document
  attr_accessor: name, collection_id,
    derivatives, creator, visibility

  def save()
    ...
  end

  def create_derivatives()
    ...
  end
end
```

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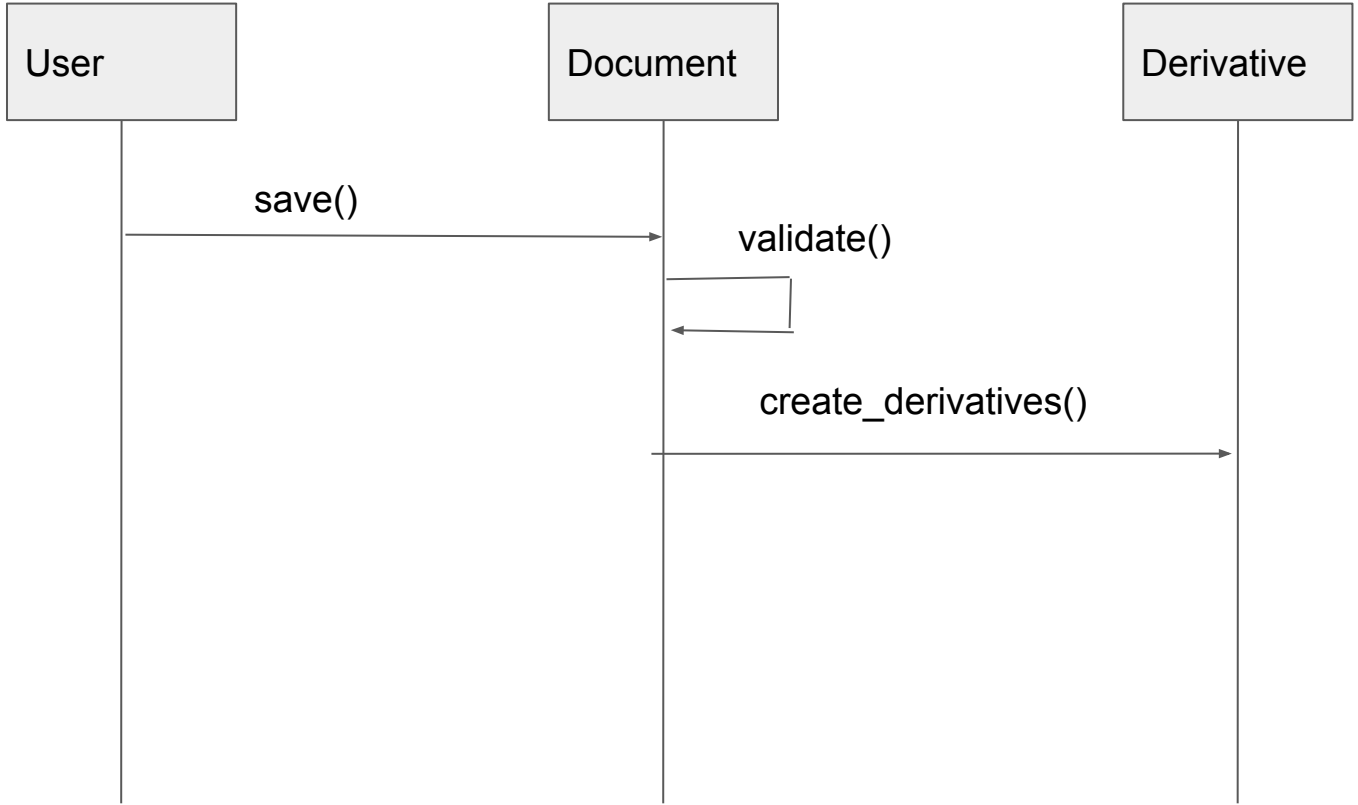

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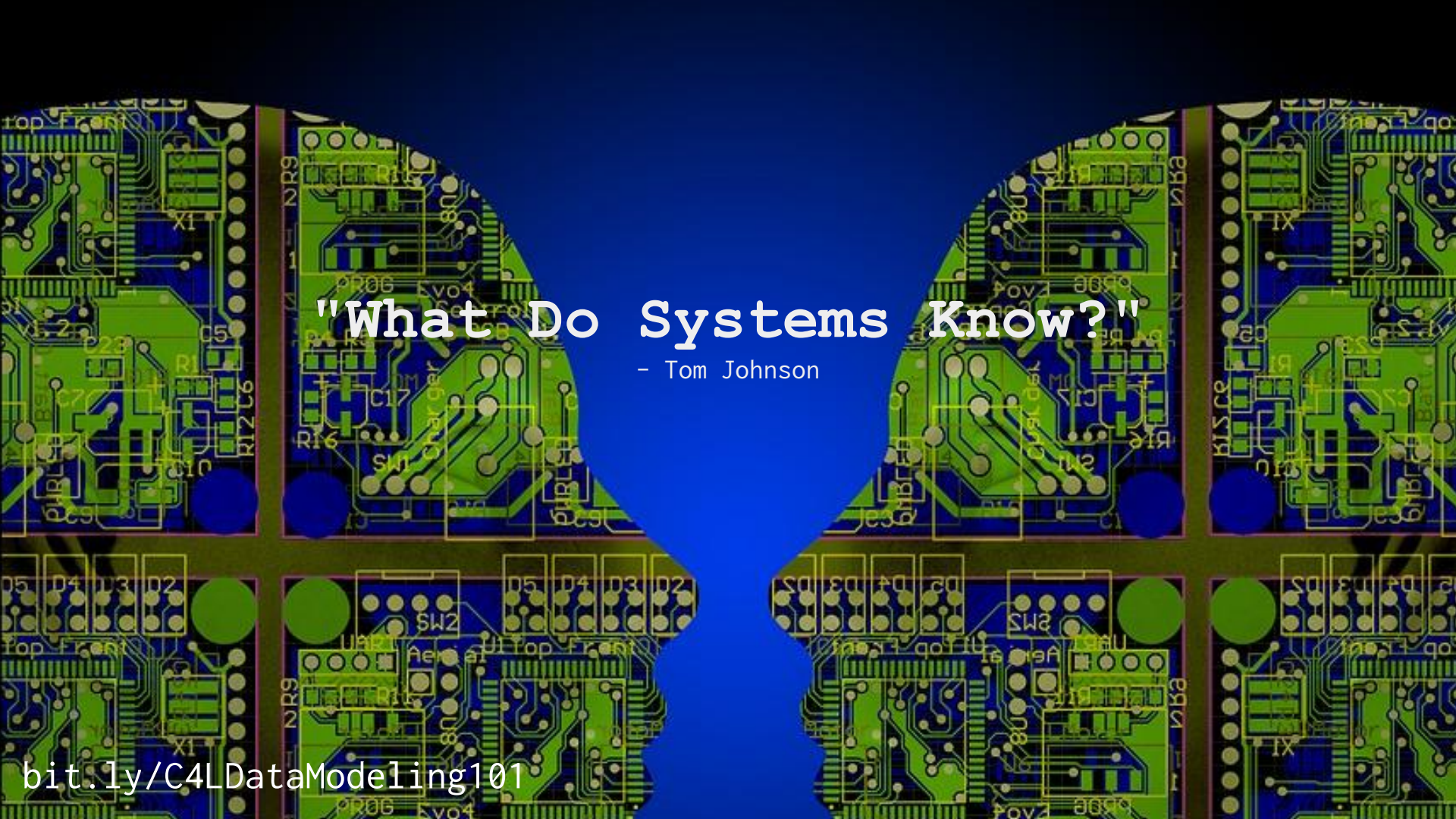
"What Do Systems Know?"
- Tom Johnson
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Why do we model?

“Models are used to organize human thought in the form of explanations”

- Semantic Web for the Working Ontologist : Effective Modeling In Rdfs and Owl.

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Models…

- Help people communicate
- Explain and make predictions
- Mediate among multiple viewpoints
- Models can be textual or visual.

- Semantic Web for the Working Ontologist : Effective Modeling In Rdfs and Owl.

Models are a great way to collaborate with others*
within your team and outside your team.

*others: people or machines

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Who are you modeling for?

- Models for humans versus models for machines
  - Informal (human readable, rely on context)
  - Formal (machine readable, proofs)
- Levels of abstraction
  - Abstract, Conceptual, Physical models
- Static vs Dynamic parts of the system
  - e.g. Database tables vs classes

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Where is the Knowledge?

- Domain standards (MARC, BIBFRAME, …)
- Design documents
- Database & System State
  - Long term storage, in-memory representations.
- Code

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Defining “Data Model”

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What is a Model?

“When we want to make resources and their metadata available in a structured manner on the web, we first need to decide what characteristics of theirs are the most important to be represented. By doing so, **we make an abstraction of the reality through the development of a model**.”

– Linked Data for Libraries, Archives & Museums, p. 12

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Conceptual Model

Captures the concepts and relationships of the data.

The Three-Schema Approach:

External ↤ Conceptual ↦ Internal

Multiple external serializations

Multiple internal schemas

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Physical Model

Data Structure

A representation of data in concrete form.

- A serialized document;
- A database schema;
- A data structure (array, hashmap, B-tree, etc…).

Physical Model

