

## *CSCE 580: Introduction to AI* *CSCE 581: Trusted AI*

### Lecture 3: Representing and Organizing Data

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PROF. BIPLAV SRIVASTAVA, AI INSTITUTE

31<sup>ST</sup> AUG 2023

**Carolinian Creed: “I will practice personal and academic integrity.”**

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# Organization of Lecture 3

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- Introduction Segment
  - Recap of Lecture 2
- Main Segment
  - Data preparation
  - Knowledge representation/ graph
  - Ontology
- Concluding Segment
  - About Next Lecture – Lecture 4
  - Ask me anything

# Introduction Section

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# Recap of Lecture 2

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- Data formats
- Big data v/s open data
- Open data
  - City data
  - Data access via Open311
  - Publishing data systematically

# Where We Are

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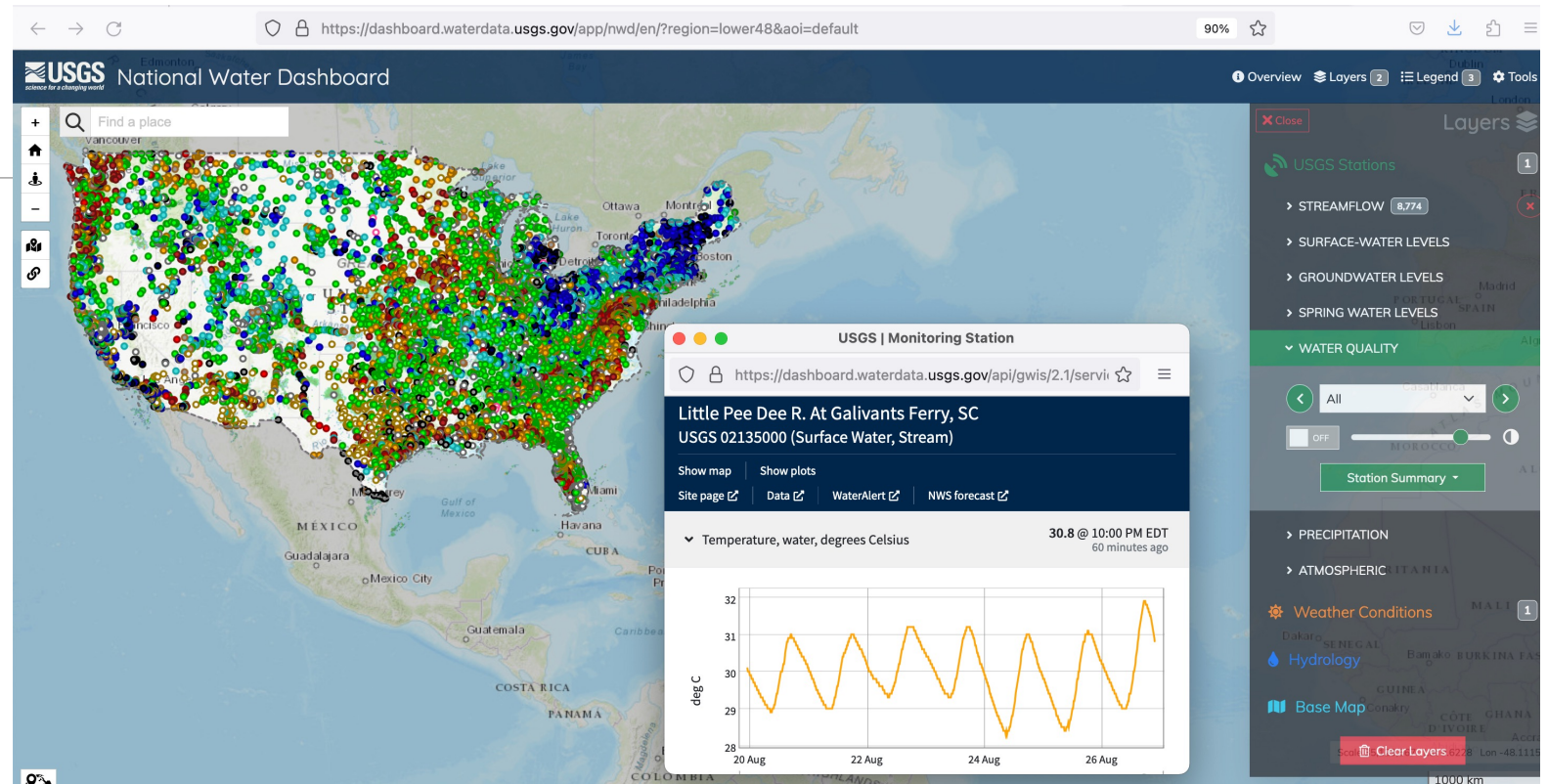
## CSCE 580/ 581 – In This Course

- Week 1: Introduction, Aim: Chatbot / Intelligence Agent
- Weeks 2-3: Data: Formats, Representation and the Trust Problem
- Week 4-5: Search, Heuristics - Decision Making
- Week 6: Constraints, Optimization – Decision Making
- Week 7: Classical Machine Learning – Decision Making, Explanation
- Week 8: Machine Learning - Classification
- Week 9: Machine Learning - Classification – Trust Issues and Mitigation Methods
- Topic 10: Learning neural network, deep learning, Adversarial attacks
- Week 11: Large Language Models – Representation, Issues
- Topic 12: Markov Decision Processes, Hidden Markov models - Decision making
- Topic 13: Planning, Reinforcement Learning – Sequential decision making
- Week 14: AI for Real World: Tools, Emerging Standards and Laws; Safe AI/ Chatbots

# Main Section

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# Water Data



<https://dashboard.waterdata.usgs.gov/app/nwd/en/?region=lower48&aoi=default>

Claims data from 13,000 locations online on 26 Aug 2023

# Common Problem: Missing Value

- Occurrence
  - Missing completely at random
  - Missing at random (a group not wanting to participate)
  - Missing not at random (a group not able to participate)
- What does it mean?
  - The value was not provided
  - The value does not exist or has no practical interpretation
  - The value is being hidden (redaction)
  - Others: The value is not reliable, ...
- How to detect it?
  - By checking for specific values: NA, Not applicable, out-of-range value, 0, -1, "".

https://waterdata.usgs.gov/nwis/current/?type=quality

\* We've detected you're using a mobile device. Find our [mobile site here](#).

