Introduction to Ontologies and Semantic Web

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Outline

1. Sharing meaning of data
   - Some examples of misunderstanding
   - What is a dataset about?
   - From conceptual models to ontologies
   - Ontologies for data integration

2. Semantic Web
   - Linked Data
   - Use-case: Open Data
   - Semantic Web Adopters

Course Organization

https://cw.fel.cvut.cz/wiki/courses/b4m36osw

Sharing meaning of data

Some examples of misunderstanding

One event or two events?

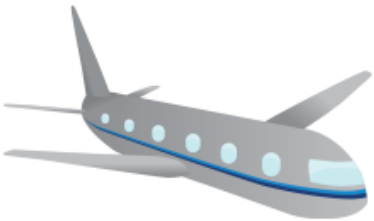
source:https://www.metabunk.org/larry-silversteins-9-11-insurance.t2375

What is an event ? How many events occurred at 9/11 – One or Two ?

Knowledge Management

9/11 ... matter of billions of USD

What is the trend of **Runway Incursion** incidents at an airline operator ?



Airline Operator

Unauthorized entering the runway

Incorrect entering (**without clearance**) **active** runway

Civil Aviation Authority

What is a dataset about?

What is inside a dataset?

Energy-efficient buildings

_id	building name	...
3	Atrium Flora	...
...	...	...

?

Are there
bus stops
or
large stores
in this dataset?

See OpenData portal of Prague OpenData portal of Prague

What is a building?

Building is a construction

- both above and below ground
- spatially compact
- with walls and roof
- with heating

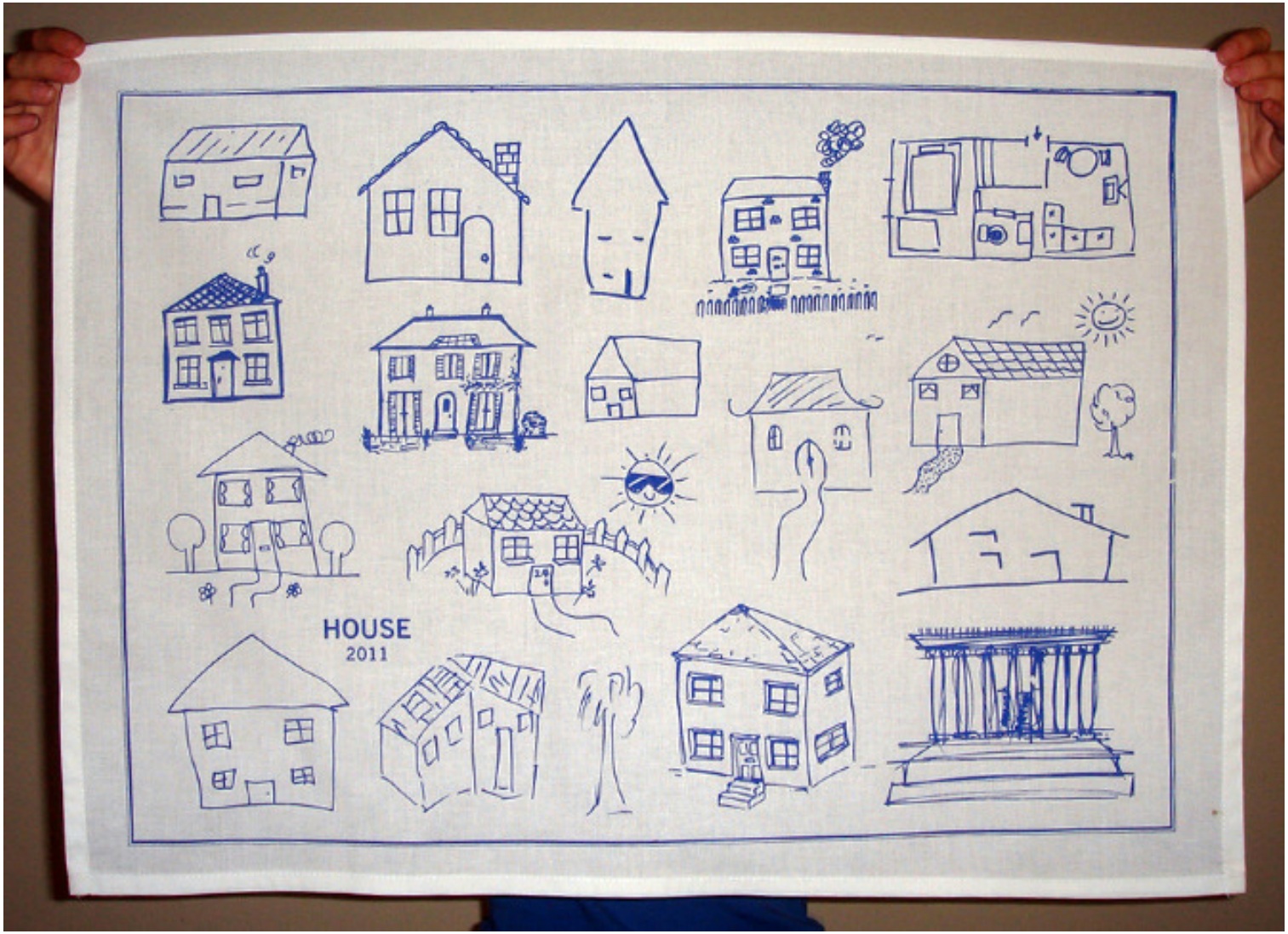
Act 406/2000 Coll., on Energy Management

Building is a construction

- above ground
- with solid foundations
- spatially compact
- with walls and roof

Act 256/2013 Coll, Cadastral Law

But things are even more complicated ...



What is a building?

1. ... is a **construction** which is **heated**.

2. ... is a **construction** to provide **protection** to their users or internal equipment and is typically **closed** and has a **permanent position**.

ČSN EN 15643-5 -Sustainability of construction works

Building

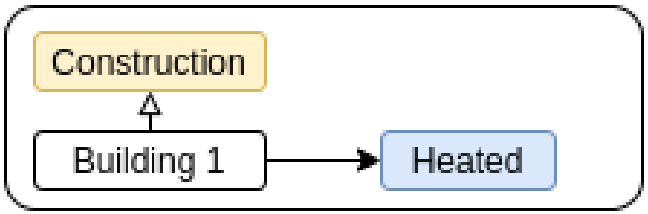
3. ... is a **construction above ground** which is **spatially-compact** and **closed by walls and roof**.

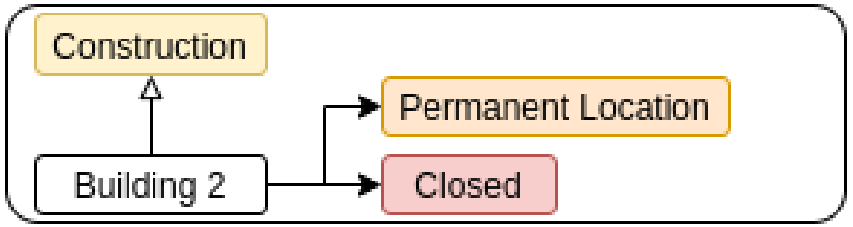
Act 256/2013 Coll., Cadastral Law

4. ... is a **construction above and below ground** which is **spatially-compact** and **closed by walls and roof** and is **heated or cooled**.

Act 406/2000 Coll., on Energy Management

What is a building?





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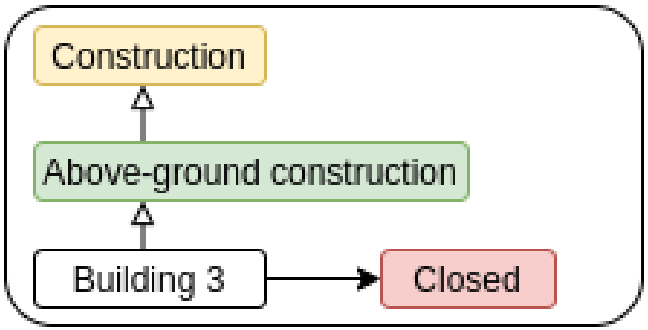
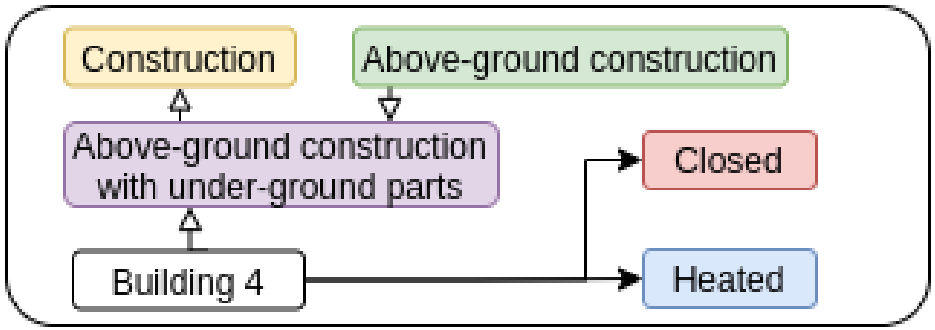
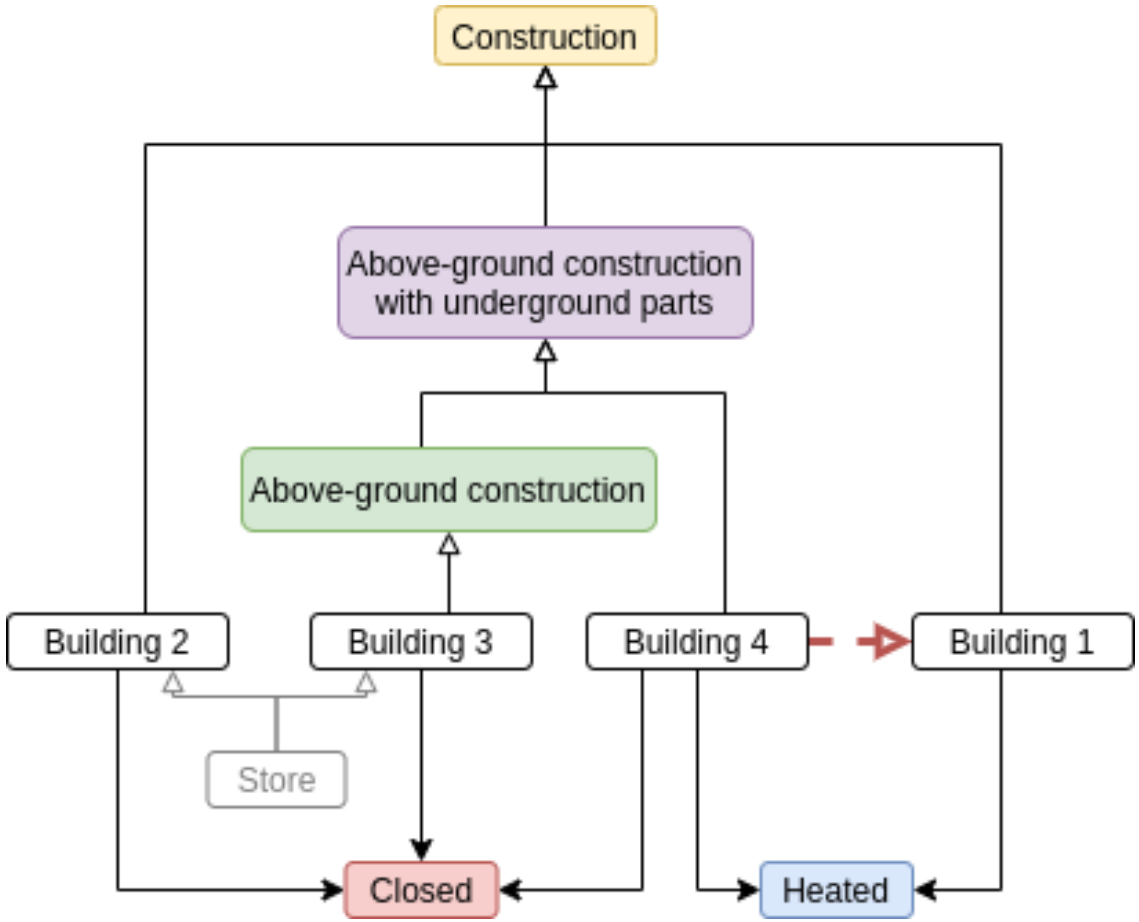