```
CREATE TABLE `blogs` (
  `id` int(11) NOT NULL AUTO_INCREMENT,
  `title` varchar(255) NOT NULL,
  `content` text,
  `createdOn` datetime NOT NULL,
  `updatedOn` datetime DEFAULT NULL,
  `postedOn` datetime DEFAULT NULL,
  PRIMARY KEY (`id`),
  KEY `blogs_index_title` (`title`),
  KEY `blogs_index_postedOn` (`postedOn`)
) ENGINE=InnoDB AUTO_INCREMENT=7 DEFAULT CHARSET=utf8
```

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Examples of Data Models We Know

Flat File Model - MARC?

Tabular Data Model - CSV, TSV, Excel

Relational Data Model - ER, RDBMS

Hierarchical Data Model - XML/JSON

Semantic Data Model - Graphs, RDF(S)

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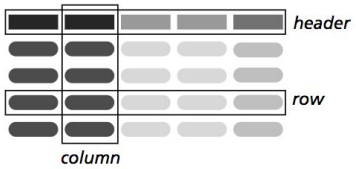
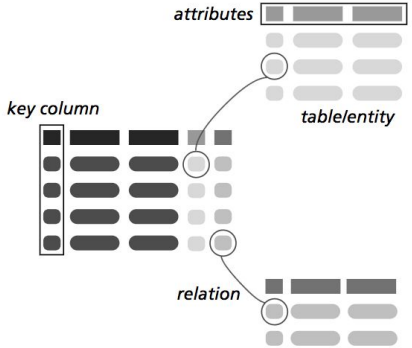


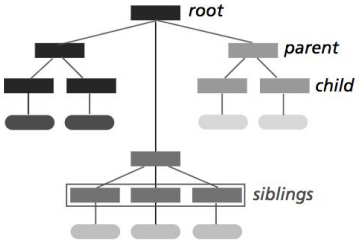
Tabular data

Each data item is structured as a line of field values. Fields are the same for all items; a header line can indicate their name.



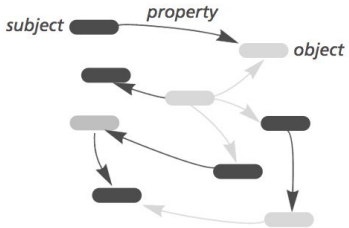
Relational model

Data are structured as tables, each of which has its own set of attributes. Records in one table can relate to others by referencing their key column.



Meta-markup languages

XML documents have a hierarchical structure, which gives them a tree-like appearance. Each element can have one or more children; there is exactly one root element.



RDF

Each fact about a data item is expressed as a triple, which connects a subject to an object through a precise relationship. This leads to graph-structured data that can take any shape.

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Source: http://book.freeyourmetadata.org/chapters/1/modelling.pdf

“Models have a profound influence on how a problem is tackled and a solution shaped”

- The Unified Modeling Language User Guide

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Examples of Data Models We Know

Semantic Modeling

RDF - basic data model, 3-part statements (triples): <s> <o> <p>

Graphs of triples

RDF Schema (RDFS) - language for writing ontologies (knowledge representation, hierarchies, inferencing)

Ontologies describe static knowledge. Problem Solving Method (PSM) - modeling reasoning processes (out of scope)

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Examples of Data Models We Know

Semantic Modeling

Big emphasis in machine readable and interoperability (cooperative information systems)

Schema becomes a bigger concern.

Data Models or Ontologies

Similar in concept but with (waaaaaaay) different scope

Data Models limited to a single system/organization

Ontologies are meant to span across organizations
(sometimes even domains)

Ontologies describe static knowledge
Problem-Solving Methods adds reasoning (e.g. inferencing)

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Semantic Modeling (i.e. Modeling using RDF)

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Our Semantic Modeling Bias: Other Approaches

- Hierarchical
- Network (see: *Programmer as Navigator*, Bachmann)
- Relational
- Object Oriented

More abstractly:

- Entity-Relationship
- Object-Role
- Definitional Theory

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Our Focus on RDF

"By adopting an extremely simple data model consisting of triples, data represented in Resource Description Framework (RDF) become schema-neutral. … This allows for maximum flexibility. Any resource in the world (the subject) can have a specific relationship (the predicate) to any resource in the world (the object). There is no limit on what can be connected to what."

- Linked Data for Libraries, Archives & Museums, p. 44

Our Semantic Modeling Bias: What Gives?

- Avoid “Database Orientation”
  - or language specific “data structure orientation”.
  - or “document model orientation”.
- Focus on Interoperability
  - Semantic Modeling = data is self-describing in a known semantics.
- Simplicity
  - model reduces to a single kind of object and binary relations.
  - “Simple” not to be confused with “easy”.

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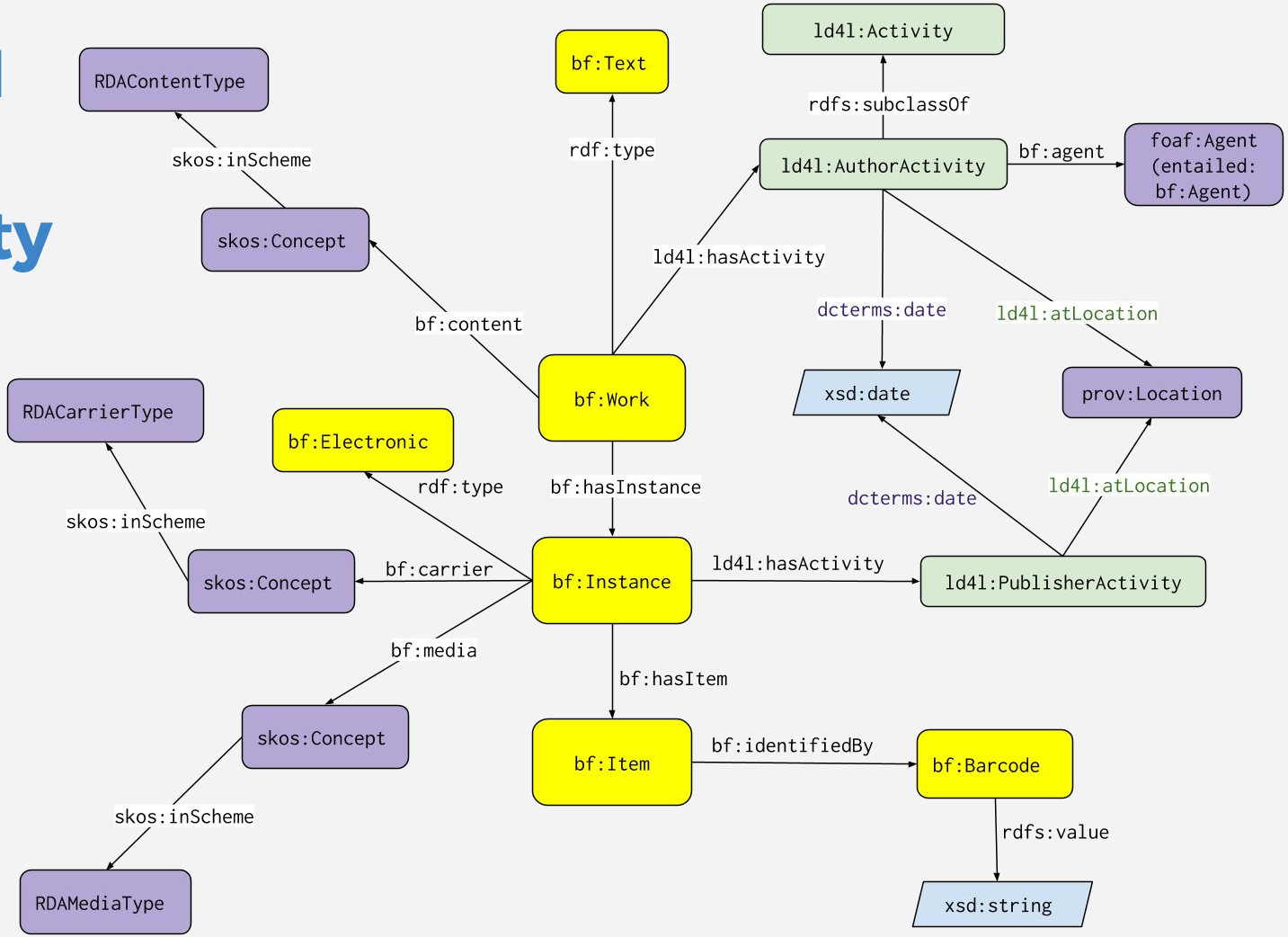
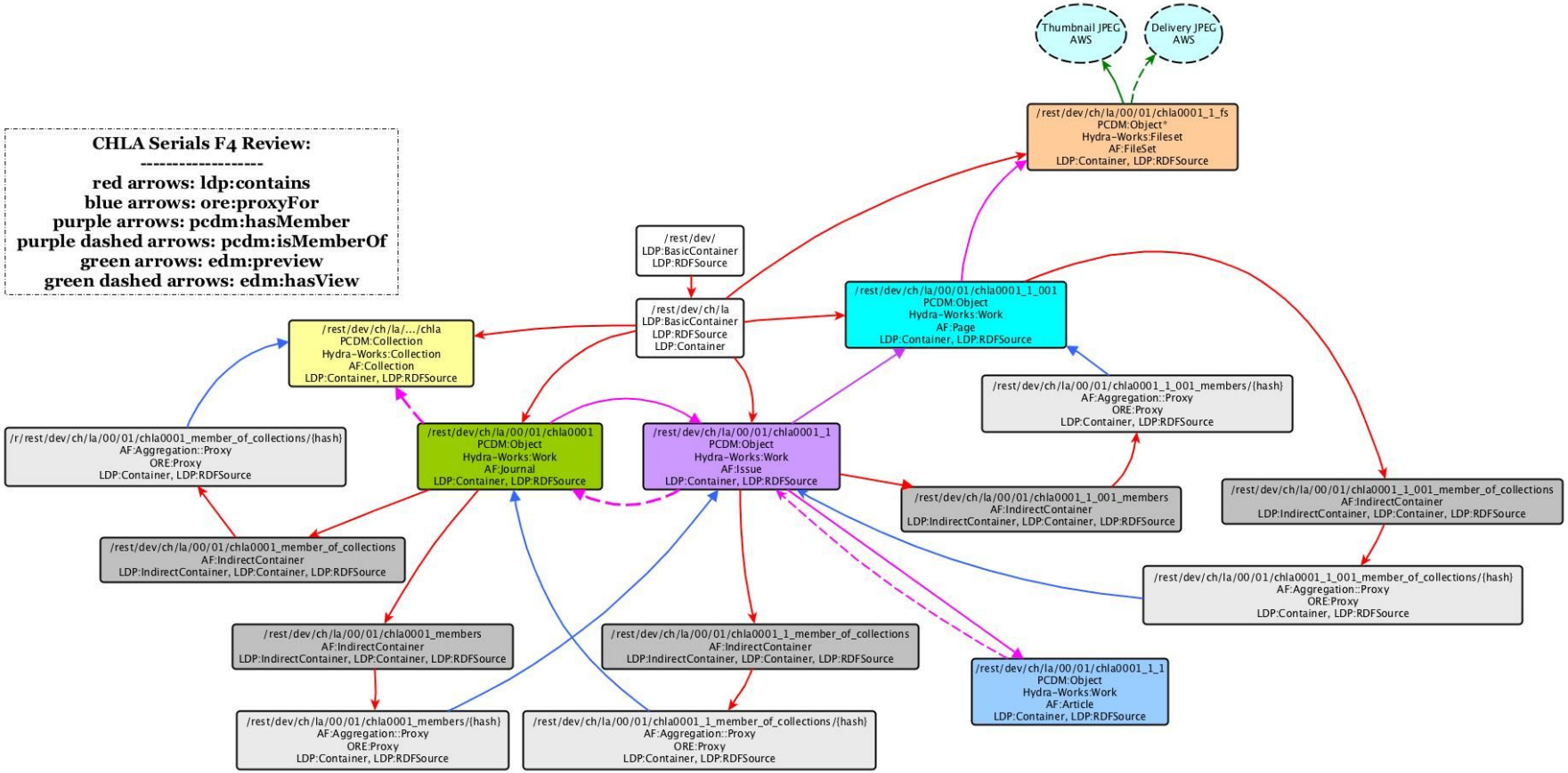
Example 1 of Extensibility



Example 2 of Extensibility

