

Lecture 2

Knowledge Graphs

COMP 474/6741, Winter 2021

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Slides Credit

- Includes slides from Jay Pujara & Sameer Singh, *Mining Knowledge Graphs from Text*, <https://kgtutorial.github.io/>
- Includes slides by Ivan Herman, W3C [Her]

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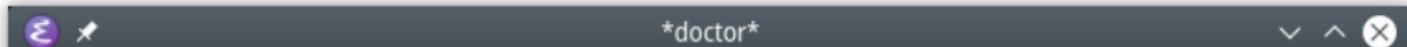
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File Edit Options Buffers Tools Text Help

I am the psychotherapist.

Please, describe your problems. Each time you are finished talking, type RET twice.

what is Concordia University?

Why do you say what is concordia university?

Just tell me what it is!

Is it because of your plans that you say just tell you what it is?



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What is Concordia University?



Concordia University (French: Université **Concordia**; commonly referred to as **Concordia**) is a public comprehensive research **university** located in Montreal, Quebec, Canada. ... **Concordia** is a non-sectarian and coeducational institution, with more than 215,000 alumni worldwide.

Athletics brand: Concordia Stingers

Subsidiary or constituent schools: Loyola Campus, Faculty of Arts

Date founded: August 24, 1974

Geographic scope: Canada



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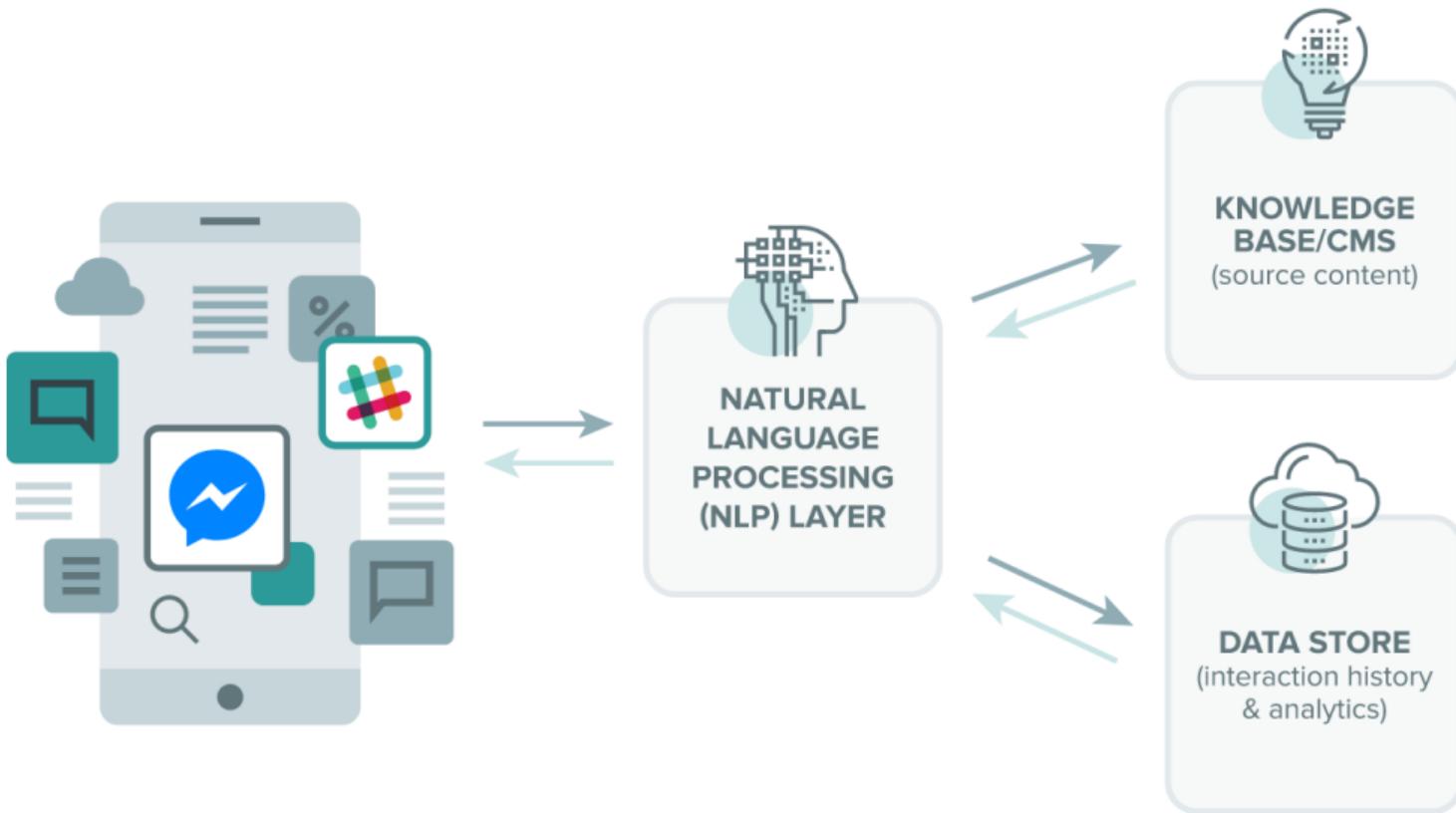
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Generic Assistant Architecture