Click to hide News Bulletins

- Introducing The Next Generation of USGS Water Data for the Nation
- Full News

**Current Conditions for the Nation -- Water Quality -- 2242 site(s) found**

**PROVISIONAL DATA SUBJECT TO REVISION**

Predefined displays: USA Water-Quality Table | Group table by: State | Select sites by number or name: | go | show sites on a map

[Customize table to display other current-condition parameters](#)

Station Number	Station name	Specific conductance, uS/cm @ 25 degC	Temperature, deg C	Dissolved oxygen, mg/L	pH, water, unfltrd, std units	Date/Time
023432415	CHATTAHOOCHEE R .36 MI DS WFG DAM NR FT GAINES, GA	79	10.2	12.4	--	01/17 13:00 EST
02397530	COOSA RIVER AT STATE LINE, AL/GA	131	8.1	11.2	7.8	01/17 13:00 EST
02400100	TERRAPIN CREEK AT ELLISVILLE AL	--	9.3	--	--	01/17 12:00 CST
02405500	KELLY CREEK NEAR VINCENT AL	--	6.2	--	--	01/17 11:00 CST
02407514	YELLOWLEAF CREEK NEAR WESTOVER, AL	--	5.6	--	--	01/17 12:00 CST
02412000	TALLAPOOSA RIVER NEAR HEFLIN, AL	--	5.9	--	--	01/17 11:30 CST
02414500	TALLAPOOSA RIVER AT WADLEY AL	--	7.7	--	--	01/17 11:15 CST
02414715	TALLAPOOSA RIVER NR NEW SITE, AL.(HORSESHOE BEND)	--	7.1	--	--	01/17 11:30 CST
02419890	TALLAPOOSA RIVER NEAR MONT.-MONT. WATER WORKS	52	19.5	--	--	10/18 11:00 CDT
02423130	CAHABA RIVER AT TRUSSVILLE, AL.	202	15.1	10.8	--	11/18 14:00 CST
02423160	CAHABA RIVER NEAR WHITES CHAPEL AL	203	7.2	14.6	8.8	01/17 12:15 CST
02423380	CAHABA RIVER NEAR MOUNTAIN BROOK AL	192	5.8	12.9	8.4	01/17 12:00 CST
02423397	LITTLE CAHABA RIVER BELOW LEEDS, AL.	379	10.6	11.1	--	01/17 12:00 CST
02423406	CAHABA RIVER NEAR HOOVER, AL	180	6.0	1.4	--	01/17 11:00 CST



# Missing Value – Handling

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- Ignoring missing value (Omission)
  - Reduces available data
- Impute new value (Imputation)
  - Mean or median
  - Default value
- Analysis techniques which are robust against missing value
  - Expectation maximization

# Code Examples

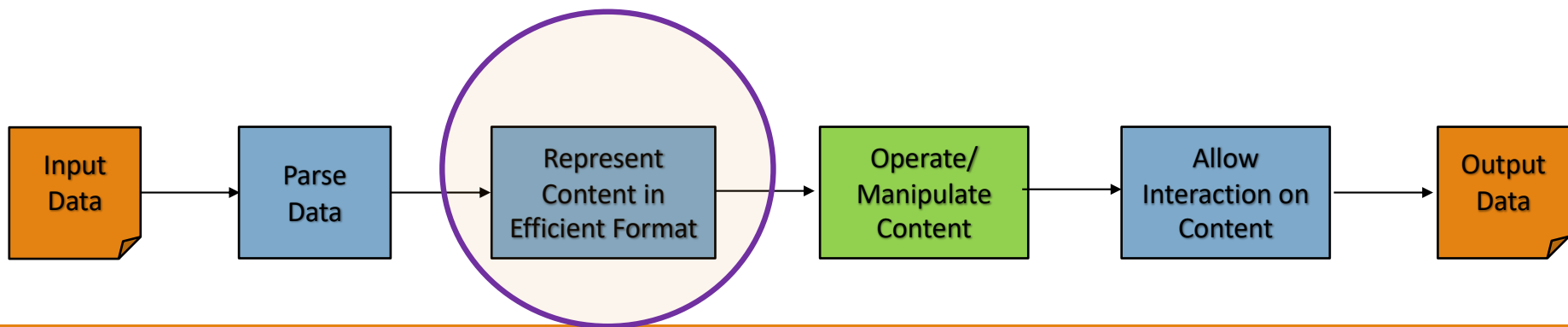
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<https://github.com/biplav-s/course-d2d-ai/blob/main/sample-code/l5-dataprep/>

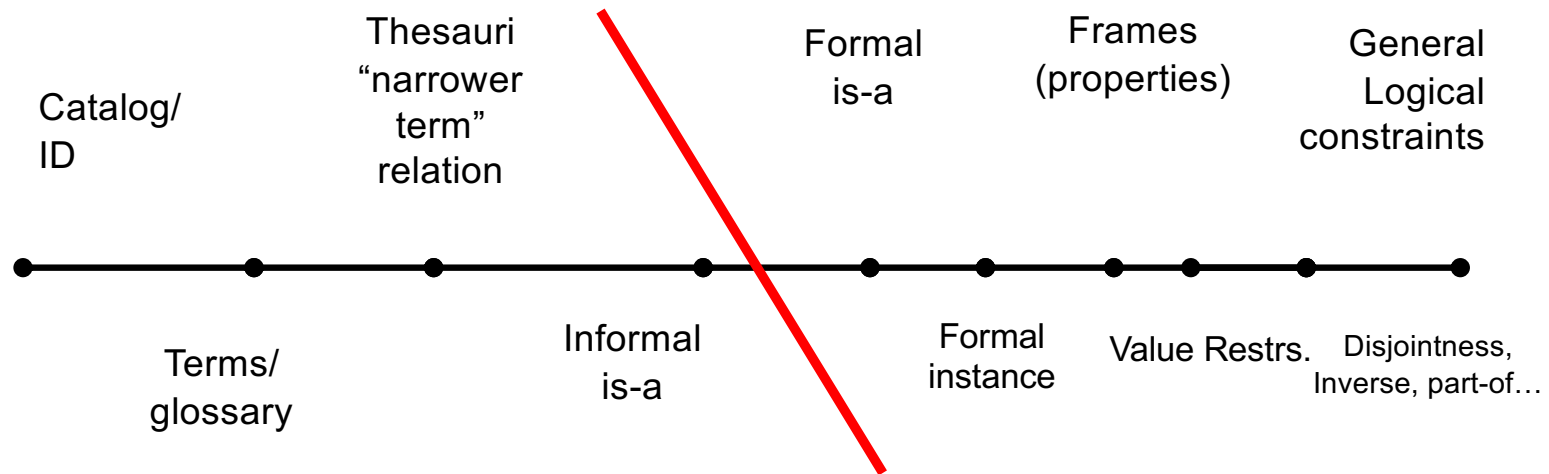
- Basic concepts: **DataPreparation-Numeric.ipynb**
- An illustration: **Clean-RealSample.ipynb**