```
aat:1000462296-de rdf:type skos:Label .
aat:1000462296-de gvp:term "hinterglasmalerei"@de .
aat:1000462296-de gvp:qualifier "visual works"@de .
aat:1000462296-de gvp:displayOrder "13"^^xs:positiveInteger .
aat:1000462296-de gvp:termType gvp:UsedForTerm .
...
```

Example of (1 Approach to) Ordering



Data Model? Ontology? Namespace?

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Model/Meta-Model/Ontology

Low-Level Model / Upper Ontology

A Model that can be used to describe other, higher level models.

An Ontology that presents a view of the world common to all Ontologies.

Let’s use RDFS, SKOS, PCDM as examples of this...

Objects & Relations

- One kind of “Object” (Entity, Resource)
  - Objects are distinct from their names & from their records.
- Binary Relations between objects
  - Interpreted as sentences: (person isAuthorOf book)
  - And as *facts*.
- Group objects into Classes (or Entity Types)
  - (person isA Person)

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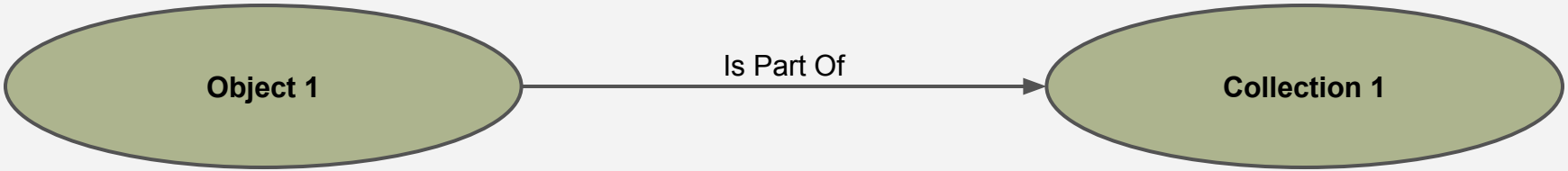
Objects & Relations



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Types of Relations

- Instances of a Relation Class
- Domain & Range
  - Not a constraint!
- Common relation types:
  - Partitive (*chapter isPartOf book*), (*book hasPart chapter*)
  - Membership (*book isMemberOf collection*)
  - Materialization (*book isPortrayalOf work*)
  - Role
    - Type (person isA author)
    - Surrogate (author isRoleOf person, book hasAuthor author)

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RDF & RDFS

Construct	Syntactic form	Description
Class (a class)	**C** rdf:type rdfs:Class	**C** (a resource) is an RDF class
Property (a class)	**P** rdf:type rdf:Property	**P** (a resource) is an RDF property
type (a property)	**I** rdf:type **C**	**I** (a resource) is an instance of **C** (a class)
subClassOf (a property)	**C1** rdfs:subClassOf **C2**	**C1** (a class) is a subclass of **C2** (a class)
subPropertyOf (a property)	**P1** rdfs:subPropertyOf **P2**	**P1** (a property) is a sub-property of **P2** (a property)
domain (a property)	**P** rdfs:domain **C**	domain of **P** (a property) is **C** (a class)
range (a property)	**P** rdfs:range **C**	range of **P** (a property) is **C** (a class)

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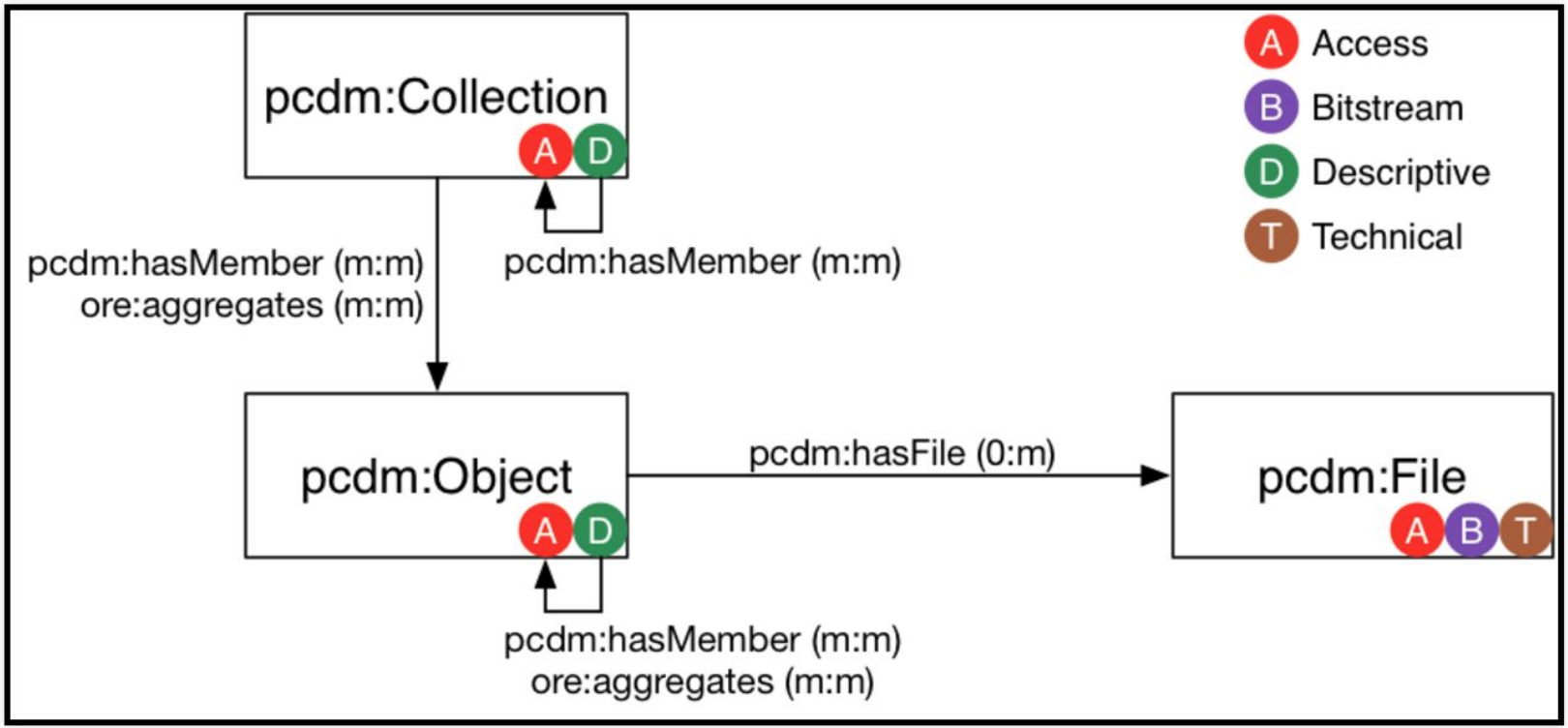
SKOS Vocabulary (Snippet)