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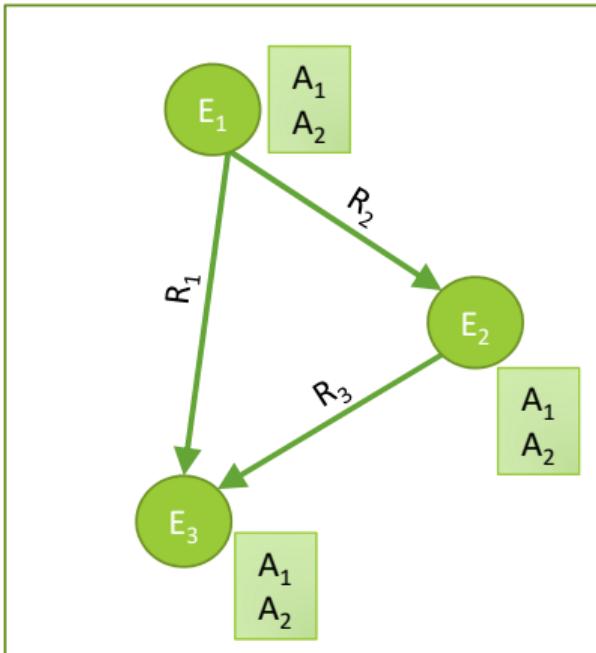
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What is a knowledge graph?

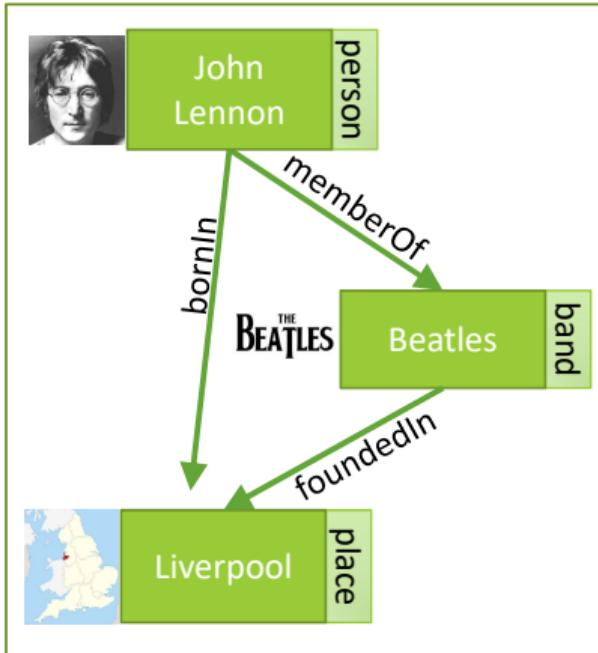
- Knowledge in graph form!
- Captures entities, attributes, and relationships
- Nodes are entities
- Nodes are labeled with attributes (e.g., types)
- Typed edges between two nodes capture a relationship between entities



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Example knowledge graph

- Knowledge in graph form!
- Captures entities, attributes, and relationships
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Why knowledge graphs?

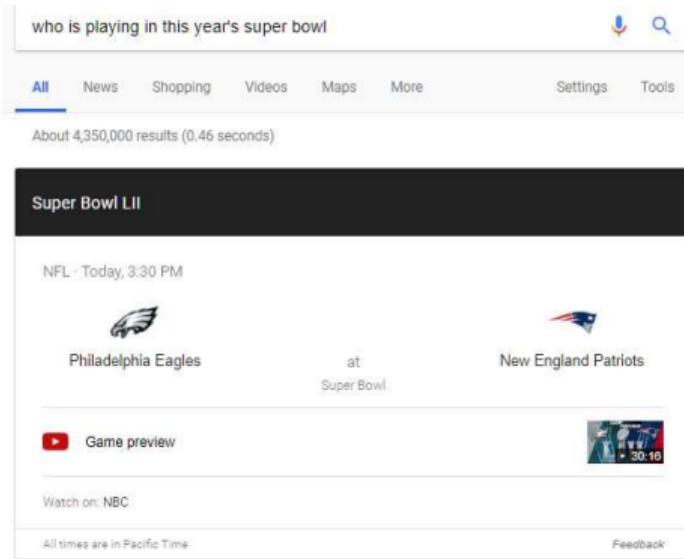
- Humans:

- Combat information overload
- Explore via intuitive structure
- Tool for supporting knowledge-driven tasks

- AIs:

- Key ingredient for many AI tasks
- Bridge from data to human semantics
- Use decades of work on graph analysis

Applications 1: QA/Agents



who is playing in this year's super bowl

All News Shopping Videos Maps More Settings Tools

About 4,350,000 results (0.46 seconds)

Super Bowl LII

NFL · Today, 3:30 PM

Philadelphia Eagles at New England Patriots
Super Bowl

Game preview

Watch on: NBC

All times are in Pacific Time Feedback

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Applications 2: Decision Support

IBM Watson Knowledge Studio

View Details Attribute View View Guidelines Completed Close

Alpha... 14pt 1

Entity Mention

Type	Subtype	Role
a	ACCIDENT_CAUSE	
o	ACCIDENT_OUTCOME	
c	CONDITION	
i	IMPACT	
m	MANUFACTURER	
y	MODEL_YEAR	
p	PART_OF_CAR	
n	PERSON	
s	STRUCTURE	
v	VEHICLE	

2004-49-168A.txt

1 V1, a 1999 Toyota Camry, was traveling southbound in the second lane of a four-lane divided (seven lanes overall, divided by raised median), concrete roadway, approaching an intersection.