# Annotation: Knowledge Graphs and Ontology

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

# The Spectrum of Annotation Methods



Ontologies Come of Age McGuinness, 2001, and From AAAI Panel 99 – McGuinness, Welty, Uschold, Gruninger, Lehmann  
Plus basis of Ontologies Come of Age – McGuinness, 2003

# Thesaurus – Authoritative Entities and Relationships

Countries: [https://en.wikipedia.org/wiki/List\\_of\\_ISO\\_3166\\_country\\_codes](https://en.wikipedia.org/wiki/List_of_ISO_3166_country_codes)

ISO 3166 <sup>[1]</sup>			ISO 3166-1 <sup>[2]</sup>			ISO 3166-2 <sup>[3]</sup>	
Country name <sup>[5]</sup> ⇄	Official state name <sup>[6]</sup> ⇄	Sovereignty <sup>[6]</sup> <sup>[7]</sup> [8] ⇄	Alpha-2 code <sup>[5]</sup> ⇄	Alpha-3 code <sup>[5]</sup> ⇄	Numeric code <sup>[5]</sup> ⇄	Subdivision code links <sup>[3]</sup> ⇄	Internet ccTLD <sup>[9]</sup> ⇄
 Afghanistan	The Islamic Republic of Afghanistan	UN member state	AF	AFG	004	ISO 3166-2:AF	.af
 Akrotiri and Dhekelia – See United Kingdom, The							
 Åland Islands	Åland	Finland	AX	ALA	248	ISO 3166-2:AX	.ax
 Albania	The Republic of Albania	UN member state	AL	ALB	008	ISO 3166-2:AL	.al
 Algeria	The People's Democratic Republic of Algeria	UN member state	DZ	DZA	012	ISO 3166-2:DZ	.dz
 American Samoa	The Territory of American Samoa	United States	AS	ASM	016	ISO 3166-2:AS	.as
 Andorra	The Principality of Andorra	UN member state	AD	AND	020	ISO 3166-2:AD	.ad
 Angola	The Republic of Angola	UN member state	AO	AGO	024	ISO 3166-2:AO	.ao
 Anguilla	Anguilla	United Kingdom	AI	AIA	660	ISO 3166-2:AI	.ai
 Antarctica <sup>[a]</sup>	All land and ice shelves south of the 60th parallel south	Antarctic Treaty	AQ	ATA	010	ISO 3166-2:AQ	.aq
 Antigua and Barbuda	Antigua and Barbuda	UN member state	AG	ATG	028	ISO 3166-2:AG	.ag
 Argentina	The Argentine Republic	UN member state	AR	ARG	032	ISO 3166-2:AR	.ar

# (Unique) US Counties Information

In COVID sample code: <https://github.com/biplav-s/course-d2d-ai/blob/main/sample-code/l3-health/CovidExploration.ipynb>,

reference made to **FIPS** code

## References:

- [https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/home/?cid=nrcs143\\_013697](https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/home/?cid=nrcs143_013697)
- [https://github.com/kjhealy/fips-codes/blob/master/county\\_fips\\_master.csv](https://github.com/kjhealy/fips-codes/blob/master/county_fips_master.csv)

**Question:** how many Richland counties are there in US ?

**Answer:** 14

## County FIPS Codes

FIPS	Name	Stat
01001	Autauga	AL
01003	Baldwin	AL
01005	Barbour	AL
01007	Bibb	AL
01009	Blount	AL
01011	Bullock	AL
01013	Butler	AL
01015	Calhoun	AL
01017	Chambers	AL
01019	Cherokee	AL
01021	Chilton	AL
01023	Choctaw	AL
01025	Clarke	AL
01027	Clay	AL
01029	Cleburne	AL
01031	Coffee	AL
01033	Colbert	AL
01035	Conecuh	AL

# Is-a Relationship

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# List of Countries, States, ... (County), City

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- United Nations: <https://unece.org/trade/cefact/unlocode-code-list-country-and-territory>
- US Source: <https://github.com/grammakov/USA-cities-and-states>



# Schema.org

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- Website: <https://schema.org/docs/about.html>
- GitHub: <https://github.com/schemaorg/schemaorg>
- An organization of metadata information for entities found on the web. Mostly backed by web search companies.
- Explore
  - Thing: <https://schema.org/Thing>
  - Product:

# Schema.org

## Example 2

No Markup

Microdata

RDFa

JSON-LD

Structure

*Example notes or example HTML without markup.*

```

Dell UltraSharp 30" LCD Monitor

87 out of 100 based on 24 user ratings

$1250 to $1495 from 8 sellers

Sellers:
<a href="save-a-lot-monitors.com/dell-30.html">
  Save A Lot Monitors - $1250</a>
<a href="jondoe-gadgets.com/dell-30.html">
  Jon Doe's Gadgets - $1350</a>
...
```