```
<rdf:Description rdf:about="#ConceptScheme">
  <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#Class"/>
  <rdfs:label xml:lang="en">Concept Scheme</rdfs:label>
  <rdfs:isDefinedBy
rdf:resource="http://www.w3.org/2004/02/skos/core"/>
  <skos:definition xml:lang="en">A set of concepts, optionally
including statements about semantic relationships between those
concepts.</skos:definition>
  <skos:scopeNote xml:lang="en">A concept scheme may be defined to
include concepts from different sources.</skos:scopeNote>
  <skos:example xml:lang="en">Thesauri, classification schemes,
subject heading lists, taxonomies, 'folksonomies', and other types of
controlled vocabulary are all examples of concept schemes
….</skos:example>
```

PCDM Model



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github.com/duraspace/pcdm/wiki

Vocabularies Are Perspectives

1. DC Terms (generalisms)
2. FOAF & BIBO (concretizations)
3. SKOS (nominalisms (bridged with foaf:focus))
4. FRBR (ideal forms)
5. PROV (entities, activities, agents; qualified roles)
6. OpenAnnotation (descriptions of descriptions)
7. BibFrame (nominal things)
8. Schema.org (a potpurri of perspectives)

What Are We Describing? Niklas Lindström, ELAG 2015 http://goo.gl/49ZCXW

10 Minute Break
Reconvene at 10:40 AM

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Modeling in (a) Context

What does Data Modeling as described look like?

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Communication & Data Modeling

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Photo from http://observer.com/2013/03/dj-spooky-spins-off-from-90s-turntable-phenom-to-the-mets-first-artist-in-residence/

Communication of Needs: An Example

Our repository contains digital collections. Digital collections contain objects that are both born-digital and digital surrogates of analog objects. Objects can be a book, journal, image, artwork, or other. Objects can contain multiple parts. Each object or part can have a digital representation. It may have multiple files for different types of representation.

Digital collections should have curators, titles, identifiers. Objects could have titles, subjects, identifiers, creators, languages, and relationships to other bibliographic resources.

Some digital collections and some objects can be viewed by only a subset of users. All objects can be edited only by a editors.

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When Starting Towards Modeling...

1. What concepts exist?
    a. Entities?
    b. Relationships?
    c. Types?
    d. Operations?
2. What information structure do you want to preserve?
3. Any existing models or patterns you could use?

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Communication of Needs: An Example

Domain: Digital Repository

- ***Classes***: digital collections, (digital) objects, analog/physical objects, parts, representation, formats, user, editor, …
- ***Attributes***: titles, subjects, identifiers, creators, languages, …
- ***Relationships***:
  - Collection contains Object ; Object contains Part
  - Object or Part has Representation
  - Object is a digital Surrogate of Analog/Physical
- ***Operations***:
  - Subset of Users can view Objects
  - Editors (Type of Users) can edit Objects
- ***Types/Enumerations***: (*format)* book, journal, image, artwork, …

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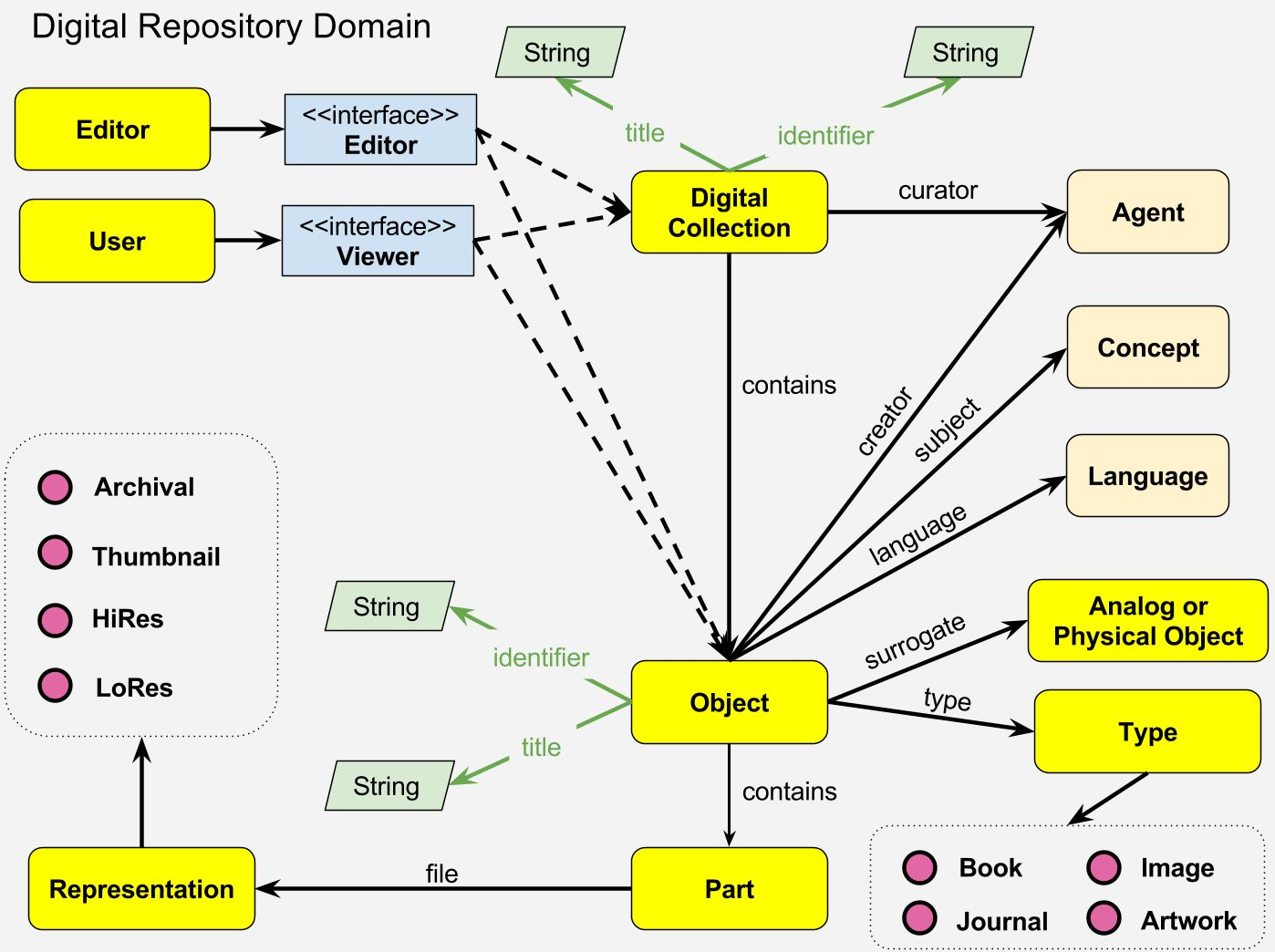
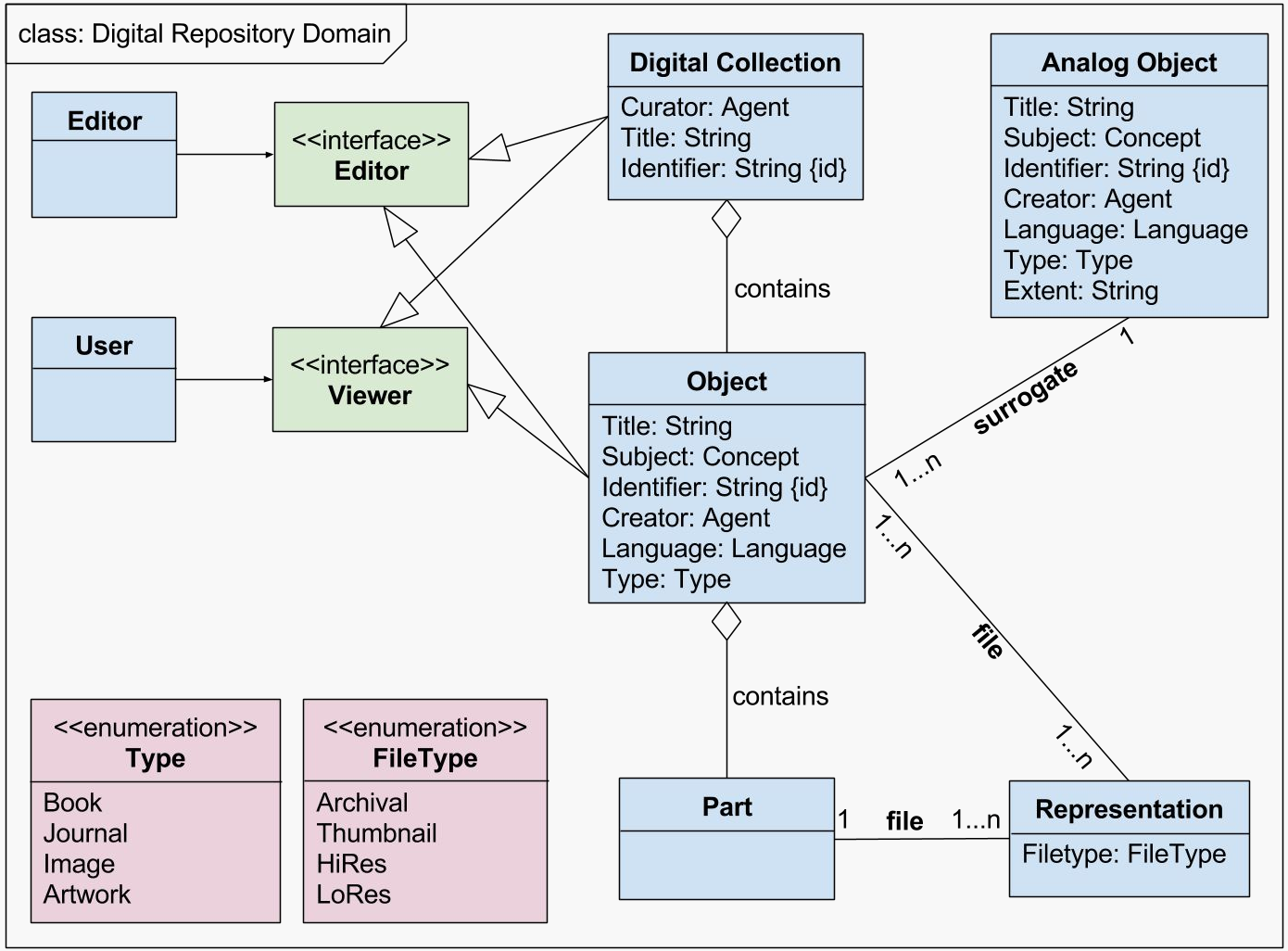
One Possible View...

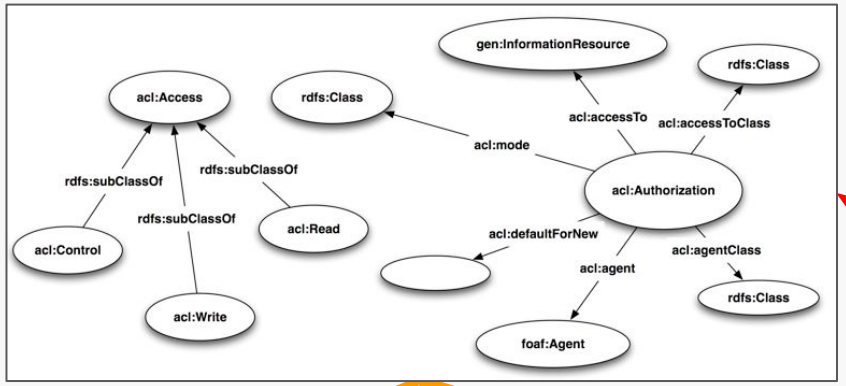


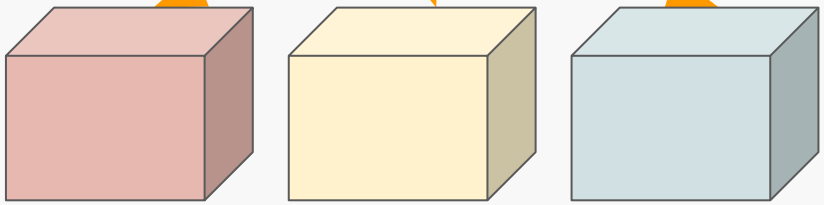


Another Possible View...

Data Models & Application Independence

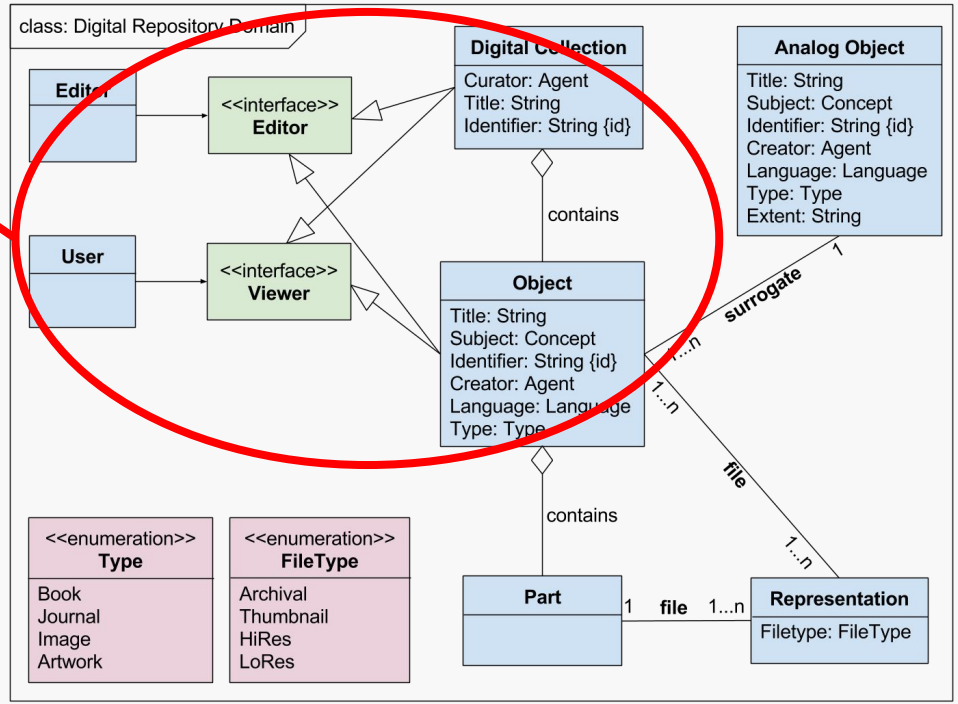
W3C WebAccessControl Model





WebAC Implementations

Our Model



Preservation of Information via Data Models

- If, or rather, as applications evolve/migrate, one can still decode the information context from the Model
- Break reliance of understanding information on 1 person, process, database structure, or application
- Capture Information Context for future re-use vis-a-vis the Conceptual Model

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Data Models & Database Structures

- Internal in Internal/Conceptual/External Approach
- Alternatively, Database Structures are Subset of Data Models (thinking Entity-Relationship Models primarily)
  - Logical Structure of Database
  - Physical Structure of Database Instance
  - In RDF & Graph Stores, Logical == Physical
- Database Structures detail how Data in Domain Data Model is Stored & Managed

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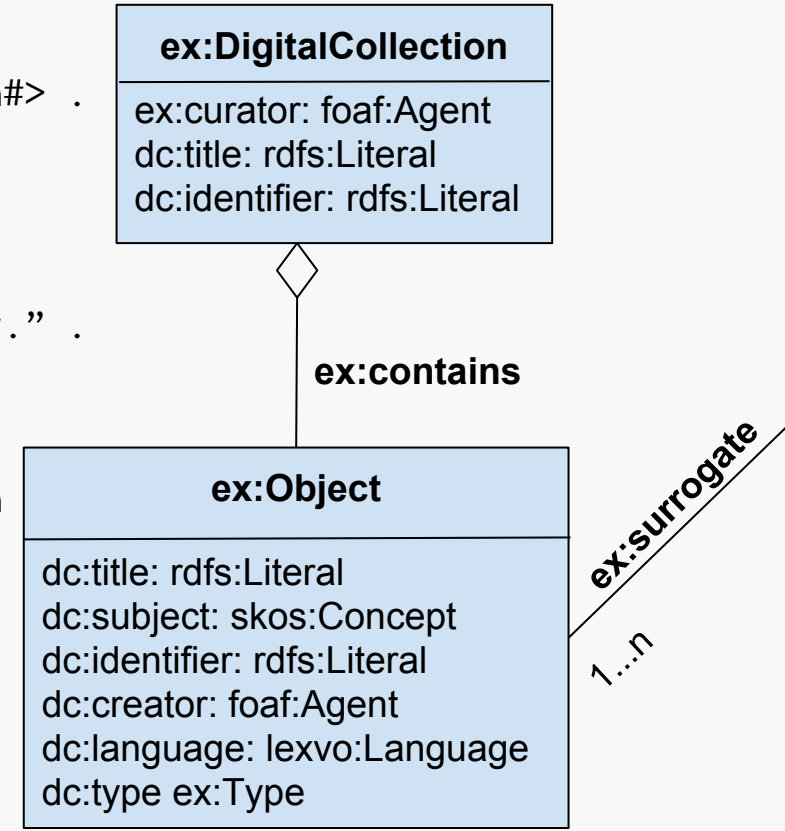
Data Models & Database Structures in RDF