Act 256/2013 Coll., Cadastral Law



Act 406/2000 Coll., on Energy Management

New knowledge can be inferred



From conceptual models to ontologies

Ontological Conceptual Modeling

- a way to **capture** and **explain** meaning.
- the language must be understandable to non-experts (UML max)
- the language must be computable – we want to use the models to infer new knowledge or validate data

About ontologies

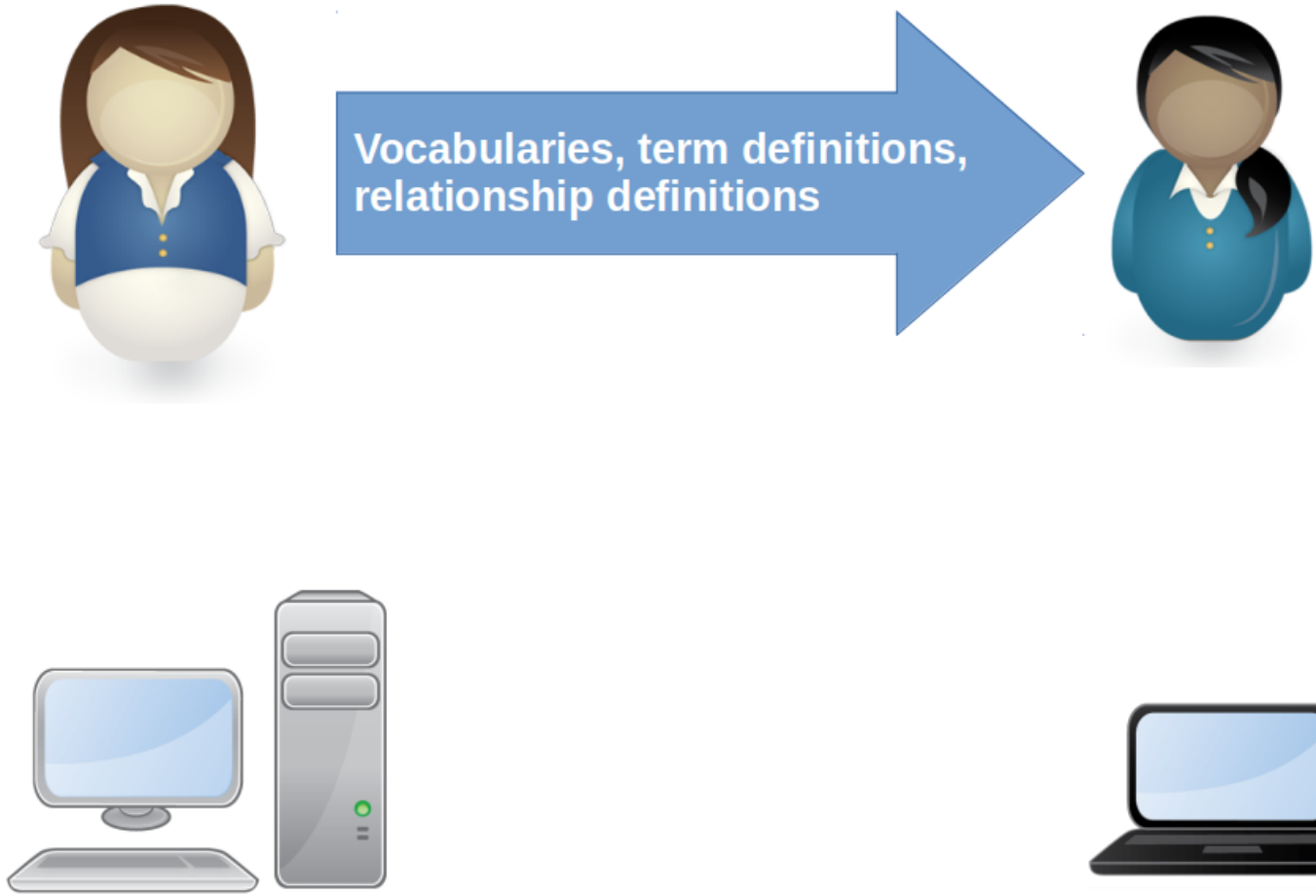
Ontologies

are **formal specifications of conceptualization**.

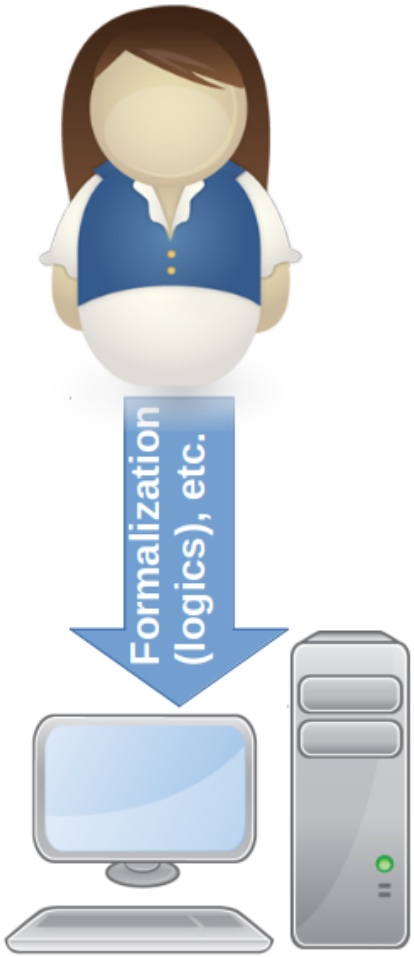
Ontologies help to stabilize the knowledge, to share meaning both among computers and among people. Use-cases include

- Data Integration
- Semantic Web
- Open (Linked) Data

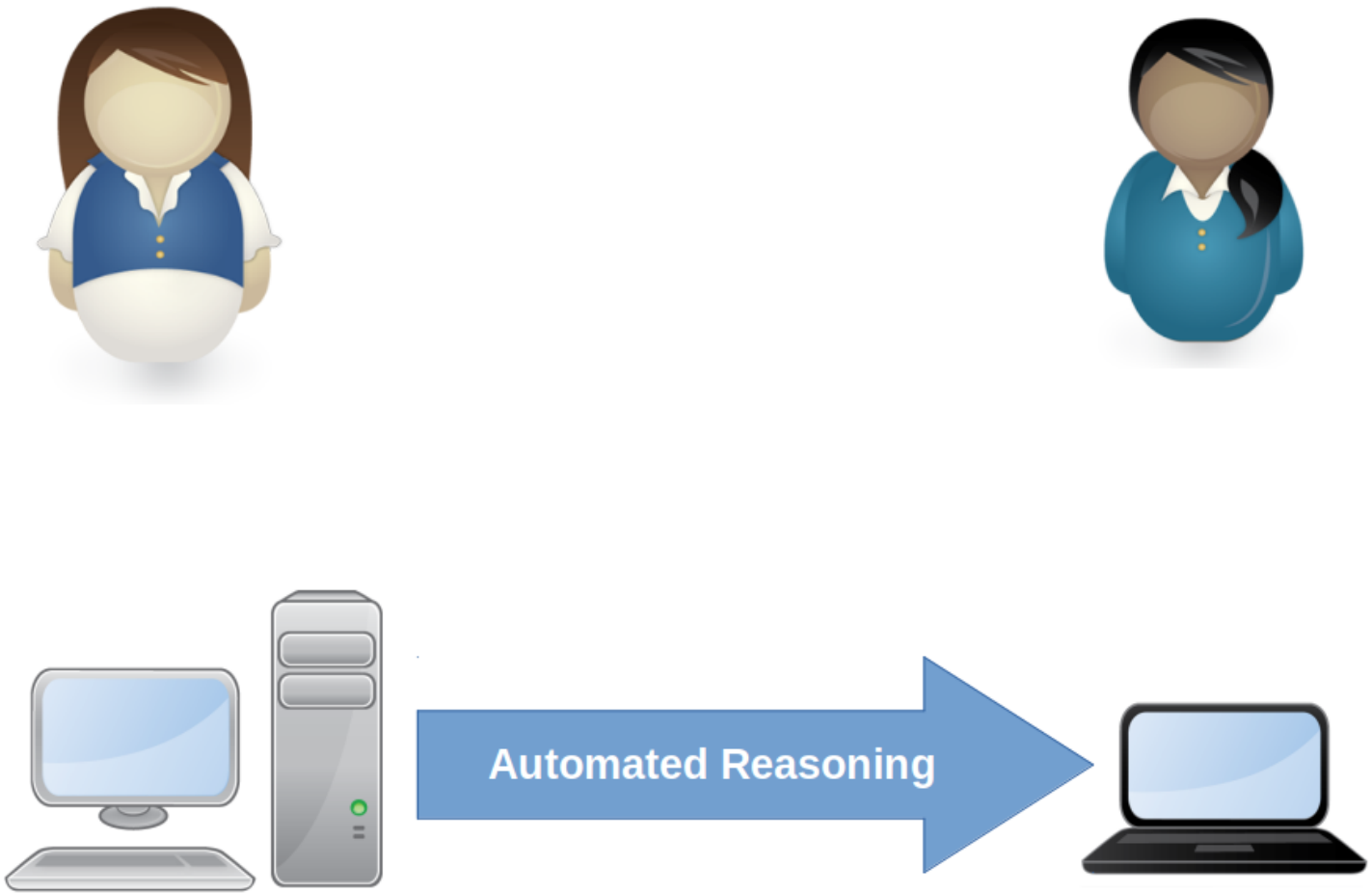
First, People Need to Understand Each Other