No structure

# Schema.org

Example 2 

No Markup Microdata RDFa JSON-LD Structure

Example notes or example HTML without markup.

```

Dell UltraSharp 30" LCD Monitor

87 out of 100 based on 24 user ratings

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Sellers:
<a href="save-a-lot-monitors.com/dell-30.html">
Save A Lot Monitors - $1250</a>
<a href="jondoe-gadgets.com/dell-30.html">
Jon Doe's Gadgets - $1350</a>
...
```

No structure

Structure in JSON-LD format

Example 2 

No Markup Microdata RDFa JSON-LD Structure

Example encoded as JSON-LD in a HTML script tag.

```
<script type="application/ld+json">
{
  "@context": "https://schema.org",
  "@type": "Product",
  "aggregateRating": {
    "@type": "AggregateRating",
    "bestRating": "100",
    "ratingCount": "24",
    "ratingValue": "87"
  },
  "image": "dell-30in-lcd.jpg",
  "name": "Dell UltraSharp 30\" LCD Monitor",
  "offers": {
    "@type": "AggregateOffer",
    "highPrice": "$1495",
    "lowPrice": "$1250",
    "offerCount": "8",
    "offers": [
      {
        "@type": "Offer",
        "url": "save-a-lot-monitors.com/dell-30.html"
      },
      {
        "@type": "Offer",
        "url": "jondoe-gadgets.com/dell-30.html"
      }
    ]
  }
}
]>
</script>
```

# Schema.org

Example 2

No Markup Microdata RDFa JSON-LD Structure

Example notes or example HTML, without markup.

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$1250 to $1495 from 8 sellers

Sellers:
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  Jon Doe's Gadgets - $1350</a>
...
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  "@type": "Product",
  "aggregateRating": {
    "@type": "AggregateRating",
    "bestRating": "100",
    "ratingCount": "24",
    "ratingValue": "87"
  },
  "image": "dell-30in-lcd.jpg",
  "name": "Dell UltraSharp 30" LCD Monitor",
  "offers": {
    "@type": "AggregateOffer",
    "highPrice": "$1495",
    "lowPrice": "$1250",
    "offerCount": "8",
    "offers": [
      {
        "@type": "Offer",
        "url": "save-a-lot-monitors.com/dell-30.html"
      },
      {
        "@type": "Offer",
        "url": "jondoe-gadgets.com/dell-30.html"
      }
    ]
  }
}
</script>
```

Structure in JSON-LD format

Example 2

No Markup Microdata RDFa JSON-LD Structure

Structured representation of the JSON-LD example.

@type	Product
name	Dell UltraSharp 30" LCD Monitor
offers	
@type	AggregateOffer
offerCount	8
lowPrice	\$1250
highPrice	\$1495
offers	
@type	Offer
url	http://example.org/jondoe-gadgets.com/dell-30.html
offers	
@type	Offer
url	http://example.org/save-a-lot-monitors.com/dell-30.html
image	http://example.org/dell-30in-lcd.jpg
aggregateRating	
@type	AggregateRating
ratingValue	87
ratingCount	24
bestRating	100

Induced Structure

# Schema.org - continued

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- **Exploration Exercise**

- Services: <https://schema.org/Service>
- Event: <https://schema.org/Event>

- **Benefit:**

- Easy to incorporate annotations
- Uses popular development tools and technologies (JSON, Microformat)

- **Disadvantage**

- Cannot perform deep inferencing
- Popular in certain communities

# Formalizing Knowledge in an Ontology

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## **Sources:**

Achille Fokoue, Anastasios Kementsietsidis Tutorial

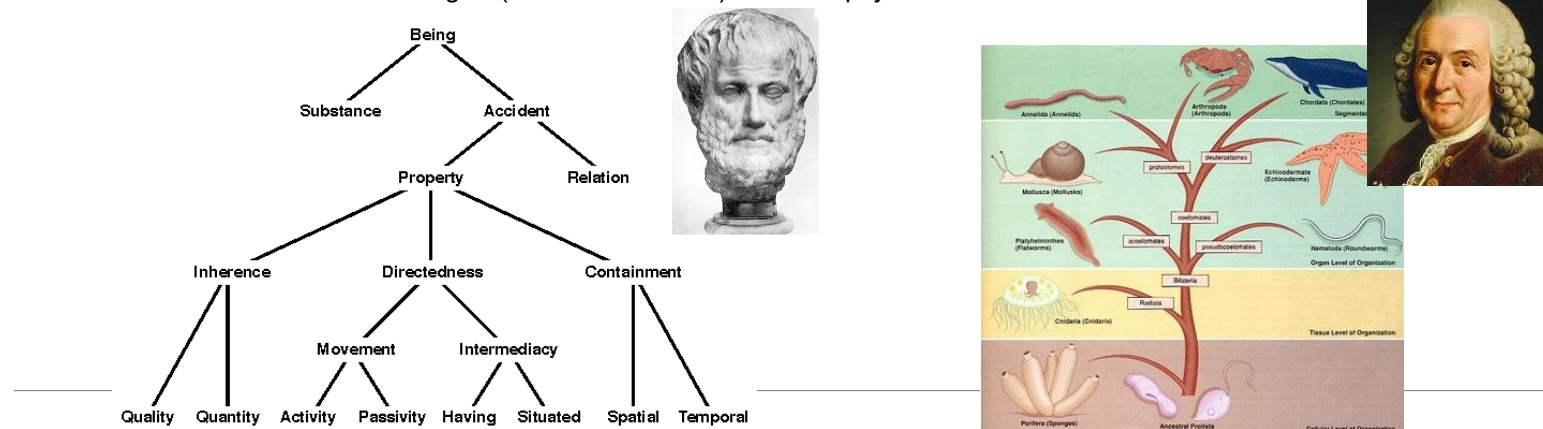
SCRIBE presentation by Rosario Usceda Sosa, Biplav Srivastava, Bob Schloss

- <https://github.com/rschloss/ismp> ,
- [https://researcher.watson.ibm.com/researcher/view\\_group.php?id=2505](https://researcher.watson.ibm.com/researcher/view_group.php?id=2505)

## What is an ontology, anyway?

In Computer Science, “An ontology is a formal explicit description of concepts in a domain of discourse (**classes** (sometimes called concepts)), **properties** of each concept describing various features and **attributes** of the concept (slots (sometimes called roles or properties)), and **restrictions** on slots (facets (sometimes called role restrictions)). An ontology together with a set of individual instances of classes constitutes a knowledge base. In reality, there is a fine line where the ontology ends and the knowledge base begins.” [Noy, 2000]

Not to be confused with ontologies (and/or taxonomies) in Philosophy or Life Sciences

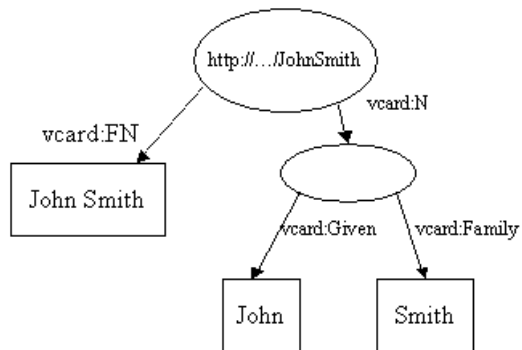


In a Smart City domain, we're concerned with modeling the *city data* (city activity data, city departments, assets, KPIs), not the city itself (the full set of spatial and temporal relations between people and objects in the city) Ontologies help us to structure and reason about city *events*, *entities* and *services*.

**Ontology = Class + Relations + Constraints**

**Knowledge Base = Ontology + instances + (Standard) Inference and rules**

# RDF / Turtle Example



---- Turtle ----