```
@prefix ex: <http://example.edu/> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix dc: <http://purl.org/dc/terms/> .
ex:Object a rdfs:Class ;
  rdfs:label “Object” ;
  rdfs:comment “Digital Object held by a repository.” .
ex:DigitalCollection a rdfs:Class ;
  rdfs:label “Digital Collection” ;
  rdfs:comment “Aggregation of Digital Objects in a
    repository.” .
ex:contains a rdfs:Property ;
  rdfs:label “surrogate of” ;
  rdfs:domain ex:DigitalCollection ;
  …
```



Data Models & Serializations

- Converts Data Structures (from Data Models) into Format
- Format is Translation of Data Structure used for Transfer, Storage, Distribution among Systems
- Serialization Contains All Needed Information to (re-)Construct In-Memory Model
  - So Serializations are Logically Equivalent
- Examples:
  - Tabular Data -> CSV, TSV
  - RDF Data -> Turtle, N-Triples, RDF/XML, JSON-LD

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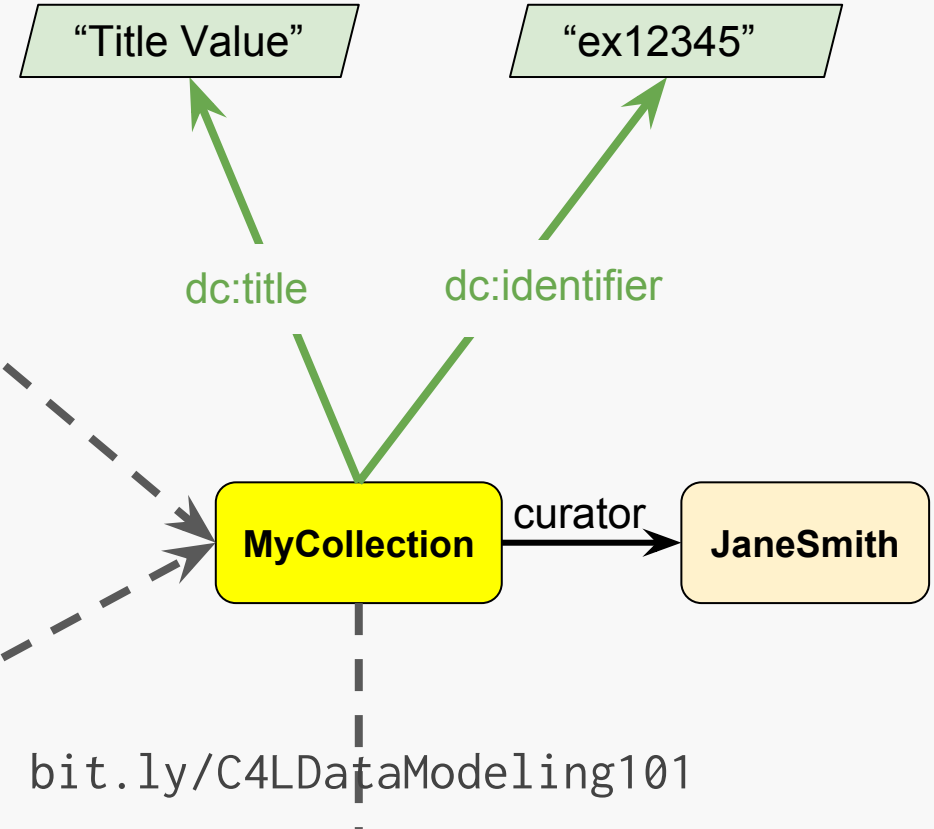
Data Models & Serializations in RDF




```
@prefix: <http://example.edu/> .
@prefix dc: <http://purl.org/dc/terms/> .
@prefix foaf: <http://xmlns.com/foaf/> .
:MyCollection a :DigitalCollection ;
  dc:identifier “ex12345” ;
  dc:title “Title Value” ;
  :curator :JaneSmith .
:JaneSmith a foaf:Agent ;
  foaf:name “Jane Smith” ;
  …
```

Data Models & Data Exchange Protocols

- Protocol State Machines in Olivé is Broader Idea
- Rules (Standards) Outlining Syntax, Semantics & Synchronization of Data or Information across Systems
- Protocols: *SOAP* ; *Z39.50* ; *SRU* ; *OAI-PMH* ; *SPARQL*
  - Also, *HTTP* == Hypertext Transfer Protocol, on which we build the Web & Leverage often for RDF transfer
- Data Models can Surface Needs, Expectations of as well as Data Instances & Formats used in Exchange Protocols

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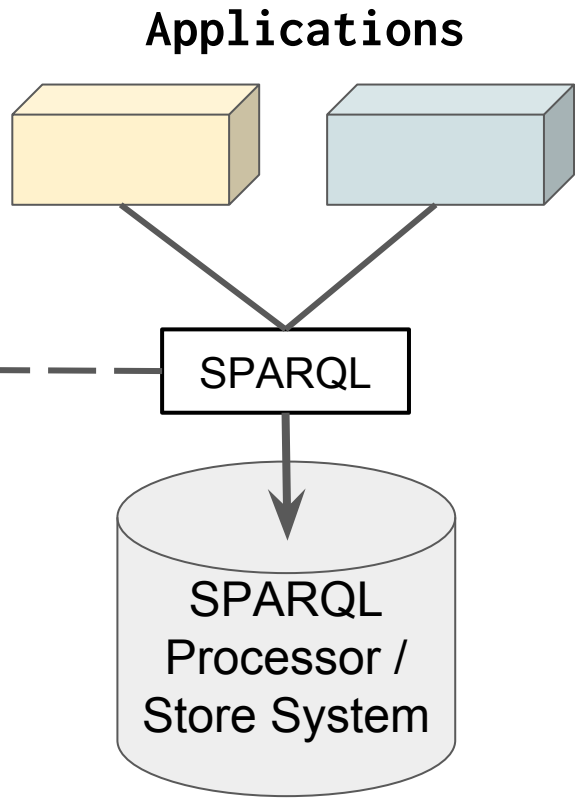
… Now Data Models & Data Protocols in RDF

```
Post
/test?graph-uri=http%3A%2F%2Fexample.edu%2F HTTP/1.1
Host: example.edu/sparql
Accept: */*
Content-Type: application/sparql-update
Content-Length: 136

PREFIX ex: <http://example.edu/>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX dc: <http://purl.org/dc/terms/>
INSERT { ?digitalCollection ex:curator ex:JaneSmith }
WHERE { ?digitalCollection dc:identifier “ex12345” }
```



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Application Logic & Data Models

- Application Logic == Logic Specific to an Application
- Fundamentally different from Domain & Infrastructure Logic due to Target & Re-usability:
    - Domain Logic should be reusable in systems or applications addressing the same domain
    - Infrastructure is generic technical capabilities
- Application Logic should leverage the Data Model, may serialize Data into Application-Language Objects

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Application Logic & Data Models with RDF

```
module Hydra::Works
  # This module provides all of the Behaviors of a Hydra::Works::GenericFile
  #
  # behavior:
  #   1) Hydra::Works::FileSet can contain (pcdm:hasFile) Hydra::PCDM::File   (inherits from Hydra::PCDM::Object)
  #   2) Hydra::Works::FileSet can contain (pcdm:hasRelatedFile) Hydra::PCDM::File   (inherits from Hydra::PCDM::Object)
  #   3) Hydra::Works::FileSet can aggregate (pcdm:hasMember) Hydra::Works::FileSet
  #   4) Hydra::Works::FileSet can NOT aggregate anything other than Hydra::Works::FileSets
  #   5) Hydra::Works::FileSet can have descriptive metadata
  #   6) Hydra::Works::FileSet can have access metadata
  module FileSetBehavior
    extend ActiveSupport::Concern

    included do
      def self.type_validator
        Hydra::PCDM::Validators::CompositeValidator.new(
          Hydra::Works::NotCollectionValidator,
          super
        )
      end
```

github.com/projecthydra/hydra-works/blob/master/lib/hydra/works/models/concerns/file_set_behavior.rb

Data Models & Metadata Standards

- Rules that Establish Common Semantics for Particular Domain of Data
- In turn supports “Correct” Use & Understanding of Data by Users vis-a-vis Commonly-Defined Attributes
- Data Models leverage Metadata Standards to define their own Semantics & Requirements
- Data Models can reuse, extend multiple Metadata Standards
- Standards can be built off of a common Model

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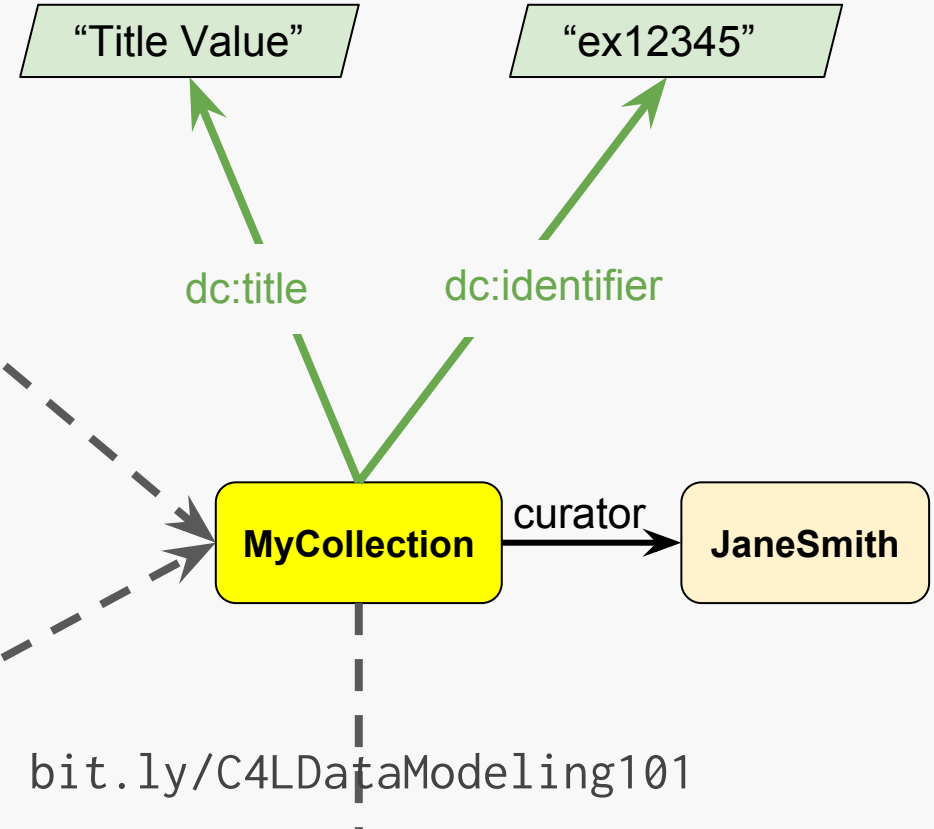
Data Models & Serializations in RDF