Second, People Need to Explain Things to Computers

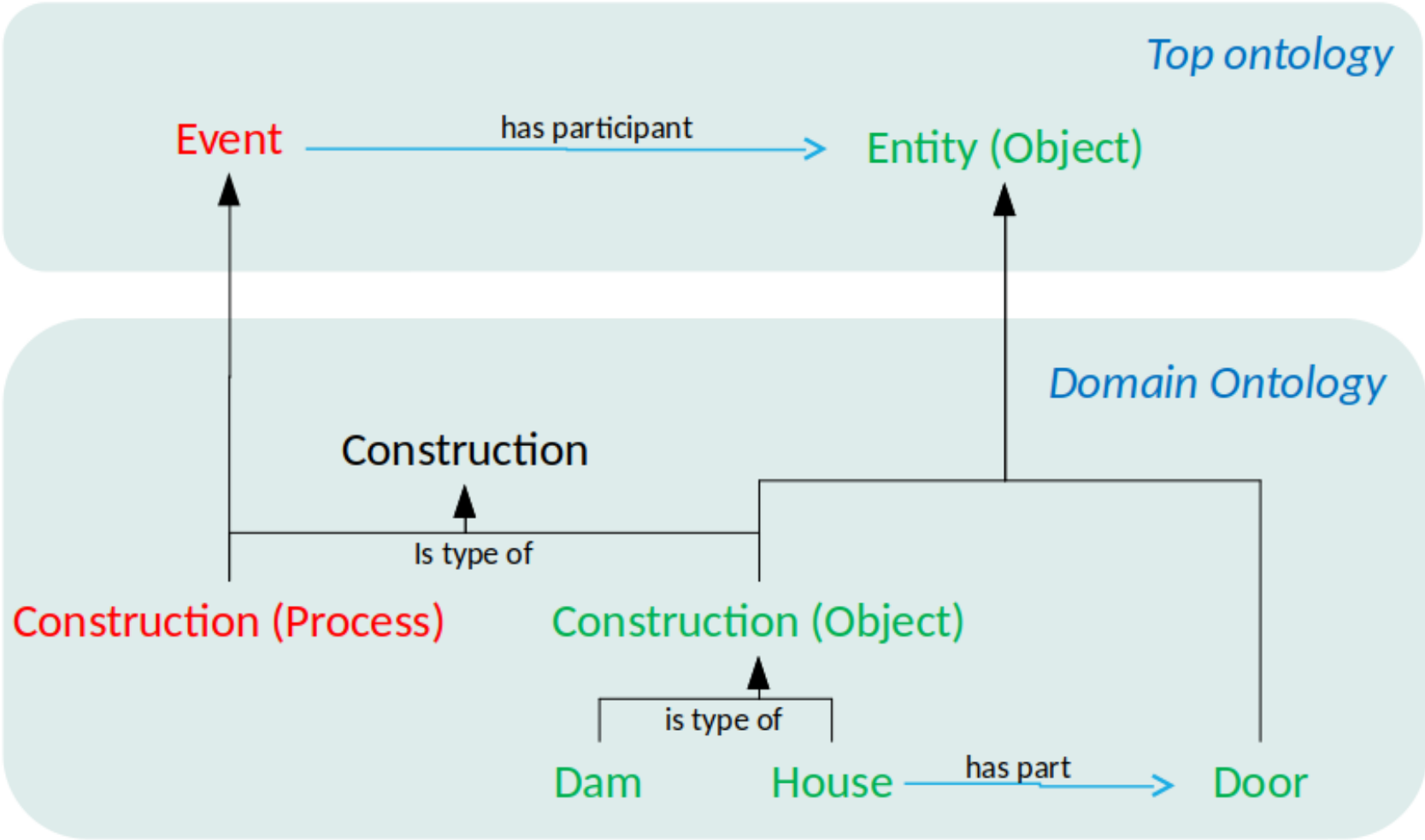


Third, Computers Can Understand One Another



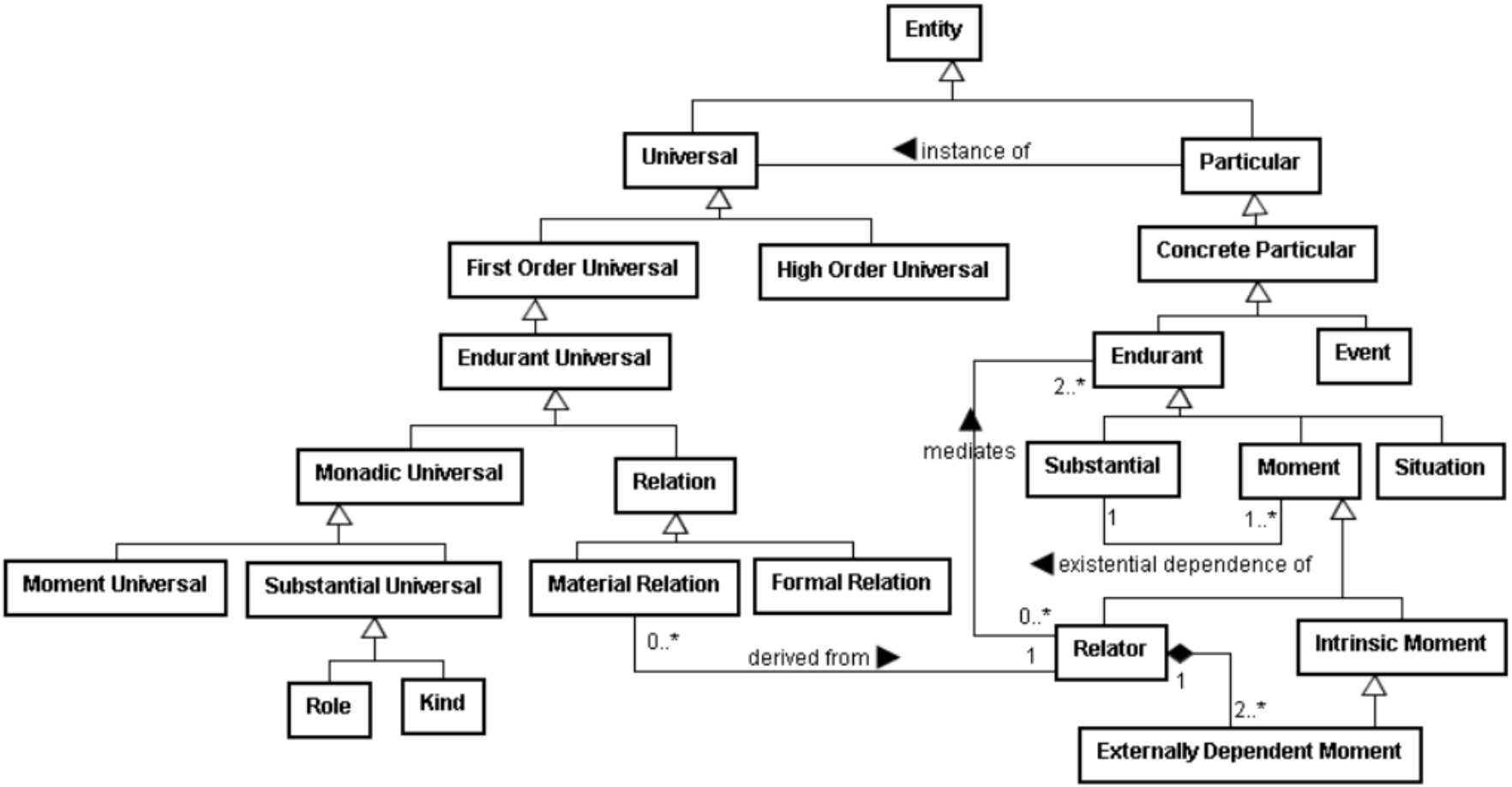
Ontology

Explicit Conceptualization of Shared Meaning



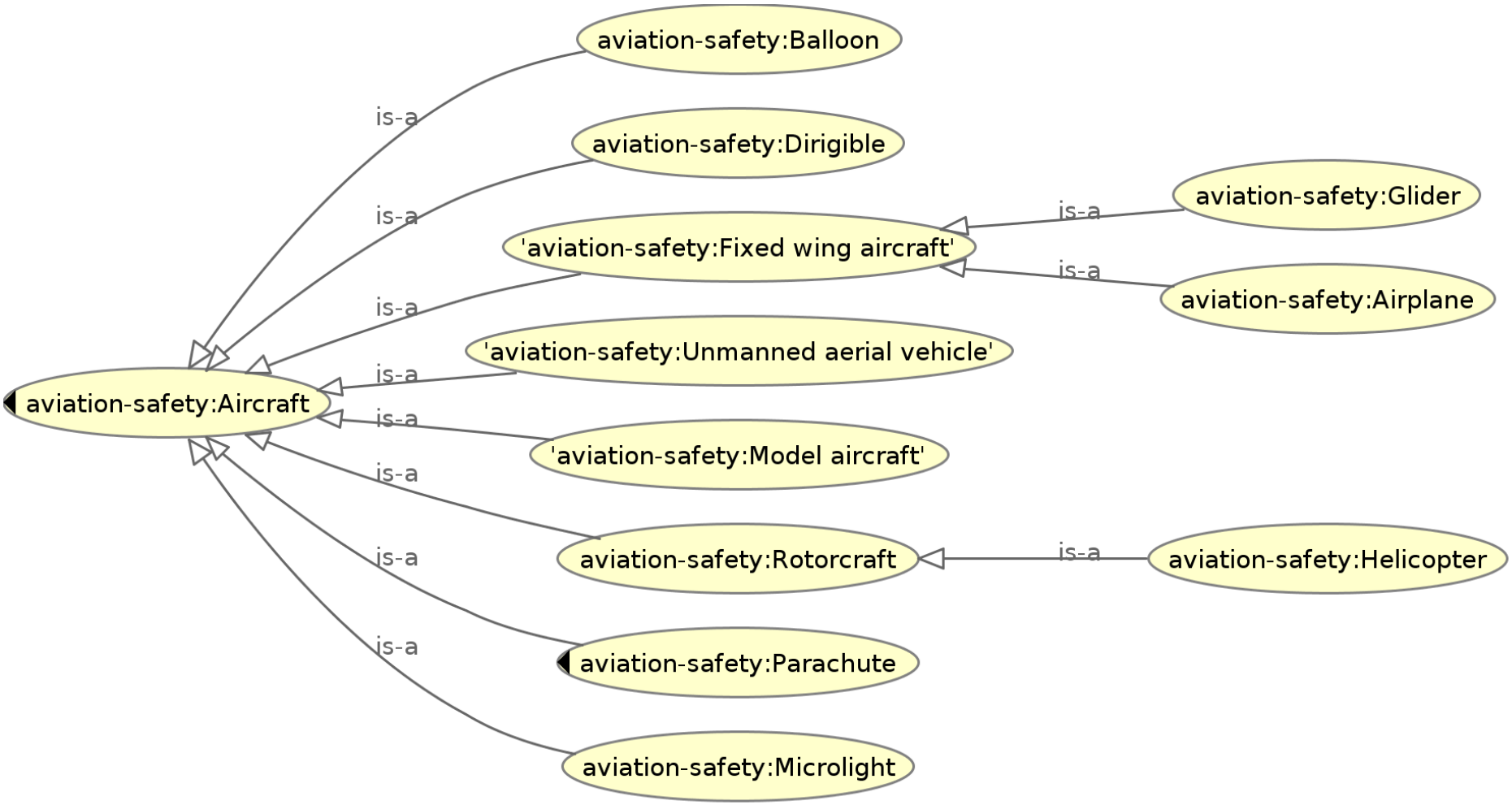
Example Top-Level Ontology

Small part of Unified Foundational Ontology (UFO)



Example Ontology Hierarchy

Each helicopter is also an aircraft.



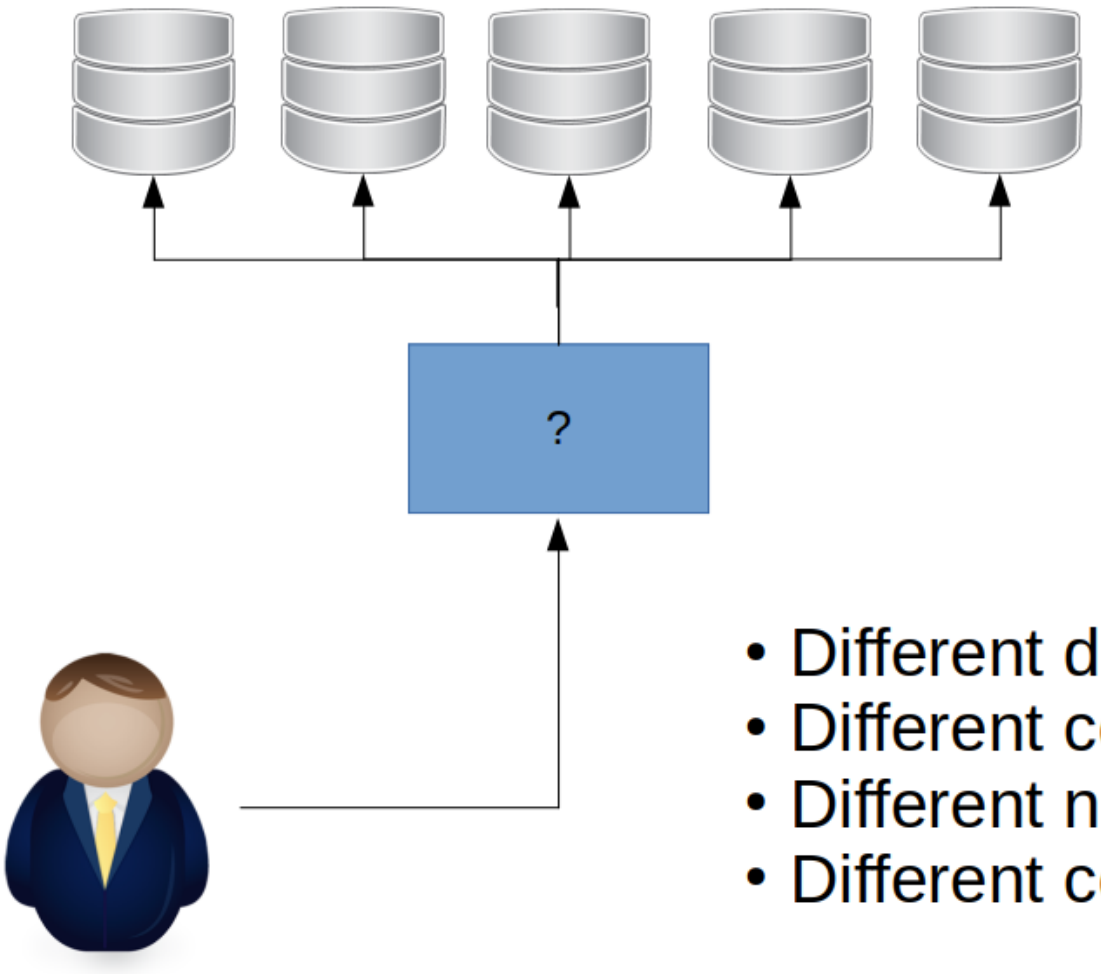
Ontologies ≠ Taxonomies

Taxonomies = just a single type of relationship.