```
<http://somewhere/JohnSmith>
  <http://www.w3.org/2001/vcard-rdf/3.0#FN>
    "John Smith" ;
  <http://www.w3.org/2001/vcard-rdf/3.0#N>
    [ <http://www.w3.org/2001/vcard-
      rdf/3.0#Family>
      "Smith" ;
      <http://www.w3.org/2001/vcard-
        rdf/3.0#Given>
        "John"
    ] .
```

```
<rdf:RDF
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-
    syntax-ns#"
  xmlns:vcard="http://www.w3.org/2001/vcard-
    rdf/3.0#" >
  <rdf:Description rdf:nodeID="A0">
    <vcard:Given>John</vcard:Given>
    <vcard:Family>Smith</vcard:Family>
  </rdf:Description>
  <rdf:Description
    rdf:about="http://somewhere/JohnSmith">
    <vcard:FN>John Smith</vcard:FN>
    <vcard:N rdf:nodeID="A0"/>
  </rdf:Description>
</rdf:RDF>
```



# OWL extends RDF...

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## RDF-schema

- Class, subclass
- Property, subproperty

## + Restrictions

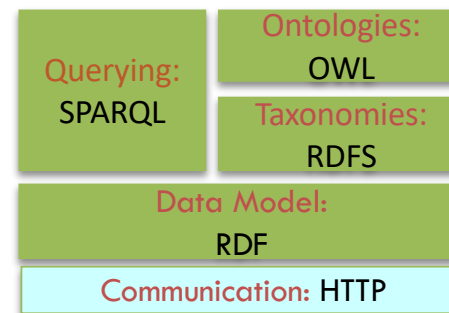
- Range, domain
- Local, global
- Existential
- Cardinality

## + Combinators

- Union, Intersection
- Complement
- Symmetric, transitive

## + Mapping

- Equivalence
- Inverse



**Source:** Achille Fokoue, Anastasios Kementsietsidis Tutorial

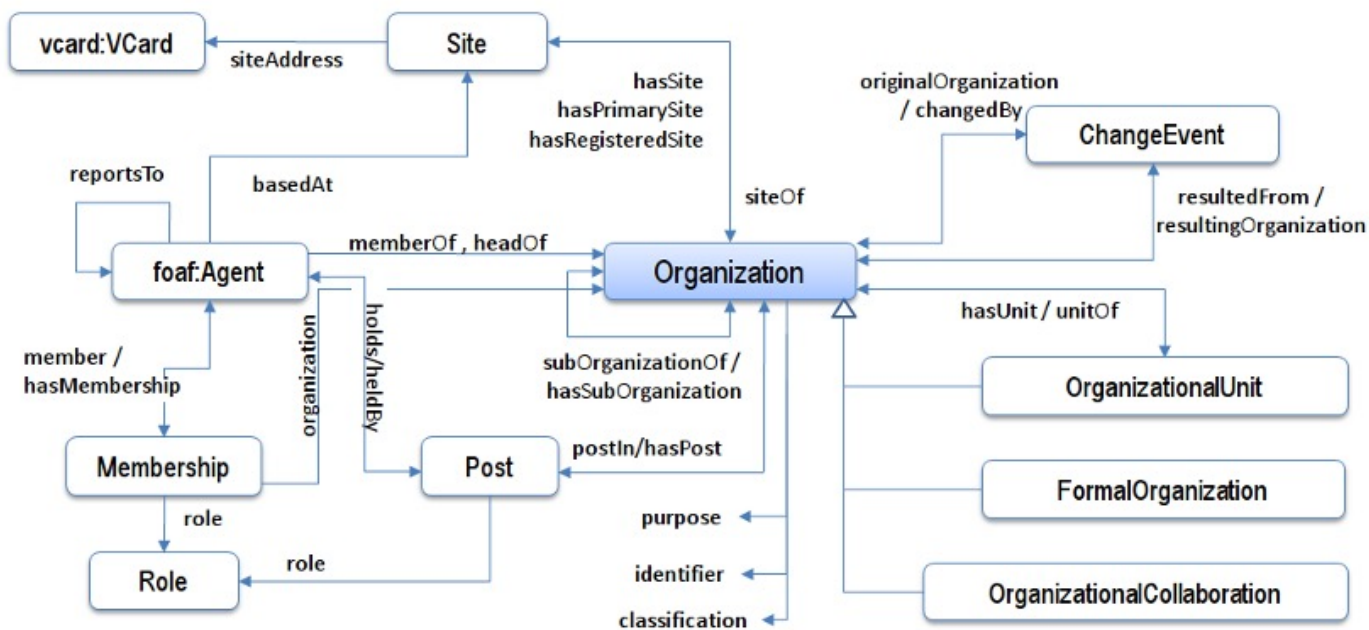
## Not all ontologies are created equal

In practice, ontologies are used -together with inferencing engines and rules-, for a variety of purposes. If we think of them as schemas, there are different ways

Normative schema		Purpose	Instances	Inferencing	Examples
	As a deductive system	Deductive System (axioms + deductive rules)	Part of the knowledge base	Defined by rules.	Expert systems, Planning, Optimization.
	As a data blueprint	Constrain a domain	Must conform to the normative schema determined by the ontology	Subsumption, class inferencing	Biomedical and life sciences (FMA, Radlex)
	As a data classifier	Classify open data	Unknown formats	Subsumption, class inferencing	Tag ontologies (MOAT, Echarte, SCOT, NAO, etc.)
Integrative Schema, depend on instances	As a data integrator	Integrating pre-defined model to existing data sources	Instances are mapped, no constraint enforcement.	Subsumption, class, entity inferencing	SCRIBE
	As data mapping vocabulary	Mapping to/from existing data sources	Mined instances determine the ontology/schema.	Subsumption, class inferencing	D2RQ (a tool)

SCRIBE belongs to the **fourth** category: It has no constraints and was designed to support the programming of tools that allow domain experts to deal with entities natural to them (even if the recorded data is actually distributed).

# Larger Example: Organization Ontology



Ontology description: <http://www.w3.org/TR/vocab-org/>

Ontology: <http://www.w3.org/ns/org.ttl>

# Larger Ontology

<http://www.w3.org/ns/org.ttl>