```
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@prefix foaf: <http://xmlns.com/foaf/> .
:MyCollection a :DigitalCollection ;
  dc:identifier “ex12345” ;
  dc:title “Title Value” ;
  :curator :JaneSmith .
:JaneSmith a foaf:Agent ;
  foaf:name “Jane Smith” ;
  …
```

Expressing Data Models

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Quick Review of Modeling Languages

How models get expressed - a limited review of some conceptual modeling languages & methods:

- UML*
- XML*
- Java (Ruby, Python, ... Programming Language) Classes
- RDF
- Diagramming

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Universal Modeling Language (UML)

- Standardized Modeling Language
- Complex but General Purpose
- Different Diagram Groups
- User for Software Engineering
- Visualizes designs of Systems from a few approaches:
  - Use Cases
  - Static or Class Diagrams
  - State changes
  - ...

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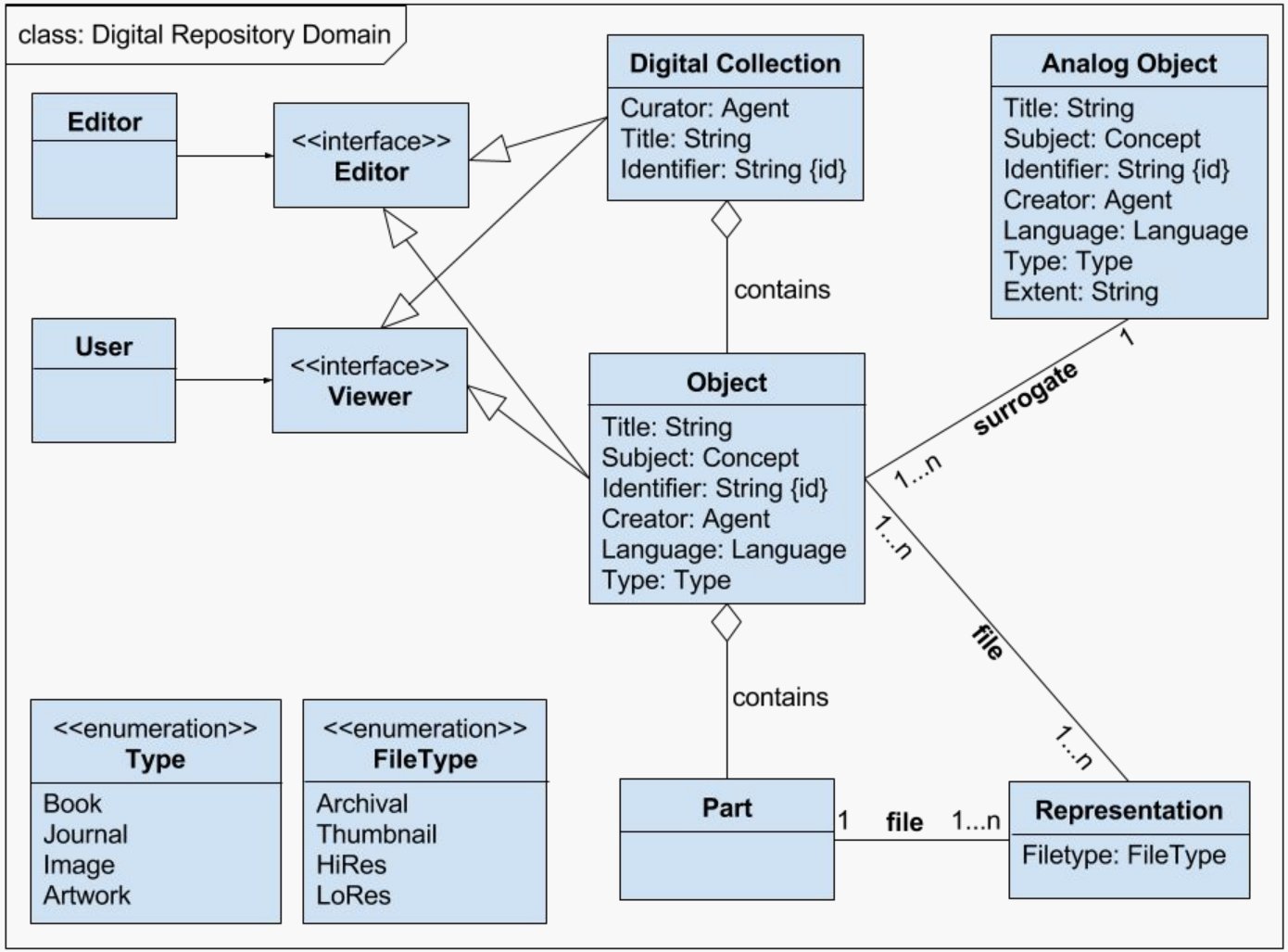
Unified Modeling Language (UML) Simple Class Diagram



uml-diagrams.org/class-diagrams-overview.html

XML

- Document-focused model, with tree structure containing nodes in hierarchies - elements, attributes, values
- Languages that support models in XML:
  - XML Schema
  - RELAX NG
  - Schematron

```
<xs:element name="location" type="locationDefinition"/>
<!--   -->
<xs:complexType name="locationDefinition">
 <xs:sequence>
   <xs:element ref="physicalLocation" minOccurs="0" maxOccurs="unbounded"/>
   <xs:element ref="shelfLocator" minOccurs="0" maxOccurs="unbounded"/>
   <xs:element ref="url" minOccurs="0" maxOccurs="unbounded"/>
   <xs:element ref="holdingSimple" minOccurs="0"/>
   <xs:element ref="holdingExternal" minOccurs="0"/>
  </xs:sequence>
  <xs:attributeGroup ref="languageAttributeGroup"/>
  <xs:attribute name="displayLabel" type="xs:string"/>
  <xs:attribute name="altRepGroup" type="xs:string"/>
</xs:complexType>
<!--

********   Subordinate Elements for <location>
  -->
<!--
********** physicalLocation **********
 -->
<xs:element name="physicalLocation" type="physicalLocationDefinition"/>
<!--   -->
<xs:complexType name="physicalLocationDefinition">
 <xs:simpleContent>
  <xs:extension base="stringPlusLanguagePlusAuthority">
    <xs:attributeGroup ref="xlink:simpleLink"/>
    <xs:attribute name="displayLabel" type="xs:string"/>
    <xs:attribute name="type" type="xs:string"/>
   </xs:extension>
  </xs:simpleContent>
</xs:complexType>
<!--   -->
<xs:element name="shelfLocator" type="stringPlusLanguage"/>
<!--
```

XML data model:

Portion of XML Schema for MODS 3.6

www.loc.gov/standards/mods/v3/mods-3-6.xsd

Java Classes

- Object-Oriented Programming Language:
  - Objects aggregate Data, Attributes & Methods
  - Objects communicate with each other by invoking methods
  - Basic Programming Unit is a Class
  - Object == Instance of a Class
- In Java, all Classes except *Object* inherit information defined in another Class
  - Java's *Object* class defines Common Behaviors
  - Java Classes define Data Representation for Objects
- Class declares variables for storing values of Primitive Types & references to Objects

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Data Models Captured in Java Classes

```java
@Scope("request")
@Path("/{path: .*}")
public class FedoraLdp extends ContentExposingResource {

    private static final Logger LOGGER = getLogger(FedoraLdp.class);
```

[SKIPPED / PARAPHRASED CONTENT HERE]

```java
    /**
     * Retrieve the node profile
     *
     * @param rangeValue the range value
     * @return a binary or the triples for the specified node
     * @throws IOException if IO exception occurred
     */
    @GET
    @Produces({TURTLE + ";qs=1.0", JSON_LD + ";qs=0.8",
            N3, N3_ALT2, RDF_XML, NTRIPLES, APPLICATION_XML, TEXT_PLAIN, TURTLE_X,
            TEXT_HTML, APPLICATION_XHTML_XML})
    public Response getResource(@HeaderParam("Range") final String rangeValue) throws IOException {
        checkCacheControlHeaders(request, servletResponse, resource(), session);

        LOGGER.info("GET resource '{}'", externalPath);
```

[…]

https://github.com/fcrepo4/fcrepo4/

Data Models with Ruby Class Using ActiveTriples

```ruby
module DPLA::MAP
  class Aggregation < ActiveTriples::Resource
    configure :type => RDF::ORE.Aggregation

    validates_presence_of :sourceResource, :originalRecord, :isShownAt, :object, :provider

    property :sourceResource, :predicate => RDF::EDM.aggregatedCHO, :class_name => 'DPLA::MAP::SourceResource'
    property :dataProvider, :predicate => RDF::EDM.dataProvider, :class_name => 'DPLA::MAP::Agent'
    property :originalRecord, :predicate => RDF::DPLA.originalRecord
    property :hasView, :predicate => RDF::EDM.hasView, :class_name => 'DPLA::MAP::WebResource'
    property :intermediateProvider, :predicate => RDF::DPLA.intermediateProvider, :class_name => 'DPLA::MAP::Agent'
    property :isShownAt, :predicate => RDF::EDM.isShownAt, :class_name => 'DPLA::MAP::WebResource'
    property :object, :predicate => RDF::EDM.object, :class_name => 'DPLA::MAP::WebResource'
    property :preview, :predicate => RDF::EDM.preview, :class_name => 'DPLA::MAP::WebResource'
    property :provider, :predicate => RDF::EDM.provider, :class_name => 'DPLA::MAP::Agent'
    property :rightsStatement, :predicate => RDF::EDM.rights, :class_name => 'DPLA::MAP::RightsStatement'

    def jsonld_context
      DPLA::MAP::CONTEXT['@context']
    end

    def to_jsonld
      JSON::LD::API.frame(JSON.parse(dump(:jsonld)), DPLA::MAP::FRAME)
    end
  end
end
```

https://github.com/dpla/dpla_map/blob/map-4.0/lib/dpla/map/aggregation.rb

RDF, RDFS, OWL, RDF/XML - here, FOAF