Construction → broad meaning (object, construction site, process)
- **Dam**
- **House** → broad meaning (dwelling, construction)
  - **Door** → specific meaning (not type of house, but its part)

Ontologies for data integration

Data Integration Scenario



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- Different communication speeds
- Different names for a concept
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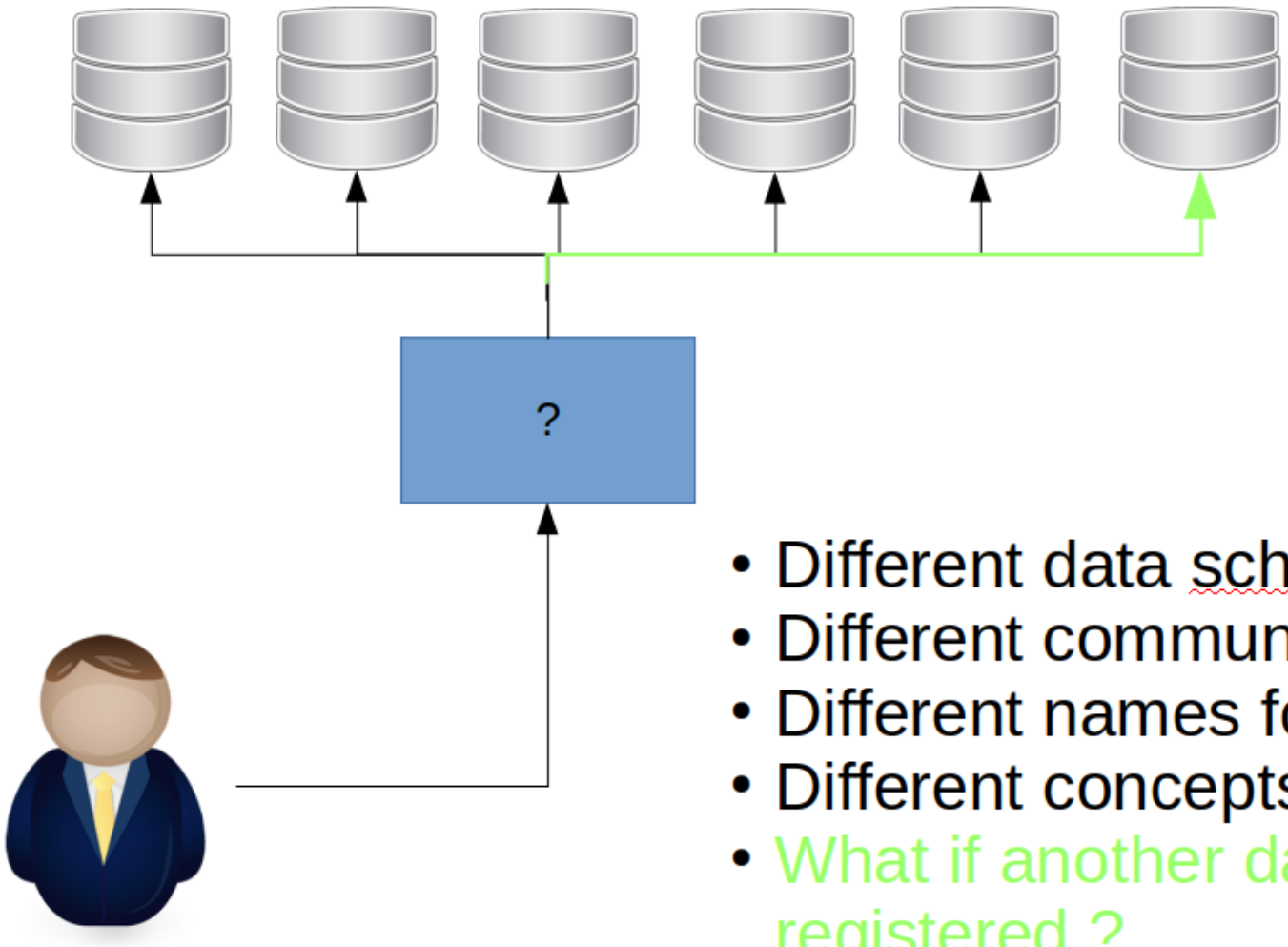
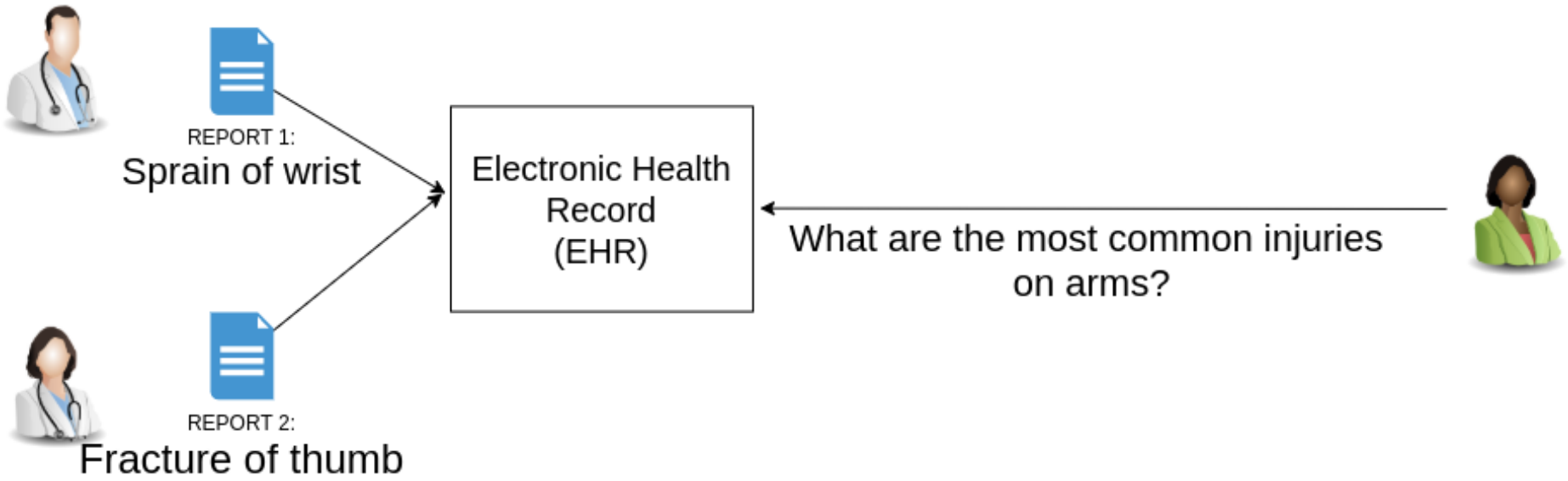


- Different data schemas
- Different communication speeds
- Different names for a concept
- Different concepts for one term
- What if another data source gets registered ?

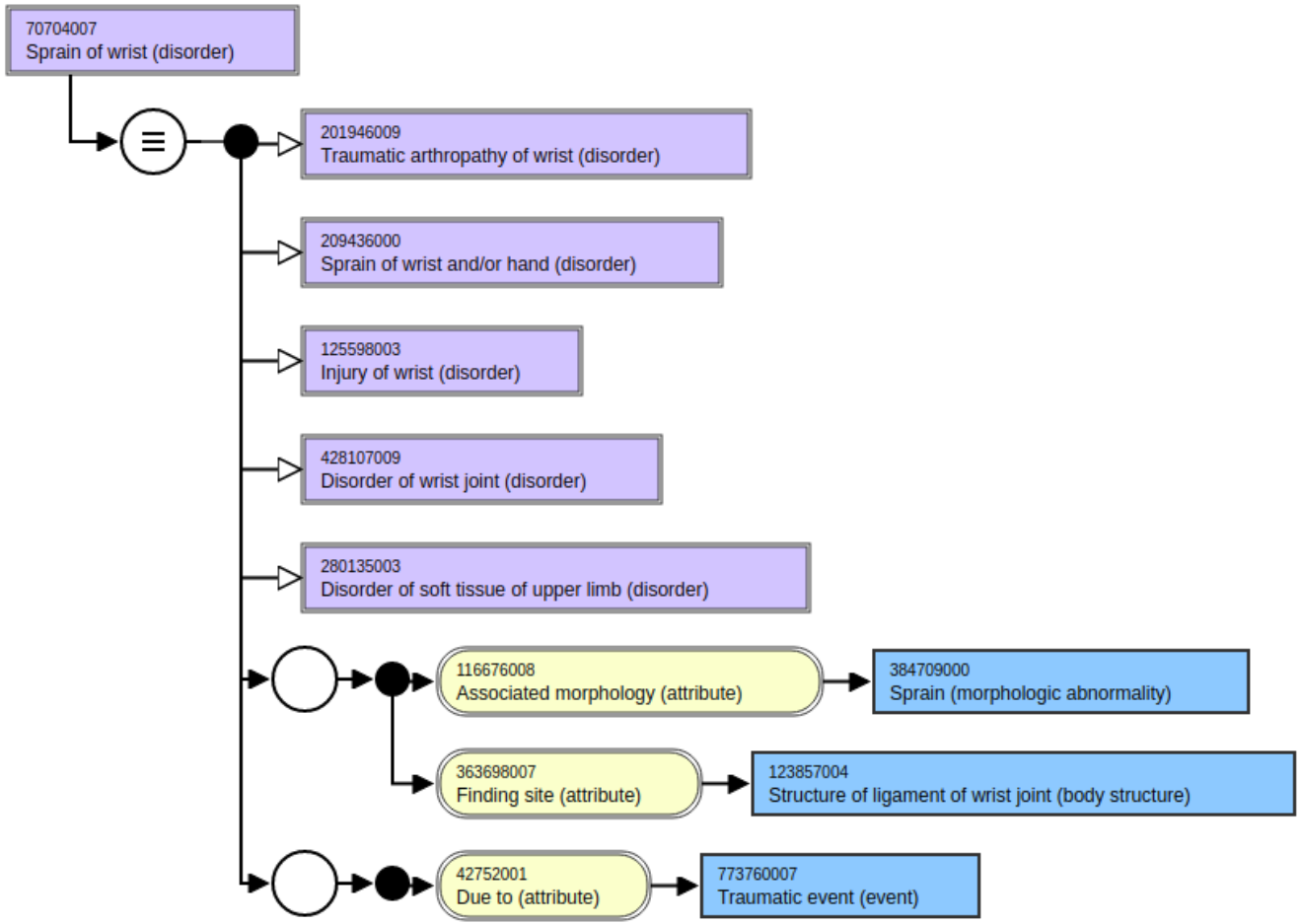
Use-case – HealthCare Data Integration



SNOMED-CT

Systematized Nomenclature of Medicine - Clinical Terms

- $\sim 300k$ clinical concepts
- international standard – adopted e.g. in UK, USA, Australia
- uses ontology reasoning to classify/query the concepts



SNOMED-CT

Systematized Nomenclature of Medicine - Clinical Terms

https://browser.ihtsdotools.org/?perspective=full&conceptId1=70704007&edition=MAIN/2020-07-31&release=&languages=en

Semantic Web

Current Web vs. Semantic Web

- SoA – semistructured HTML or XML data. There is vast amount of search engines like Google, Yahoo, MSN, etc. Many of them are invaluable, but as the engines use just keywords and/or some natural language preprocessing methods, the search results contain lots of irrelevant results that need to be processed manually.