```
@prefix rdf:      <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs:     <http://www.w3.org/2000/01/rdf-schema#> .
@prefix owl:    <http://www.w3.org/2002/07/owl#> .
@prefix xsd:      <http://www.w3.org/2001/XMLSchema#> .
@prefix skos:     <http://www.w3.org/2004/02/skos/core#> .
@prefix foaf:     <http://xmlns.com/foaf/0.1/> .
...
@prefix :         <http://www.w3.org/ns/org#> .

# -- Meta data -----

<http://www.w3.org/ns/org#>
  a owl:Ontology;
  owl:versionInfo "0.7";
  rdfs:label "Core organization ontology"@en;
  rdfs:comment "Vocabulary for describing organizational structures, specializable to a
broad variety of types of organization."@en;
  dct:created "2010-05-28"^^xsd:date;
  dct:modified "2010-06-09"^^xsd:date;
  dct:modified "2010-10-08"^^xsd:date;
...
  rdfs:seeAlso <http://www.w3.org/TR/vocab-org/> ;
.

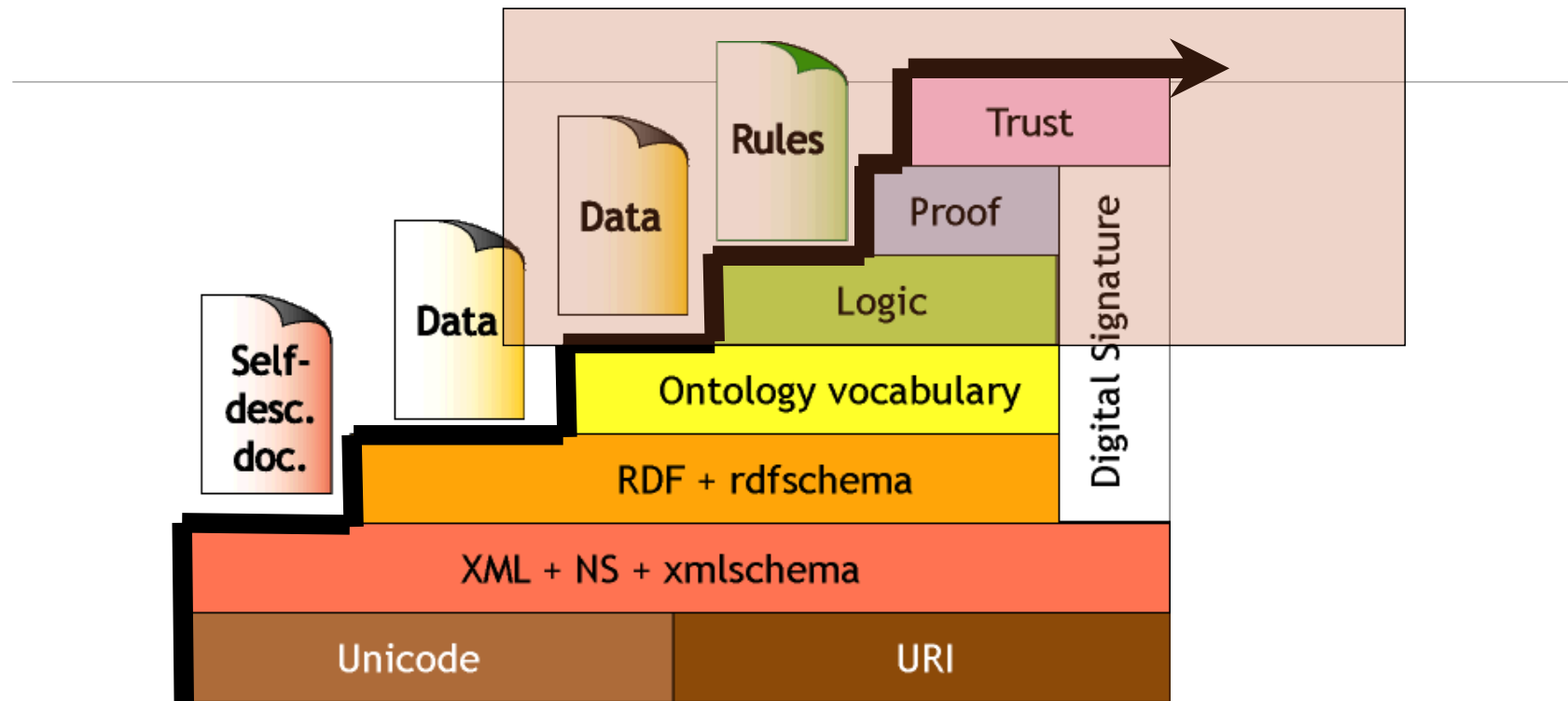
# -- Organizational structure -----

org:Organization a owl:Class, rdfs:Class;
  rdfs:subClassOf foaf:Agent;
  owl:equivalentClass foaf:Organization;
  rdfs:label "Organization"@en;
  rdfs:label "Organisation"@fr;
  owl:hasKey (org:identifier) ;
  rdfs:comment ""Represents a collection of people organized together into a community
or other social, commercial or political structure. ... Alternative names: _Collective_
_Body_ _Org_ _Group_ ""@en;
  rdfs:comment ""Représente un groupe de personnes organisées en communauté où tout
autre forme de structure sociale, commerciale ou politique. ... code provenant d'une liste
de code.""@fr;
  rdfs:isDefinedBy <http://www.w3.org/ns/org> ;
.
```