```
  <rdfs:Class rdf:about="http://xmlns.com/foaf/0.1/Organization" rdfs:label="Organization"
    rdfs:comment="An organization." vs:term_status="stable">
    <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#Class"/>
<!--    <rdfs:subClassOf><owl:Class rdf:about="http://xmlns.com/wordnet/1.6/Organization"/></rdfs:subClassOf> -->
    <rdfs:subClassOf rdf:resource="http://xmlns.com/foaf/0.1/Agent"/>
    <rdfs:isDefinedBy rdf:resource="http://xmlns.com/foaf/0.1/"/>
    <owl:disjointWith rdf:resource="http://xmlns.com/foaf/0.1/Person"/>
    <owl:disjointWith rdf:resource="http://xmlns.com/foaf/0.1/Document"/>
  </rdfs:Class>
  <rdfs:Class rdf:about="http://xmlns.com/foaf/0.1/Group" vs:term_status="stable" rdfs:label="Group"
    rdfs:comment="A class of Agents.">
    <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#Class"/>
    <rdfs:subClassOf rdf:resource="http://xmlns.com/foaf/0.1/Agent"/>
  </rdfs:Class>
  <rdfs:Class rdf:about="http://xmlns.com/foaf/0.1/Agent" vs:term_status="stable" rdfs:label="Agent"
    rdfs:comment="An agent (eg. person, group, software or physical artifact).">
    <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#Class"/>
    <owl:equivalentClass rdf:resource="http://purl.org/dc/terms/Agent"/>
<!--    <rdfs:subClassOf><owl:Class rdf:about="http://xmlns.com/wordnet/1.6/Agent-3"/></rdfs:subClassOf> -->
  </rdfs:Class>
```

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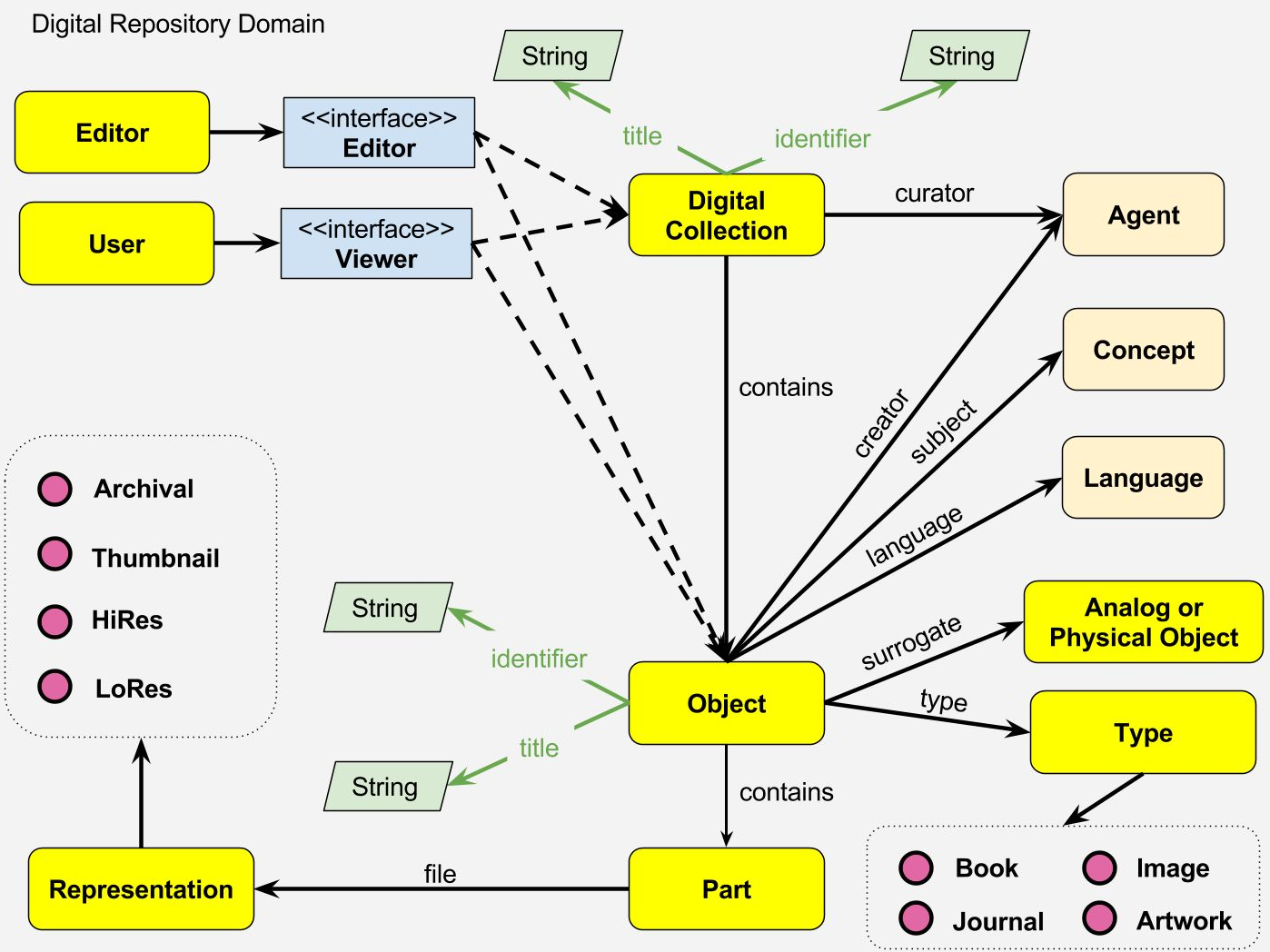
http://xmlns.com/foaf/spec/

RDF Diagram (Mostly) Using Graffoo



Breakouts

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4 Data Models Breakout Groups Options

1. BIBFRAME 2.0
2. Portland Common Data Model (PCDM)
3. Europeana Data Model (EDM) / Digital Public Library of America (DPLA) Metadata Application Profile
4. International Image Interoperability Framework (IIIF) Presentation API

If possible, pick model you're least familiar with

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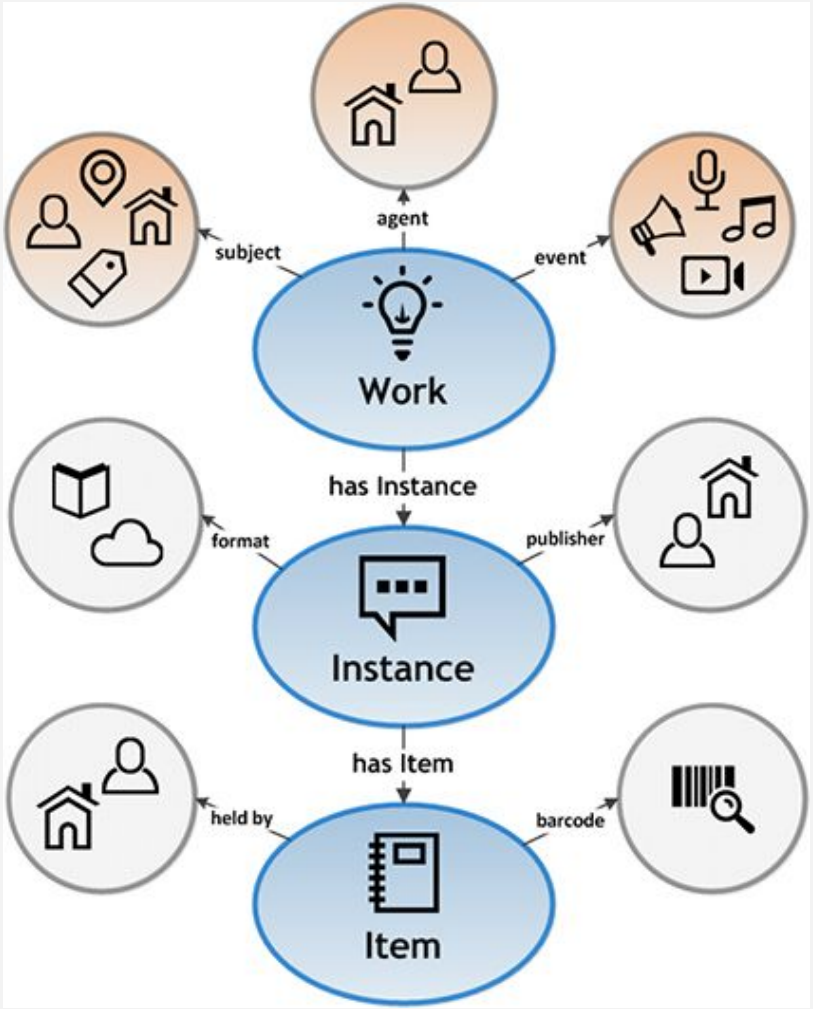
BIBFRAME 2.0

- Conceptual/practical **model** for bibliographic resources & other other cultural materials
- BIBFRAME “Core” breaks with FRBR & RDA, using simplified *Work - Instance - Item*
- BIBFRAME v.“2.0” released in 2016 & is still being developed
  - Differs from BIBFRAME v.“1.0” in some significant ways
  - *Analysis of the BIBFRAME Ontology* / Rob Sanderson, 2015 (bit.ly/bibframe-analysis) followed in many regards

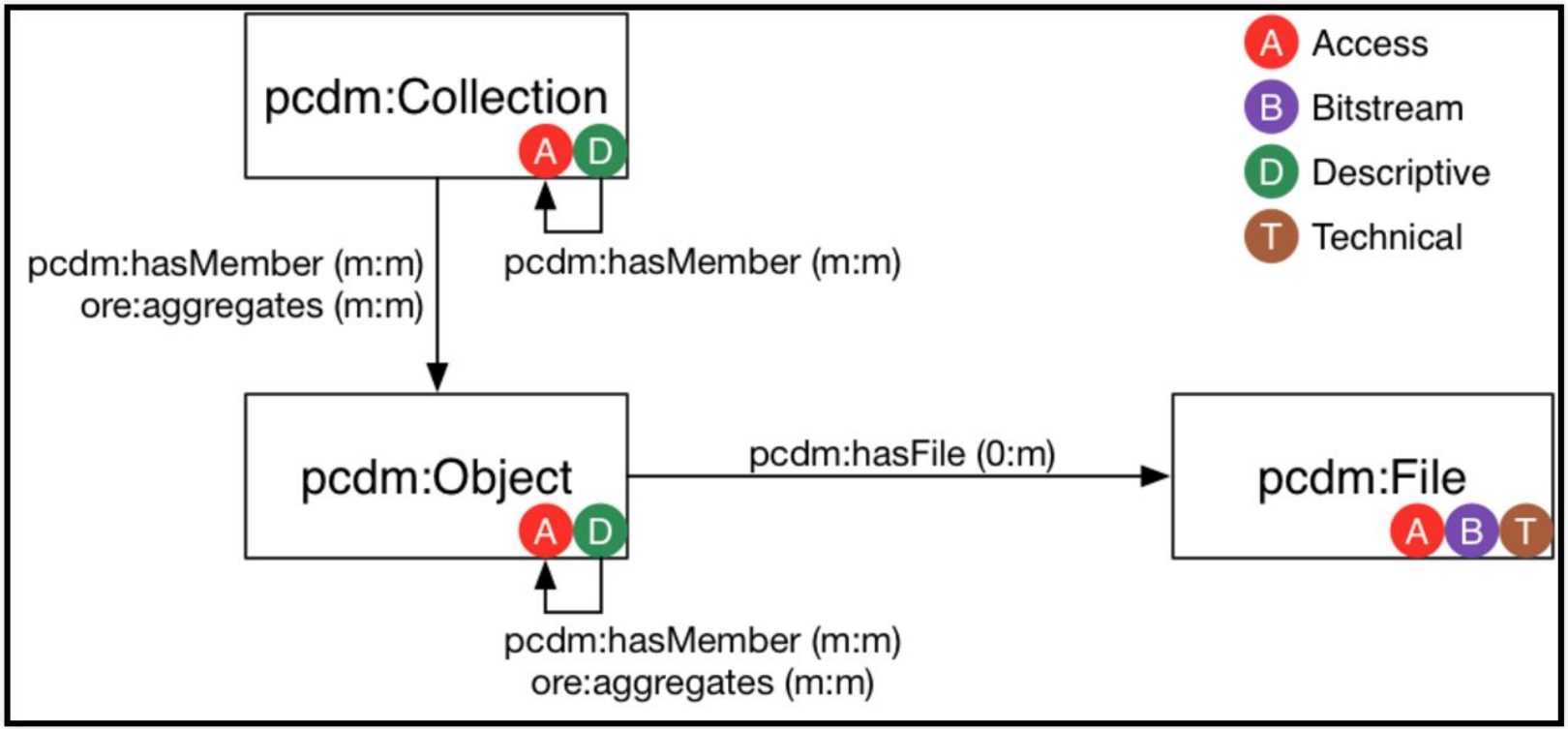
BIBFRAME 2.0
“Core”



Portland Common Data Model (PCDM)

- Started Officially in 2015
- Community Effort for Interoperable Modeling of Digital Repository Objects
- PCDM extends Object Reuse & Exchange (ORE) Data Model
- Interacts with Other Specifications (like LDP), Platforms (like Fedora 4), but Modeled to be Neutral
- Hydra works with PCDM Data from Datastore (Fedora 4) by Translating into Ruby Objects leveraging ActiveFedora

PCDM “Core”

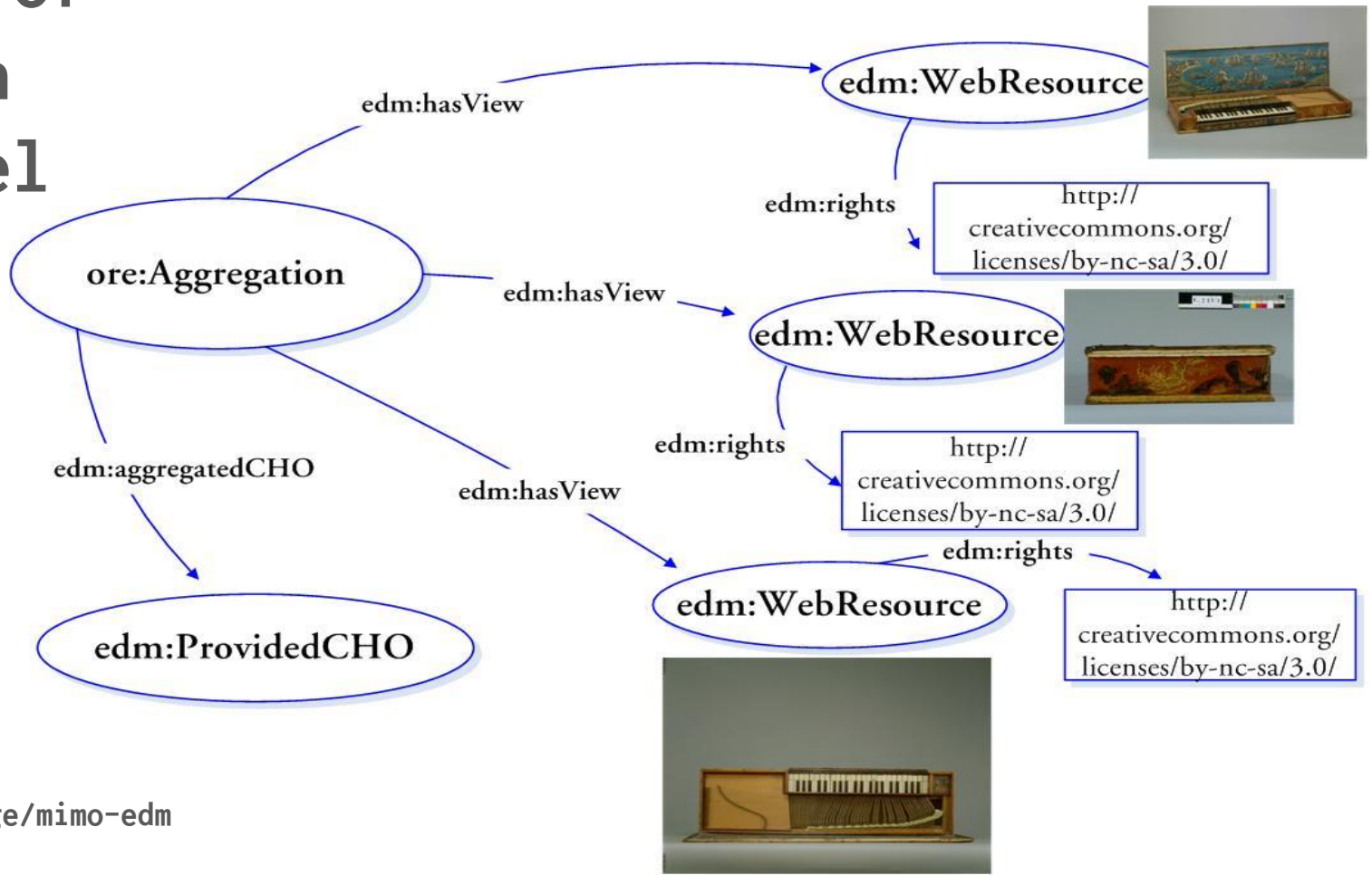


github.com/duraspace/pcdm/wiki

Europeana Data Model (EDM) / Digital Public Library of America (DPLA) MAP

- RDF-based, Descriptive Models
- Focus is Cultural Heritage Resource Aggregation
- Extends CIDOC-CRM as well as Other Models, Vocabularies
- DPLA is Subset of EDM