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  - more efficient search engines to handle SW languages – new inference techniques for these languages,

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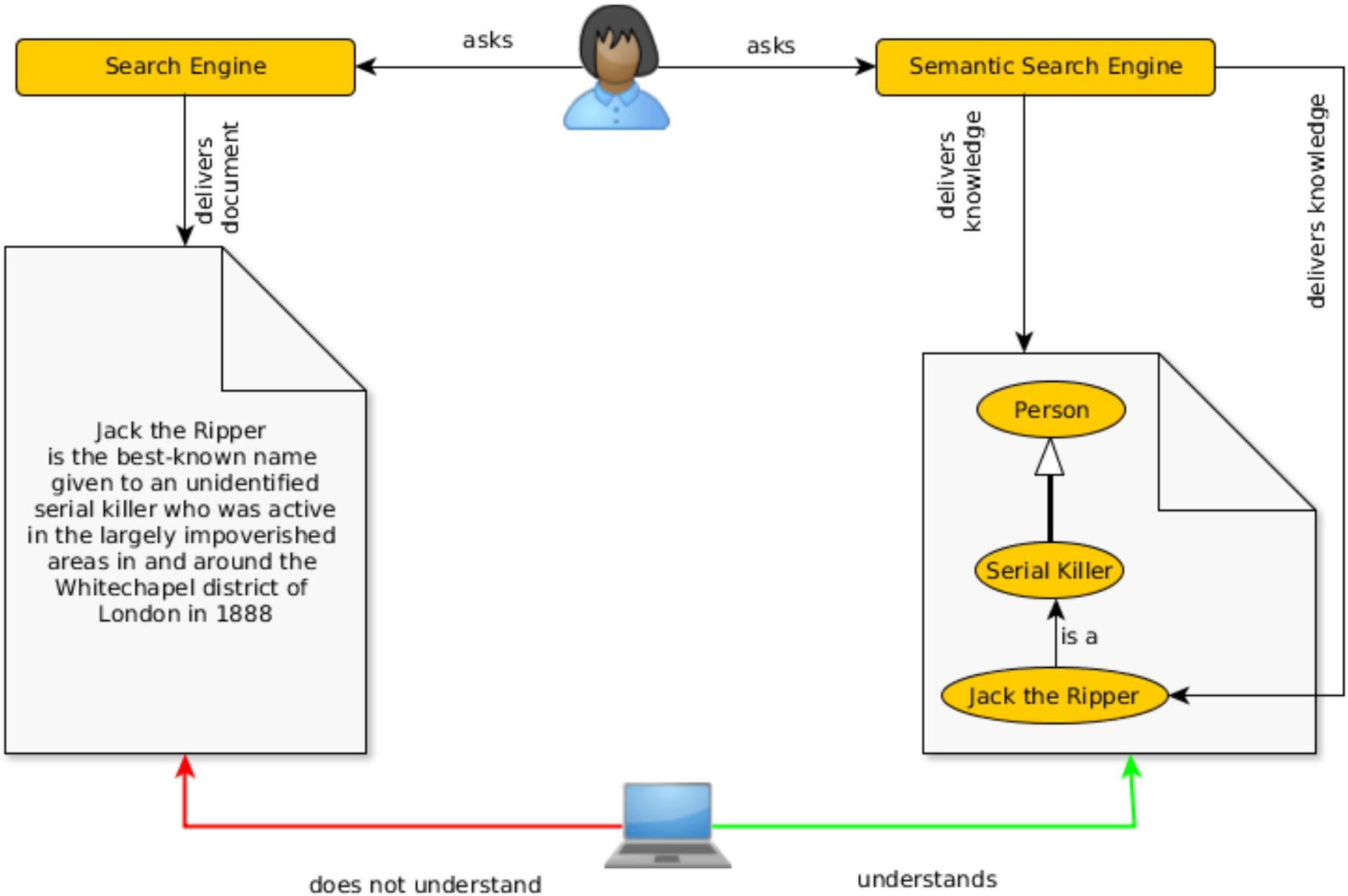
- **the amount of (unstructured) data is steadily growing**

Semantic search



Ontologies and Semantic Web

ontology has many definitions, but let's consider it **a formal representation of a complex domain knowledge that is shared with others to ensure intelligent system interoperability,**

semantic web is *an extension of the current Web in which information is given well-defined meaning, better enabling computers and people to work in cooperation.* (cit. Semantic Web. Tim Berners-Lee, James Hendler and Ora Lassila, Scientific American, 2001)

Idea of Semantic Web

- W3C web page - `http://www.w3.org/2001/sw`

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- Reasoners for OWL can be used for derivation in RDF(S)

Unique Data Identification – URIs

Semantic web speaks about resources.

URI is a unique identifier for adressing web resources in the form

```
<scheme name> : <hier. part> [ ? <query> ] [ # <fragment> ]
```

. HTTP scheme is used typically.

URN a URI with *scheme name* equal to 'urn'; used e.g. in SWRL atom identification,

URL a URI that can be resolved to a content using the protocol (e.g. HTTP),

IRI generalization of URIs allowing non-ascii characters. IRI is the standard identifier for OWL.

Open World Assumption

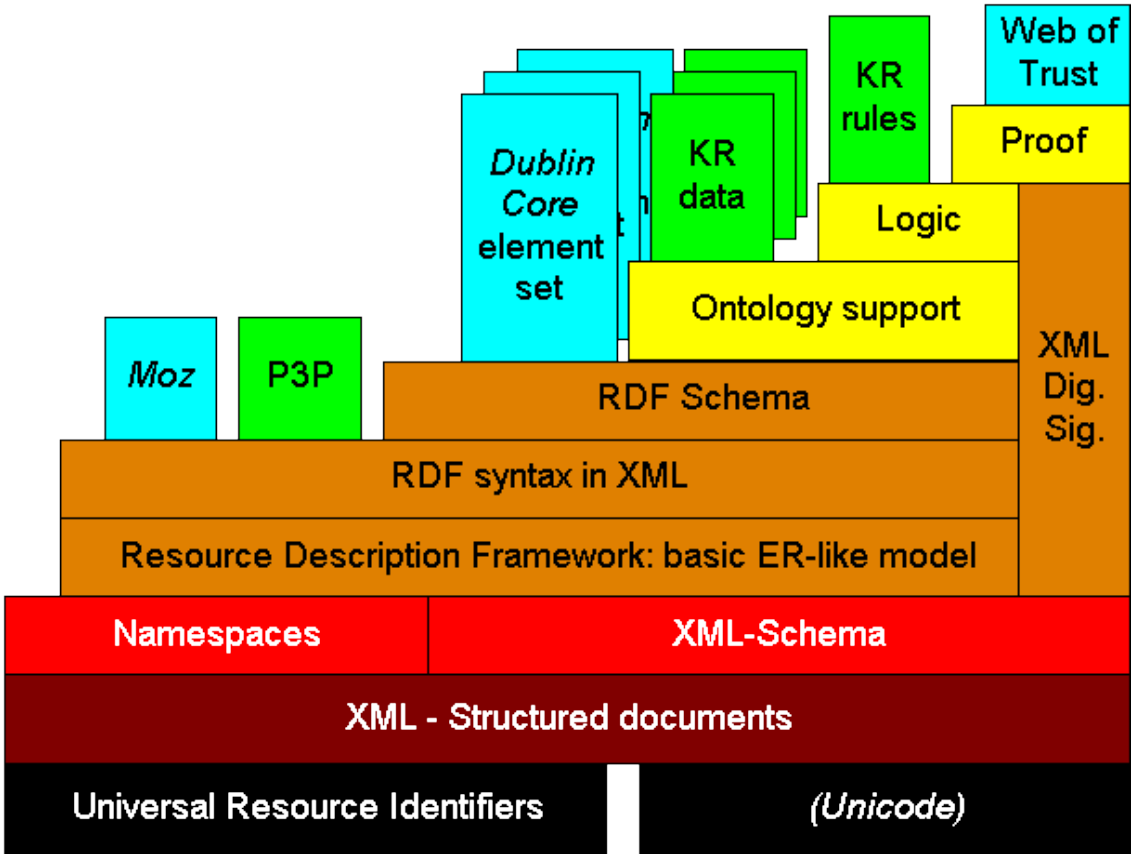
The semantic web inference must take into account that we handle *incomplete knowledge*.

Description

Open world (OWA): Everything that cannot be proven is unknown,
Closed world (CWA): Everything that cannot be proven is false.

Statement : "John is a Man."
Query: "Is Jack a Man ?"
OWA Answer: "I don't know."
CWA Answer: "No."

Semantic Web Stack



Taken from `http://www.w3.org/2000/Talks/0906-xmlweb-tbl/slide9-0.html`, by Tim Berners Lee.

Linked Data

How to publish data related to other ?

Based on semantic web principles, Linked Data provide means to efficiently connect data created by different publishers.

- Web of Documents – WWW
  - webpage – readable by human
  - identifiers – IRI
  - transfer protocol – HTTP
  - unified language – HTML
- Web of Data – Linked Data
  - webpage – readable by machine
  - identifiers – IRI
  - transfer protocol – HTTP
  - unified language – RDF

Linked Data [**Heath2011**] is a method for publishing structured and interlinked data on the web, building up on URIs, HTTP and RDF technologies.

Linked Data Principles

1. Use URIs as names for things.
2. Use HTTP URIs so that people can look up those names.
3. When someone looks up a URI, provide useful information, using the standards (RDF, SPARQL).
4. Include links to other URIs, so that they can discover more things.

(Tim Berners-Lee, 2009 – `http://www.w3.org/DesignIssues/LinkedData.html`)

URIs satisfying the third point are **dereferencable**.

Document vs. its Content

When designing a URI scheme it is necessary to ensure proper distinction between a **document** and its **content**

Example

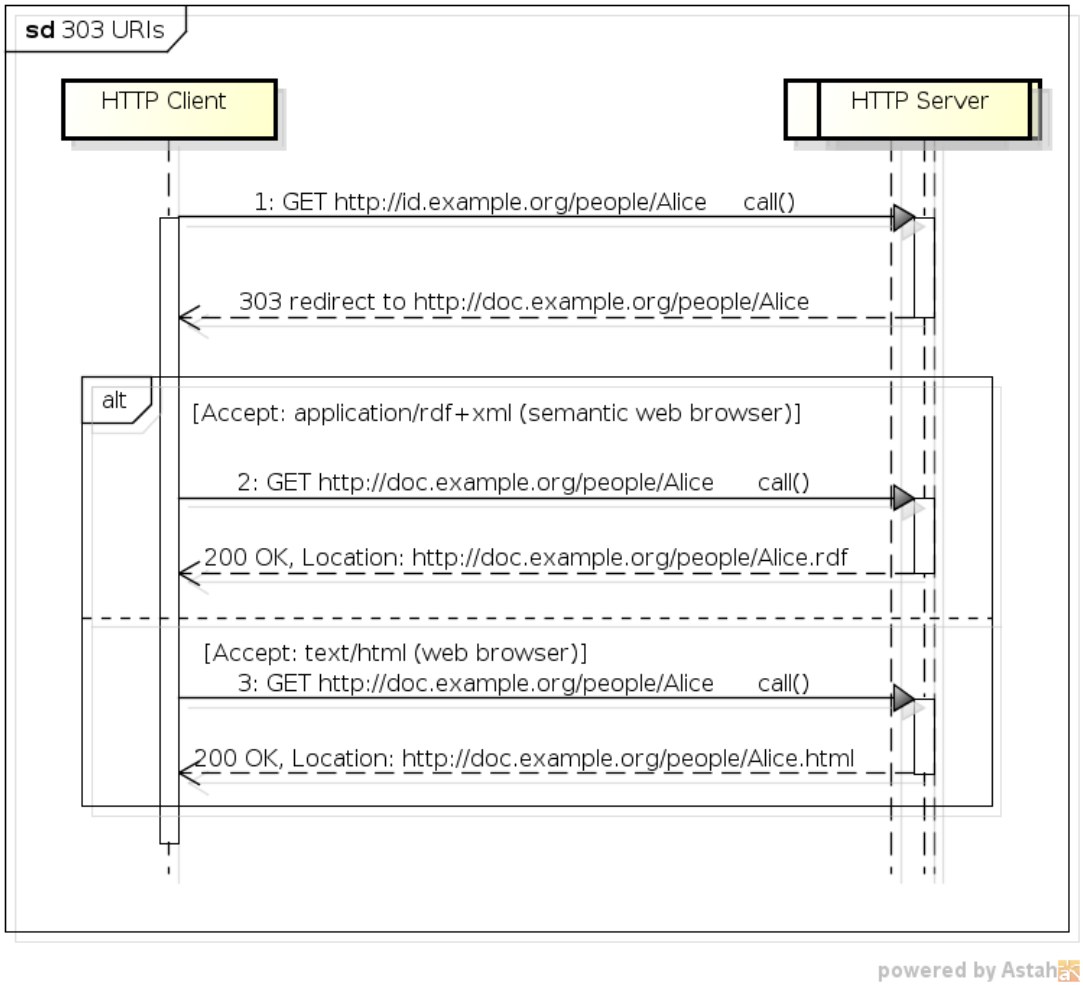
```
@prefix people: <http://example.com/people/>
people:John people:likes people:Mary
```

Is `http://example.com/people/Mary` a web document or a resource ? (Consider semantic consequences of each option).