```
- <rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:skos="http://www.w3.org/2004/02/skos/core#" xmlns:foaf="http://xmlns.com/foaf/0.1/"
  xmlns:org="http://www.w3.org/ns/org#" xmlns:gr="http://purl.org/goodrelations/v1#"
  xmlns:owl="http://www.w3.org/2002/07/owl#" xmlns:dct="http://purl.org/dc/terms/"
  xmlns:prov="http://www.w3.org/ns/prov#" xmlns:owlTime="http://www.w3.org/2006/time#"
  xmlns:xsd="http://www.w3.org/2001/XMLSchema#" xmlns:vcard="http://www.w3.org/2006/vcard/ns#"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
+ owl:Ontology rdf:about="http://www.w3.org/ns/org#" />
+ <rdfs:Class rdf:about="http://www.w3.org/ns/org#Organization">
- <rdfs:Class rdf:about="http://www.w3.org/ns/org#Role">
  <rdfs:label xml:lang="fr">Rôle</rdfs:label>
- <owl:disjointWith>
  <owl:Class rdf:about="http://www.w3.org/ns/org#ChangeEvent" />
  </owl:disjointWith>
  <rdfs:subClassOf rdf:resource="http://www.w3.org/2004/02/skos/core#Concept" />
- <owl:disjointWith>
  <owl:Class rdf:about="http://www.w3.org/ns/org#Site" />
  </owl:disjointWith>
  <rdfs:comment xml:lang="fr">Indique le rôle qu'une Personne ou un autre Agent peut avoir dans une
Organisation. Les instances de cette classe décrivent le rôle dans l'absolu; pour indiquer une personne
ayant ce rôle spécifique dans une Organisation, utilisez une instance de "org:Membership". Il est
courant que les rôles soient organisés dans une sorte de taxonomie, ce qui peut être représenté avec
SKOS. Les propriétés de libellés standards de SKOS devraient être utilisées pour libeller le Rôle.
D'autres propriétés additionnelles pour ce rôle, comme une fourchette de Salaire peuvent être ajoutées
par une extension de ce vocabulaire.</rdfs:comment>
- <owl:disjointWith>
  <owl:Class rdf:about="http://www.w3.org/ns/org#Membership" />
  </owl:disjointWith>
  <rdfs:label xml:lang="en">Role</rdfs:label>
  <rdfs:isDefinedBy rdf:resource="http://www.w3.org/ns/org" />
  <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#Class" />
  <rdfs:comment xml:lang="en">Denotes a role that a Person or other Agent can take in an organization.
Instances of this class describe the abstract role; to denote a specific instance of a person playing that
role in a specific organization use an instance of "org:Membership". It is common for roles to be
```

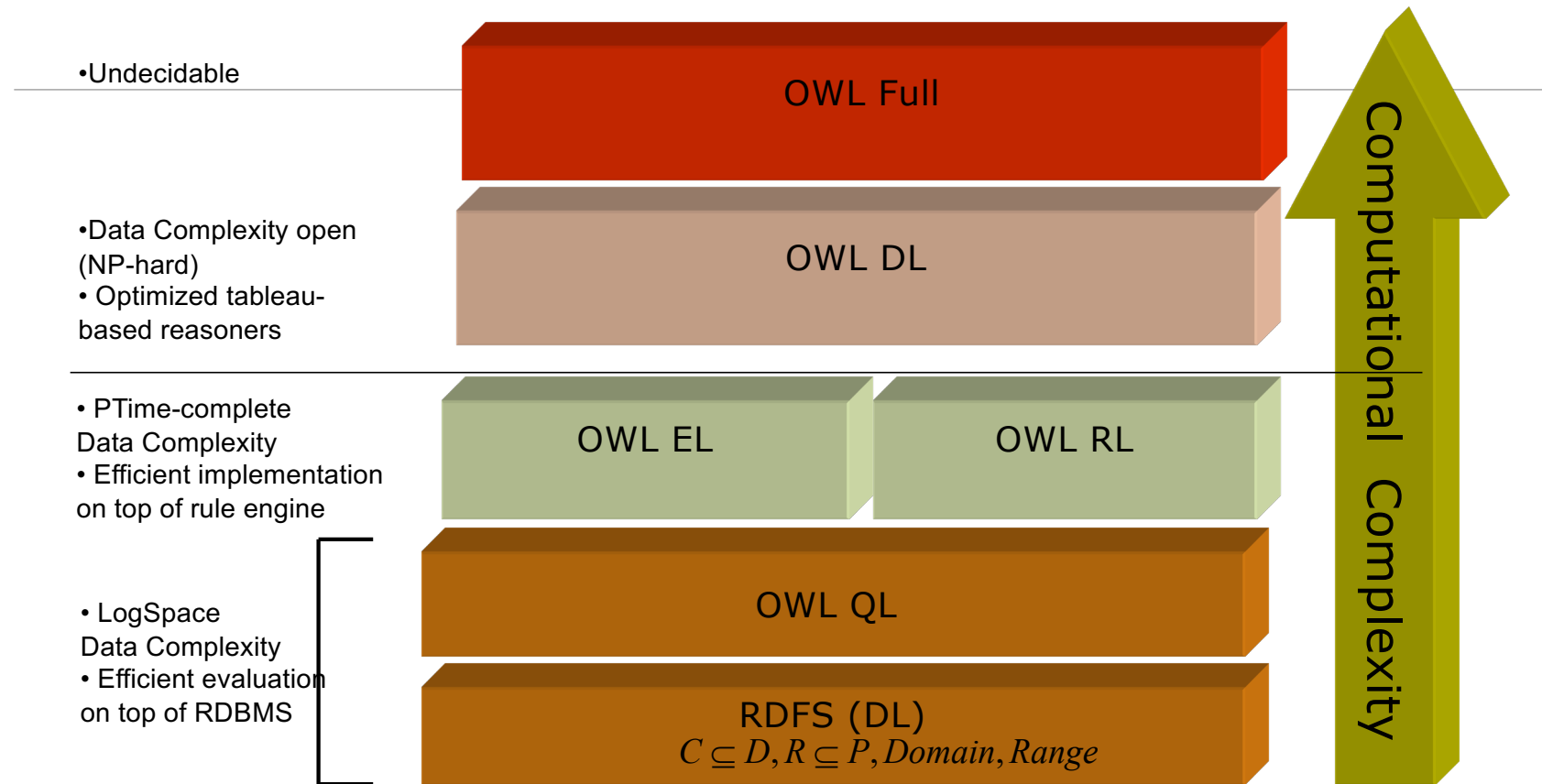
<http://www.w3.org/ns/org>

# Moving to the future of the web



Semantic Web LayerCake (Berners-Lee, 99; Swartz-Hendler, 2001)

# Challenge of Reasoning on Ontologies



## What makes a good ontology for data integration?

A *good* ontology is a *useful* ontology, an ontology that *both* humans and systems can process.

### Human Usability

**Communicable.** Naming, natural language support, etc.

**Concise.** A simple way to describe the key entities of the model and yet able to infer many facts

**Consistent.** Naming conventions and modeling patterns

**Authoritative** to domain experts

**Documented**, not just descriptions, but also provenance

**Managed and maintained** by people throughout the model lifecycle.

**Reusable** in similar domains, for similar instances.

▣ **Formal** representation of **knowledge** in a particular domain

▣ Formally defines key **concepts** and **relations** in the domain

▣ Specifies relationships between those key concepts and relations

▣ Supports **automated reasoning** about entities in the domain

### System Usability

**Scalable** so large amounts of data can be parsed, stored and retrieved.

**Efficient** query and inferencing

**Programmable** solutions, both in open and closed data paradigms.

**Open** infrastructure and tools

# Using Ontology

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- Visually via tools like Protégé - <https://protege.stanford.edu/>
- Programmatically with APIs like