- Basis for Profiles, i.e. not Designed to be Exhaustive
- More Concerned with Resource Description than System Functions

Fragment of Europeana Data Model Diagram

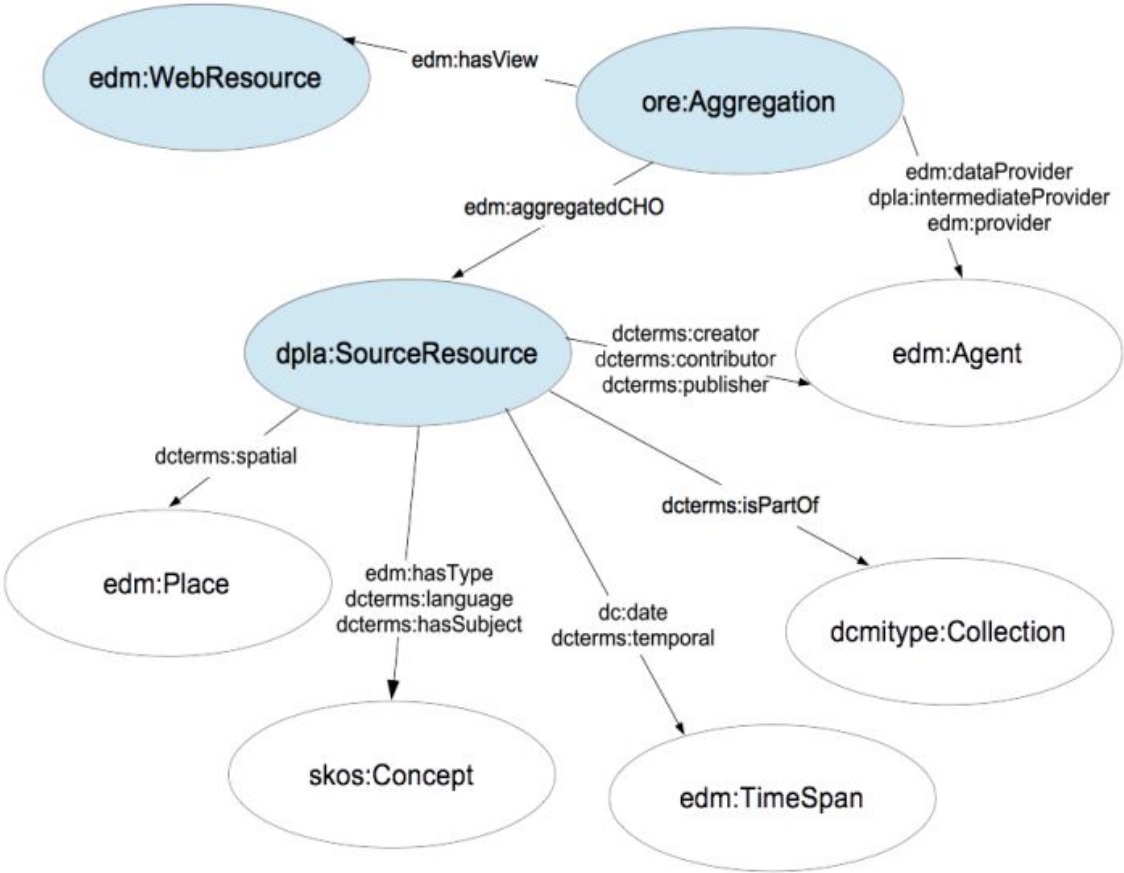


pro.europeana.eu/page/mimo-edm

DPLA v.4 Model Diagram

2.0 Digital Public Library of America Domain Model, v4

Core classes highlighted in blue.

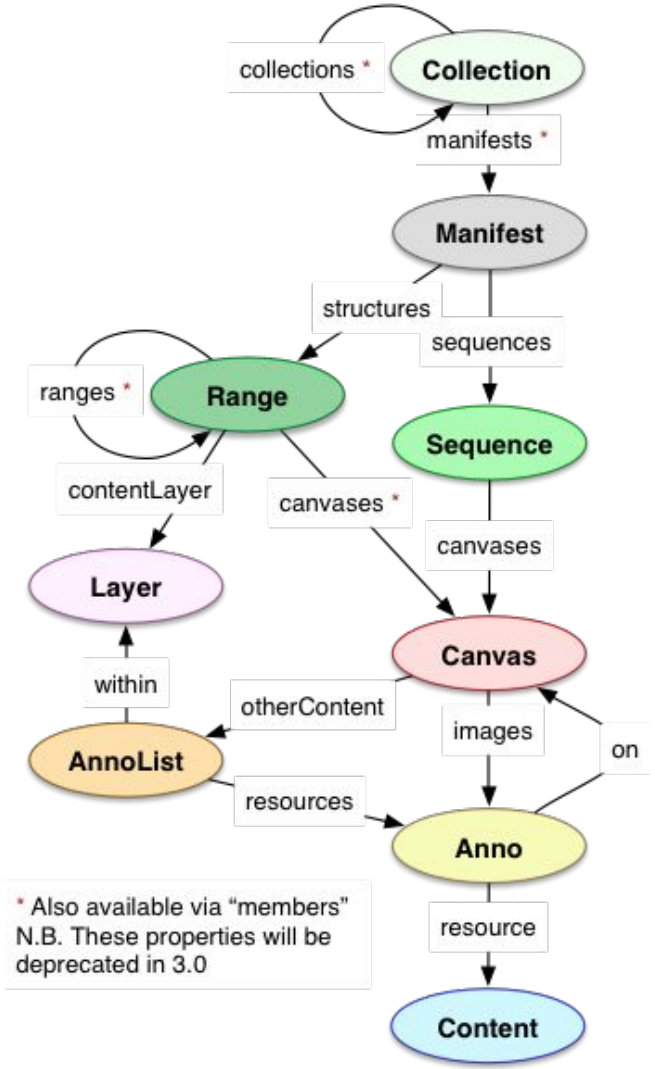


dp.la/info/developers/map/

International Image Interoperability Framework (IIIF)

- Set of 4 APIs & Models Working Together to Share Images:
  - Presentation (the focus of the break-out)
  - Image
  - Authentication
  - Search
- Growing Range of IIIF-Compatible Image Viewer Systems
  - Mirador
  - Universal Viewer
  - ...

IIIF Presentation API Model Diagram



iiif.io/api/presentation/2.1/

Breakouts' Shared Example

Digital Surrogate of *"A. Danforth's Great Vegetable Pain Destroyer [inscribed]"* from UCLA Digital Collections

http://bit.ly/C4L17DataModelExample

Data Models Breakouts Activity

Learn about Your Data Model & Discuss:

1. Entity Types ;
2. Relationships Types ;
3. Attributes .
4. Contextualize within Domain, Applications, Standards ;
5. Diagram an Instance of the Data Model with a Shared Example.

*** Please Capture Work & Diagrams in the Shared Notes ***

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Breakouts until 11:50

BIBFRAME 2 - Christina

PCDM - Steve

IIIF - Hector

EDM/DPLA - Mark

Use the Shared Drive for Notes

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Breakouts Recap

Volunteer from each Breakout to Report Back on Your Group's Modeling Work

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Different Models, Different Data?

- How do our breakout group responses, ideas, approaches compare?
- How do we use modeling to build interoperability + shared understanding?
- Where do we see differences in what data modeling accomplishes across these breakouts?

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Building Data Modeling in the Code4lib Community/Beyond

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Maintaining Data Modeling Momentum

- Code4lib Slack channels that discuss modeling:
  - #c4l17-datamodeling -> #datamodeling
- Hydra Metadata Interest Group
  - #metadata on project-hydra Slack
- Others…?
- Notes/Shared Resources from Workshop - Keep Adding to this!

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Broader or Related Communities Working on Modeling

- PCDM
- IIIF
- Fedora 4 (& Fedora broadly)
- Islandora
  - CLAW / Islandora & Fedora 4 Architecture
  - Islandora Interest Groups (Includes Metadata)
- Europeana Data Modeling Work
- W3C Efforts: LDP, Shapes, …
- DCMI Work

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Data Modeling Tools & Resources

- Data Modeling Resources Going Forward
  - Starter List of Tools
  - Some Links to Modeling Work in Cultural Heritage Institutions
- Data Modeling Needs in Code4Lib & Related Communities:
  - Location for Open Discussions & Issues

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Your ideas to continue support for data modeling in communities?

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Thank you!

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