This is handled by two strategies – 303 URIs and Hash URIs, each being suitable for different scenarios.

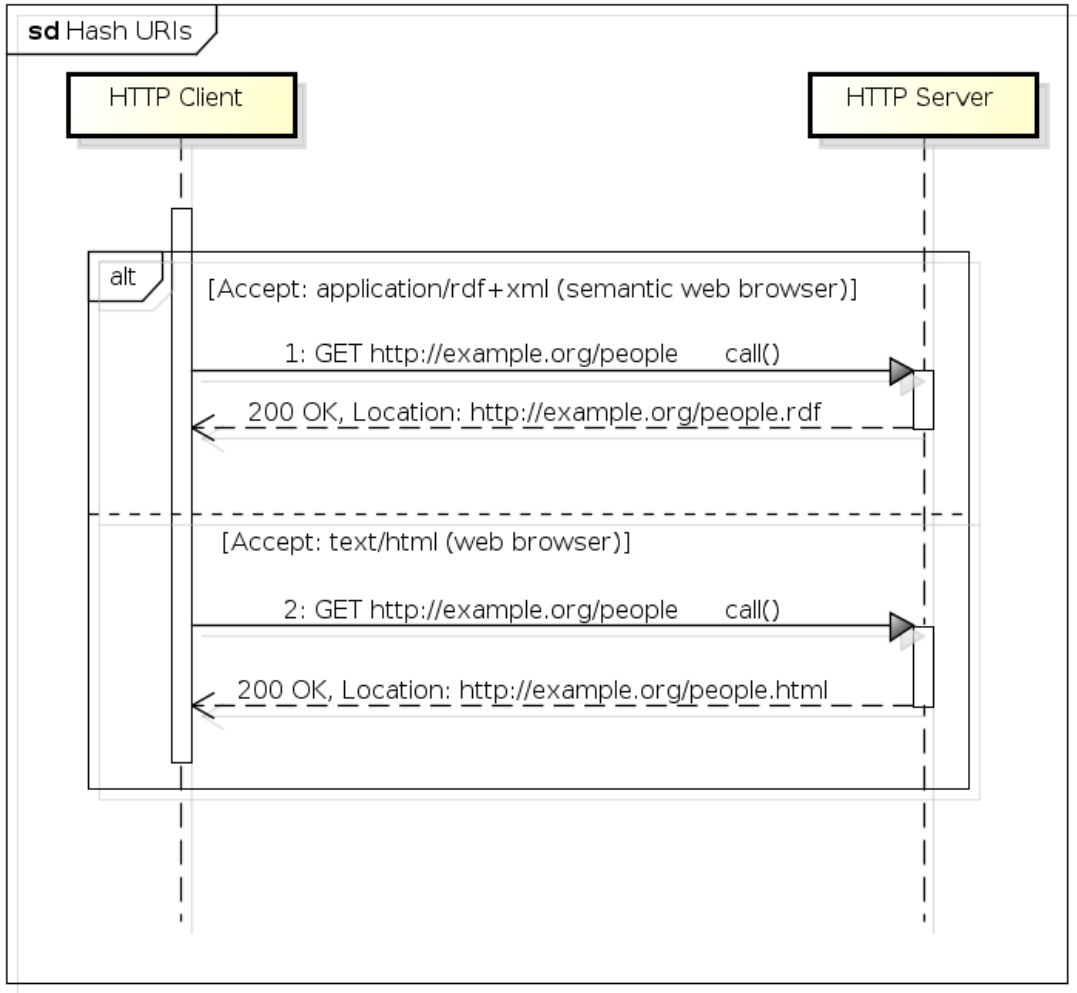
303 URIs

- 303 URIs are of the form `http://id.example.org/people/Alice`
- HTTP server sends 303 redirect to the corresponding **document** of the requested **resource**.
- HTTP client makes another request, based on Accept headers, the RDF/HTML version is delivered.



Hash URIs

- Hash URIs are of the form `http://example.org/people#Alice`
- HTTP server sends the whole **document** of either RDF or HTML type based on Accept headers.
- Within the document, the HTTP client gets the particular entity after the hash symbol.



303 URIs vs. Hash URIs

Hash URIs are suitable for small datasets that will hardly grow up,

303 URIs are suitable for large datasets for the sake of good performace.

Reason

The fragment part of an URL (after #) is evaluated on the HTTP client (not the HTTP server), so the HTTP client must fetch all data first and then filter them for the subsequent use locally.

Linked Data Platforms

Pubby is a simple Linked Data publication server connectable to SPARQL endpoints,

Callimachus is an application server for linked data applications. To be explored in the tutorials,

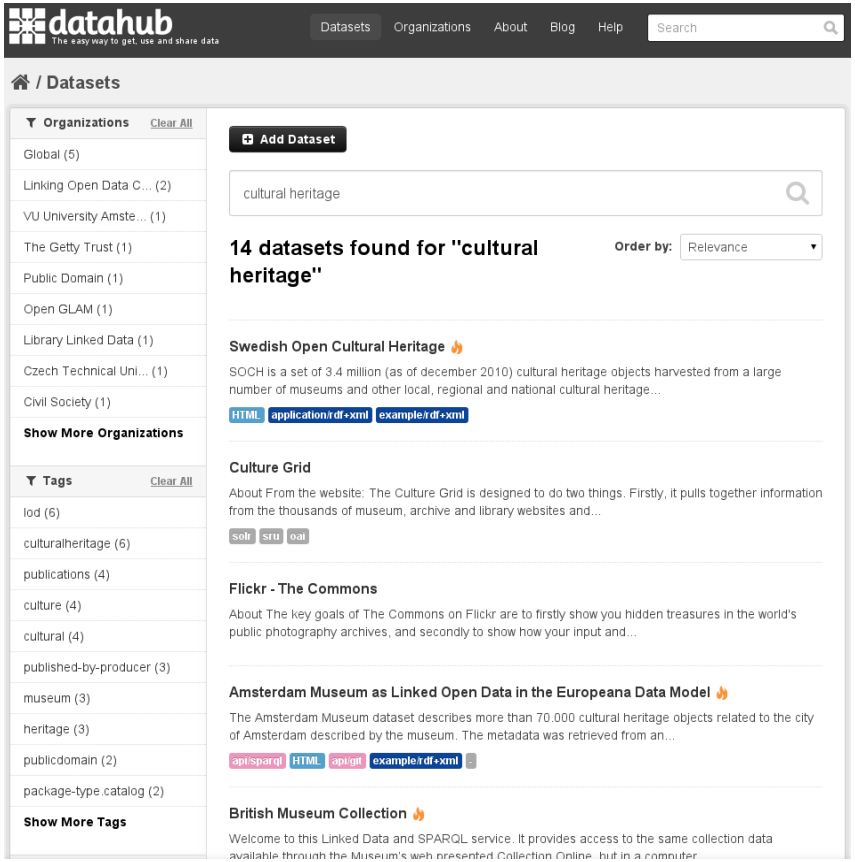
Marmotta is a platform for publishing Linked Data (contributed from Linked Media Framework),

D2R is a platform for publishing relational database data in the form of Linked Data.

Use-case: Open Data

CKAN and DataHub

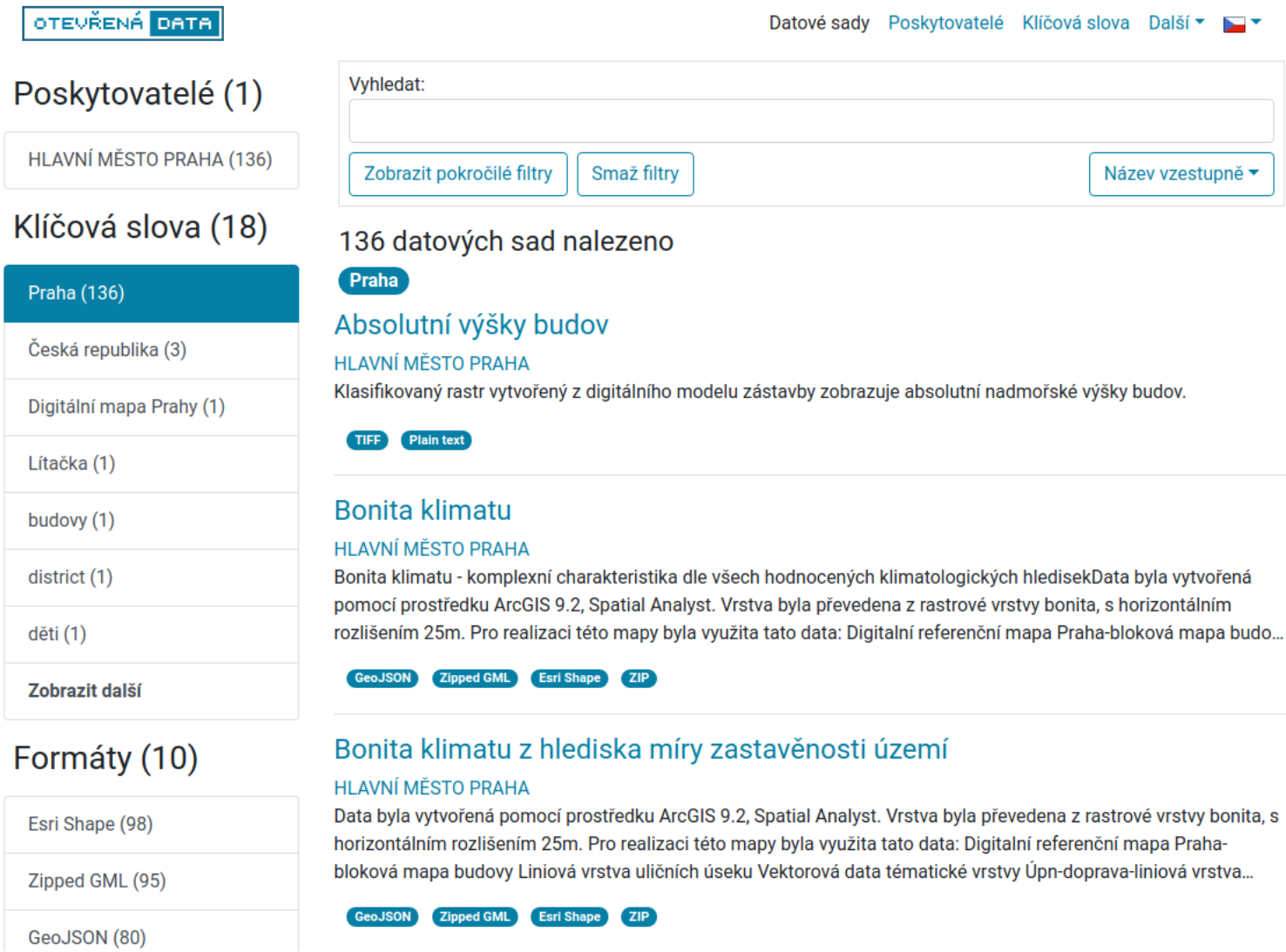
CKAN (`http://ckan.org/`) is an open-source data portal for publishing, sharing and search of datasets.
It is prominently hosted at `http://datahub.io`.
Datasets on DataHub can be submitted to the Linked Data Cloud.