  - Jena (Java) - <https://jena.apache.org/documentation/ontology/>
  - OwlReady2 (Python) - <https://bitbucket.org/jibalamy/owlready2/src/master/>
  - RdfLib (Python) - <https://github.com/RDFLib/OWL-RL>
- A compendium of resources - <https://github.com/totogo/awesome-knowledge-graph>



# Code Illustration

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On Github:

<https://github.com/biplav-s/course-nl/blob/master/I11-ontology/Exploring%20ontologies.ipynb>

# Knowledge Graph

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- No clear definition
  - "Towards a Definition of Knowledge Graphs," by Lisa Eherlinger and Wolfram Wöß, CEURWorkshop Proceedings. 2016, <http://ceur-ws.org/Vol-1695/paper4.pdf>
  - For practical purposes, concepts and their relationships; not constraints
  - Driven by applications in search and information integration
  - See discussion at: <http://accidental-taxonomist.blogspot.com/2019/05/knowledge-graphs-and-ontologies.html>
- But ontology as knowledge graph widely used in industries
  - Industry-Scale Knowledge Graphs: Lessons and Challenges, CACM 2019, <https://cacm.acm.org/magazines/2019/8/238342-industry-scale-knowledge-graphs/fulltext>

## KG Usage

	<b>Data model</b>	<b>Size of the graph</b>	<b>Development stage</b>
<b>Microsoft</b>	The types of entities, relations, and attributes in the graph are defined in an ontology.	~2 billion primary entities, ~55 billion facts	Actively used in products
<b>Google</b>	Strongly typed entities, relations with domain and range inference	1 billion entities, 70 billion assertions	Actively used in products
<b>Facebook</b>	All of the attributes and relations are structured and strongly typed, and optionally indexed to enable efficient retrieval, search, and traversal.	~50 million primary entities, ~500 million assertions	Actively used in products
<b>eBay</b>	Entities and relation, well-structured and strongly typed	Expect around 100 million products, >1 billion triples	Early stages of development and deployment
<b>IBM</b>	Entities and relations with evidence information associated with them.	Various sizes. Proven on scales documents >100 million, relationships >5 billion, entities >100 million	Actively used in products and by clients

Figure courtesy: Industry-Scale Knowledge Graphs: Lessons and Challenges, CACM 2019

# Lecture 3: Summary

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- We talked about
  - Data preparation
  - Knowledge representation/ graph
  - Ontology

# Concluding Section

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# Course Project

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# Project Discussion: What Problem Fascinates You ?

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- Data
  - Water
  - Finance
- Analytics
- Application
  - Building chatbot
- Users
  - Diverse demographics
  - Diverse abilities
  - Multiple human languages

## Project execution in sprints

- Sprint 1:
  - **Solving**: Choose a decision problem, identify data, work on solution methods
  - **Human interaction**: Develop a basic chatbot (no AI), no problem focus
- Sprint 2:
  - **Solving**: Evaluate your solution on problem
  - **Human interaction**: Integrated your choice of chatbot (rule-based or learning-based) and methods
- Sprint 3:
  - **Evaluation**: Comparison of your solver chatbot with an LLM-based alternative, like ChatGPT

# Project Ideas

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- 1. City snapshot for Columbia, SC (like for London - <http://citydashboard.org/london/>)
- ...



# About Next Lecture – Lecture 3

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# Lecture 4: Representing Knowledge

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- World Knowledge: Physical, Beliefs, Probabilities
- Logic
- Inferencing