Datasets search

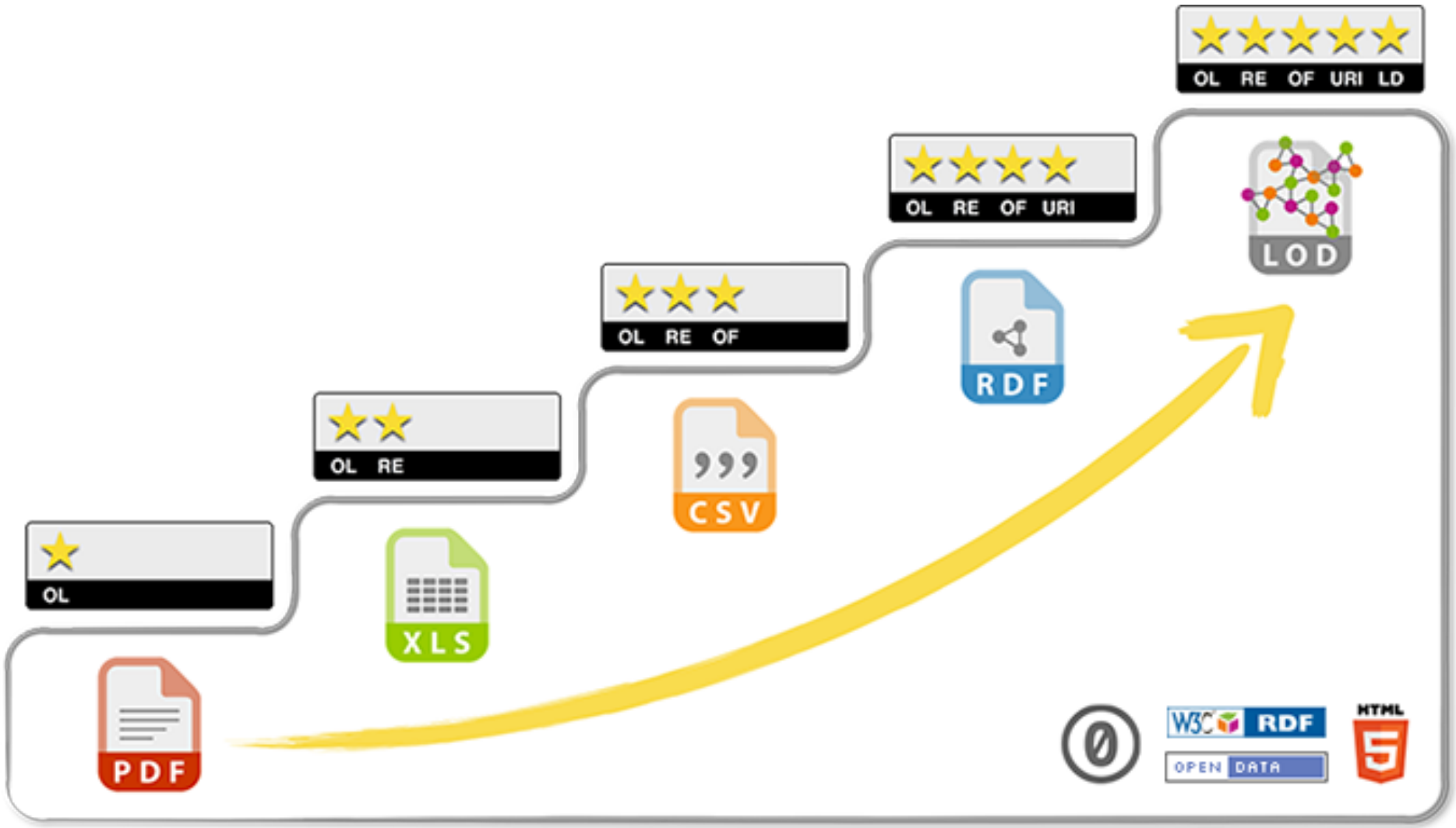
`https://datahub.io/search?q=coronavirus`

Národní katalog otevřených dat (NKOD)



https://data.gov.cz/

Open Data Levels



Taken from `http://5stardata.info/cs/`.

Open Data Levels – description

- ⋆ Available on the web (whatever format) but with an open licence, to be Open Data
- ⋆⋆ Available as machine-readable structured data (e.g. excel instead of image scan of a table)
- ⋆⋆⋆ All the above, plus – Non-proprietary format (e.g. CSV instead of excel)
- ⋆⋆⋆⋆ All the above, plus – Use open standards from W3C (RDF and SPARQL) to identify things, so that people can point at your stuff
- ⋆⋆⋆⋆⋆ All the above, plus – Link your data to other people's data to provide context

(Tim Berners-Lee, 2009 – `http://www.w3.org/DesignIssues/LinkedData.html`)

From Open Data to Linked Data

★★★ ★★★★

Aircraft (CAA)

s/n	type	**operator_ic**
1	Boeing 737	1234567
2	Airbus 319	9876543

→ ?

Companies (Business Registry)

company_ic	company_name
1234567	Best Airlines
9876543	Funny Flight School

From Open Data to Linked Data

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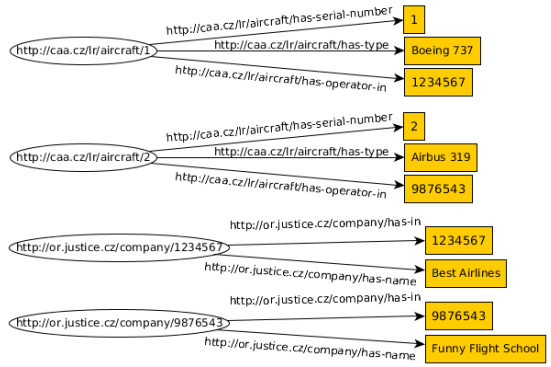
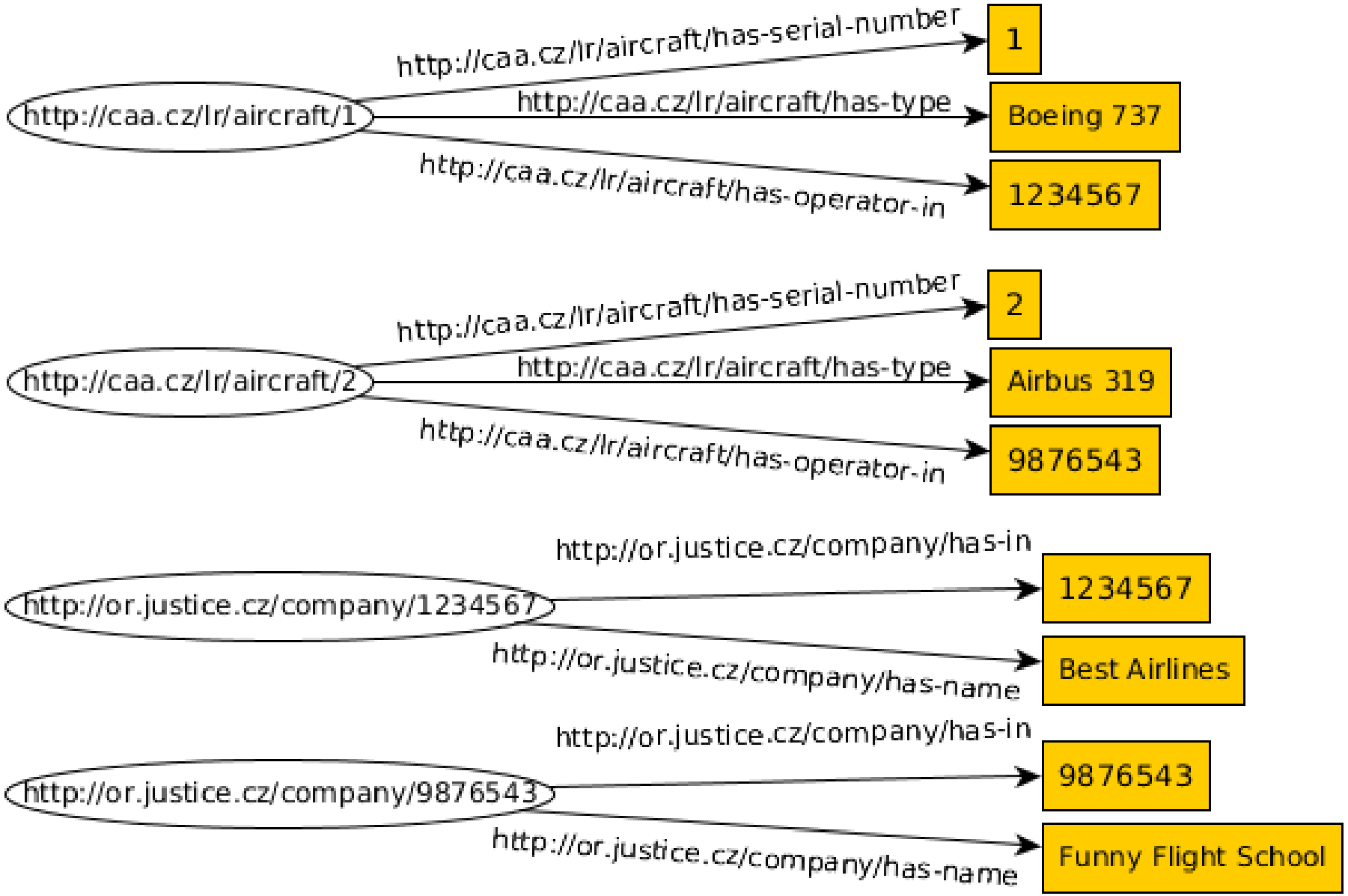
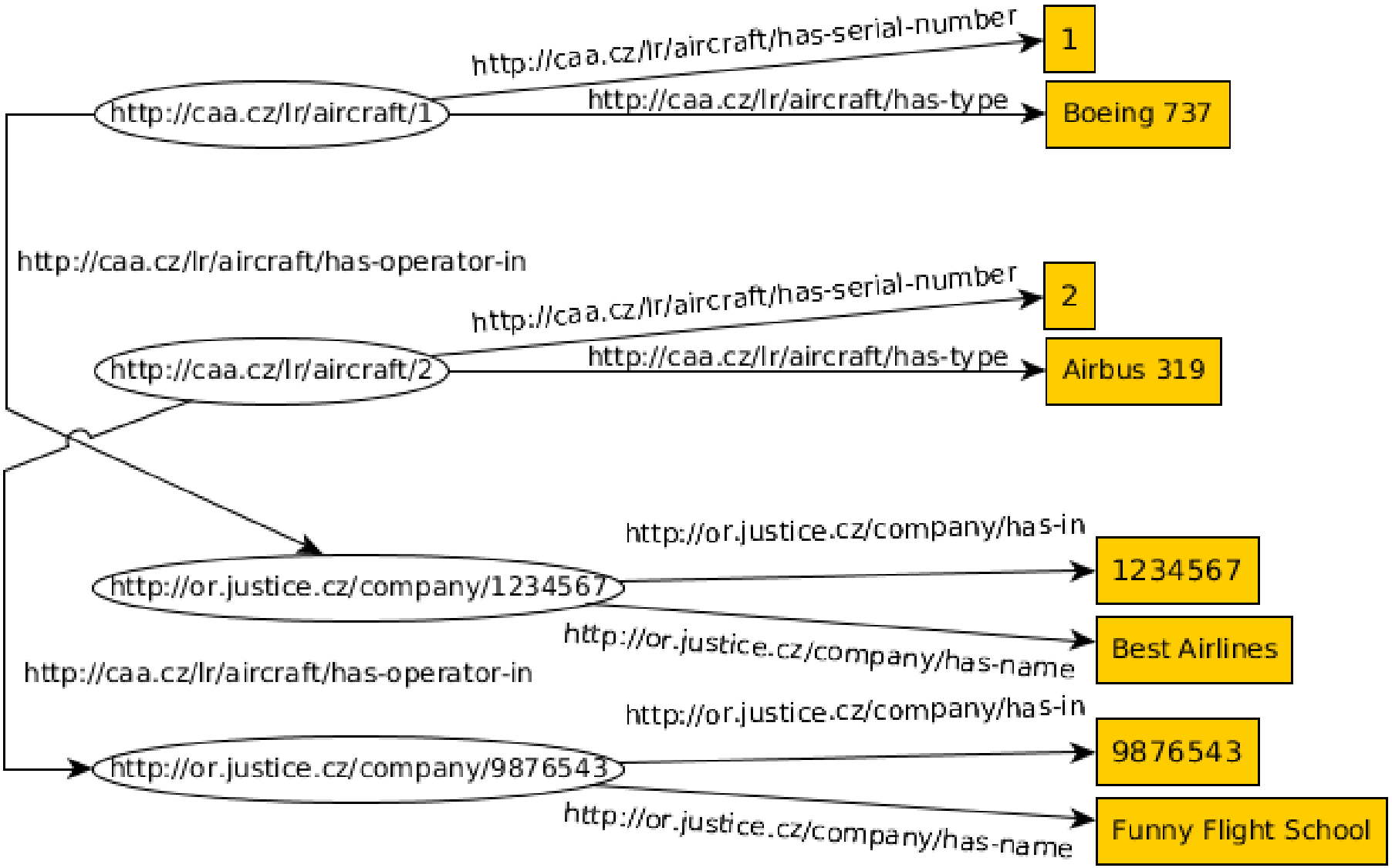


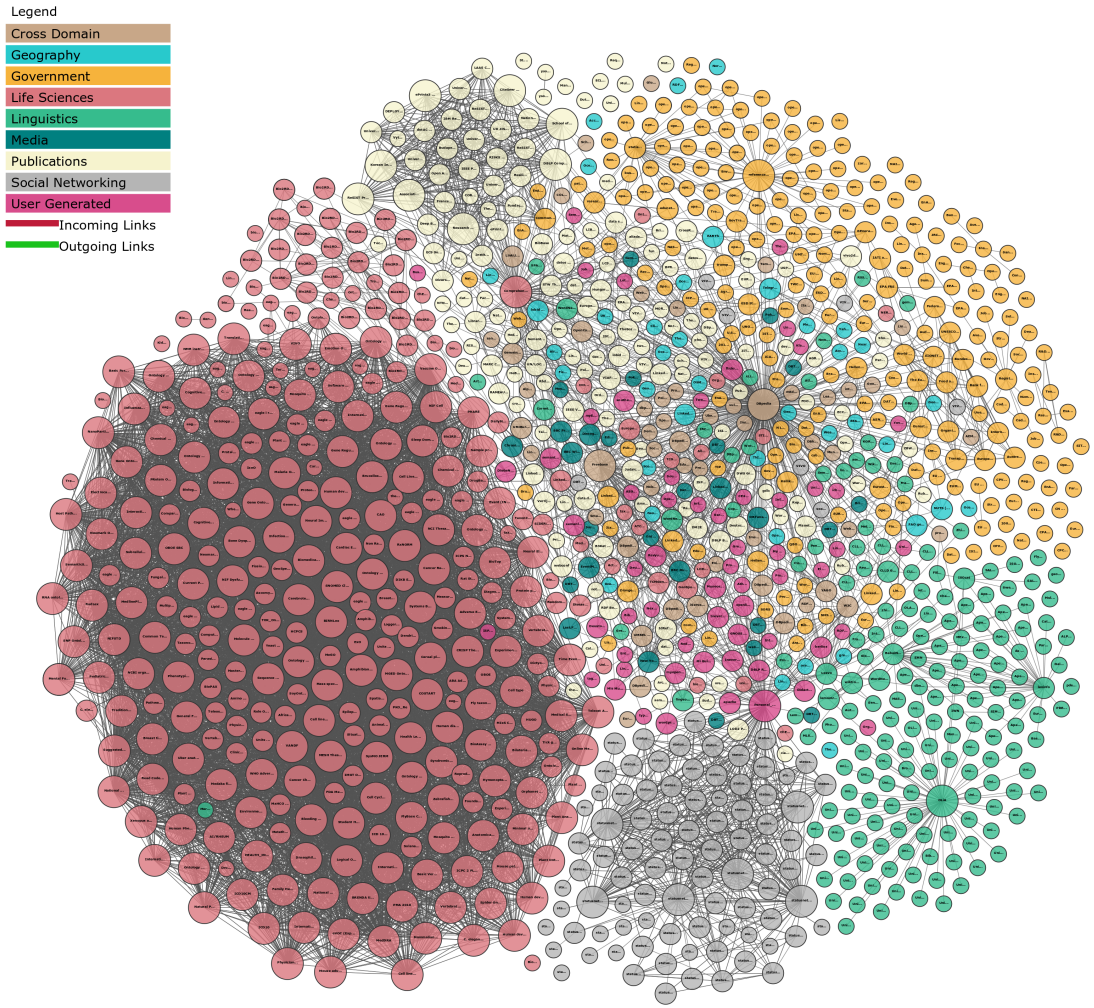
From Open Data to Linked Data (4*)



From Open Data to Linked Data (5*)



Linked Open Data Cloud



http://lod-cloud.net/,2018

Linked Data vs. Open Data

linked, not open – enterprise data, master data

linked, open – 5* data

not linked, open – typical case in OpenData

not linked, not open – we do not care

Semantic Web Adopters

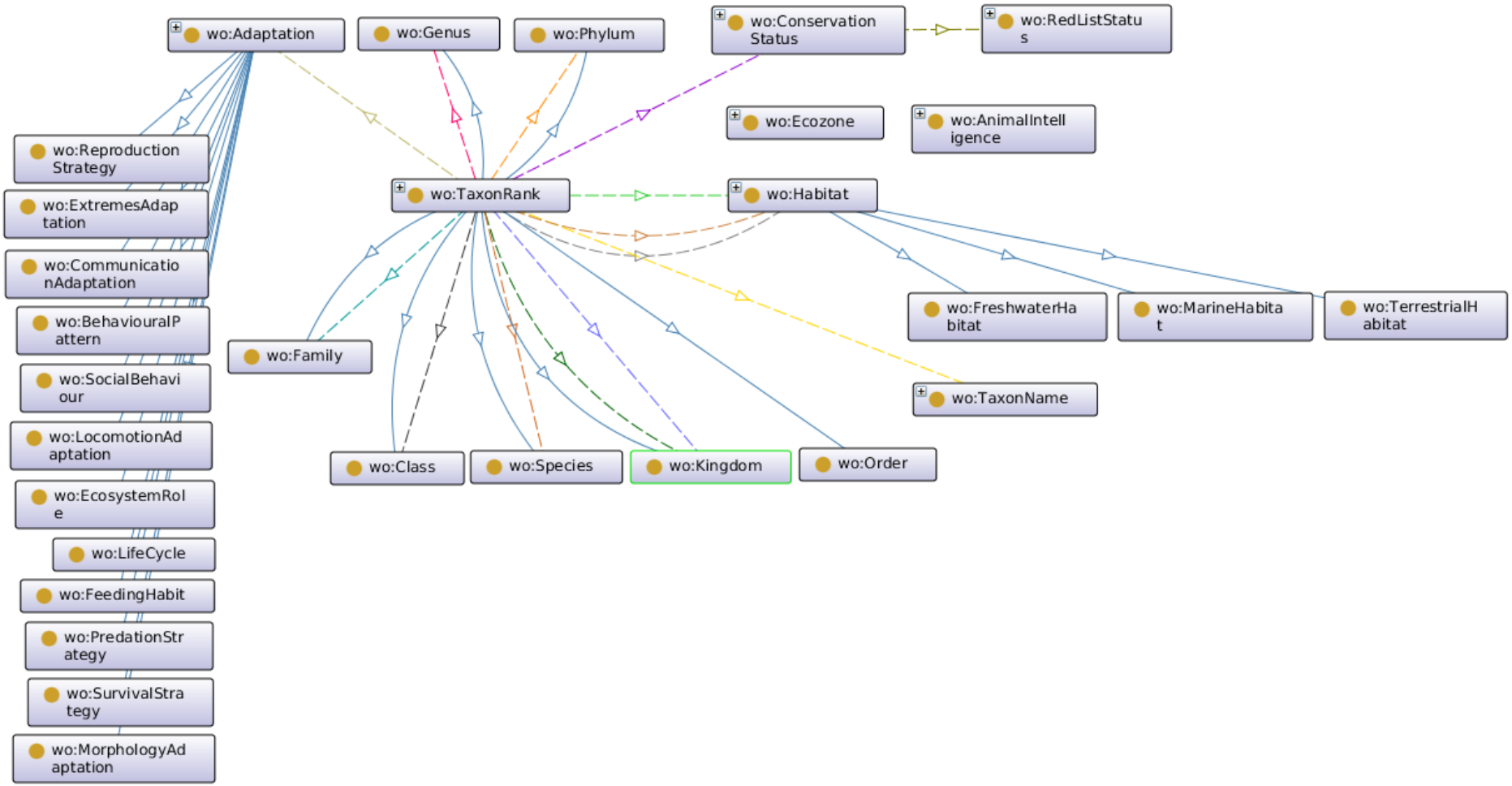
Public Sector

- national governments (e.g in Czechia - DIA - `https://data.gov.cz`)
- EU administration - `https://data.europa.eu/en/publications/datastories/linking-data-dataeuropaeu`
- US administration - `https://data.gov/`
- ...

Private Sector

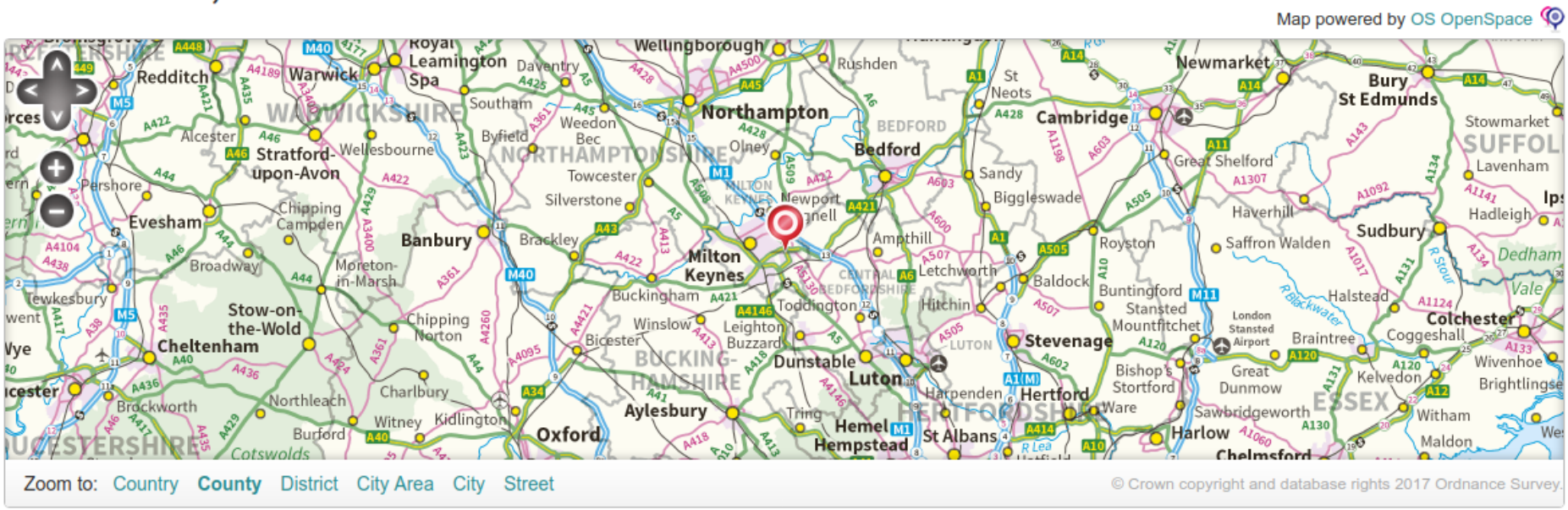
- Google – *Knowledge Graph* (although they do not name it Semantic web – `http://semanticweb.com/google-just-hi-jacked-the-semantic-web-vocabulary_b29092`)
- Microsoft – Satori, `http://research.microsoft.com/en-us/projects/trinity/query.aspx`
- Facebook – Open Graph Protocol `http://ogp.me/`
- BBC – various datasets in RDF – `http://www.bbc.co.uk/developer/technology/apis.html`
- Ordnance Survey – geographic datasets in RDF – `http://data.ordnancesurvey.co.uk`

BBC Wildlife Ontology



Ordnance Survery Linked Data

Kents Hill, Monkston and Brinklow



Kents Hill, Monkston and Brinklow is a Parish in Milton Keynes.

Objects related to "Kents Hill, Monkston and Brinklow"

Extent	41649-49
In European Region	South East
Within	Milton Keynes
In District	Milton Keynes
Touches	Walton Broughton Old Woughton Milton Keynes Wavendon

Core facts about "Kents Hill, Monkston and Brinklow"

Type	Parish
Label	Kents Hill, Monkston and Brinklow
Pref Label	Kents Hill, Monkston and Brinklow
Alt Label	Kents Hill, Monkston and Brinklow CP
Northing	238013.803835
Easting	489602.596729
Lat	52.0333028515
Long	-0.695254366017
Area Code	CPC

Selected Materials

- RDF Primer – https://www.w3.org/TR/rdf11-primer/
- SPARQL Query Language Spec – https://www.w3.org/TR/2013/REC-sparql11-query-20130321/
- OWL Primer – https://www.w3.org/TR/owl2-primer/
- SKOS Primer – https://www.w3.org/TR/skos-primer/
- Description Logic Reasoning – P. Křemen, Ontologie a Deskripční logiky. In Umělá inteligence VI., Academia, 2013.
- Linked Data – http://linkeddata.org
- Tutorial on RDF/OWL – https://www.obitko.com/tutorials/ontologies-semantic-web/