2 V2, a 2004 Mercedes S430, was northbound in the fourth lane of a four-lane, divided (seven lanes overall, divided by raised median), concrete roadway, about to turn left into westbound traffic at the same intersection.

3 As both vehicles entered the intersection, the front of V1 impacted the front of V2.

4 V1 rotated clockwise as V2 rotated counter-clockwise, and the left side of V1 impacted the right side of V2 in a sideslap configuration.

5 Both vehicles moved southwest to final rest.

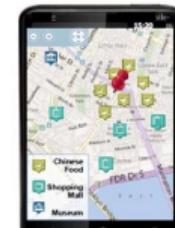
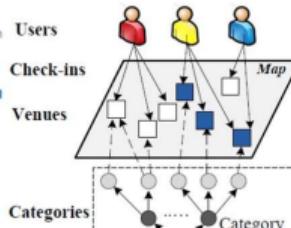
6 Both vehicles were towed due to damage.

7 The unrestrained driver of V1 was hospitalized with foot and rib fractures as well as a liver laceration.

8 The restrained driver of V2 was treated and released with minor abrasion and contusion as well as a finger fracture.

9 The restrained male right passenger in V2 was pronounced brain dead two days later from brain injuries.

10 V2 was equipped with airbags and dual front airbags which deployed.


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Applications 3: Fueling Discovery

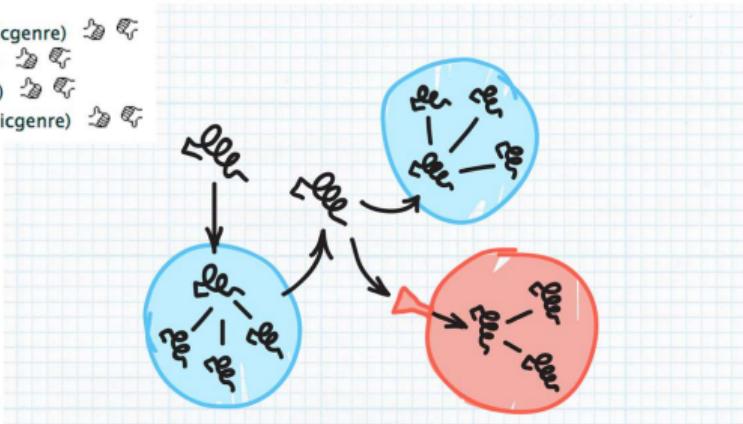
beatles (musicartist)

literal strings: BEATLES, Beatles, beatles

Help NELL Learn!

NELL wants to know if these beliefs about beatles are true.
If they are or ever were, click thumbs-up. Otherwise, click thumbs-down.

- beatles is a musical artist  
- beatles is a musician in the genre classic pop (musicgenre)  
- beatles is a musician in the genre pop (musicgenre)  
- beatles is a musician in the genre rock (musicgenre)  
- beatles is a musician in the genre classic rock (musicgenre)  



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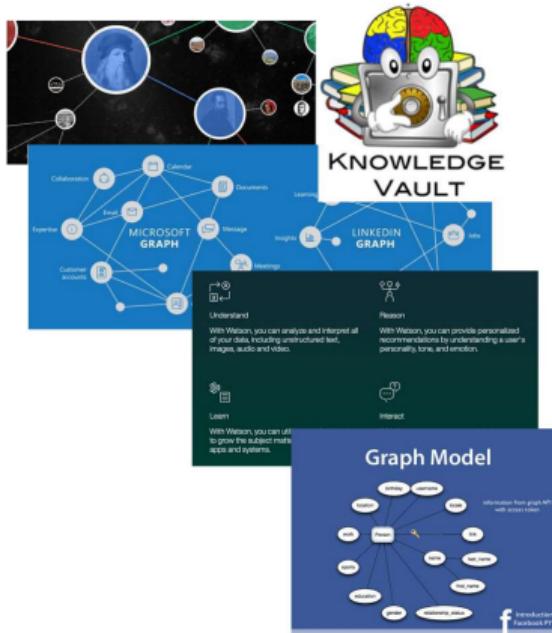
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Knowledge Graphs & Industry

- Google Knowledge Graph
 - Google Knowledge Vault
- Amazon Product Graph
- Facebook Graph API
- IBM Watson
- Microsoft Satori
 - Project Hanover/Literome
- LinkedIn Knowledge Graph
- Yandex Object Answer
- Diffbot, GraphIQ, Maana, ParseHub, Reactor Labs.

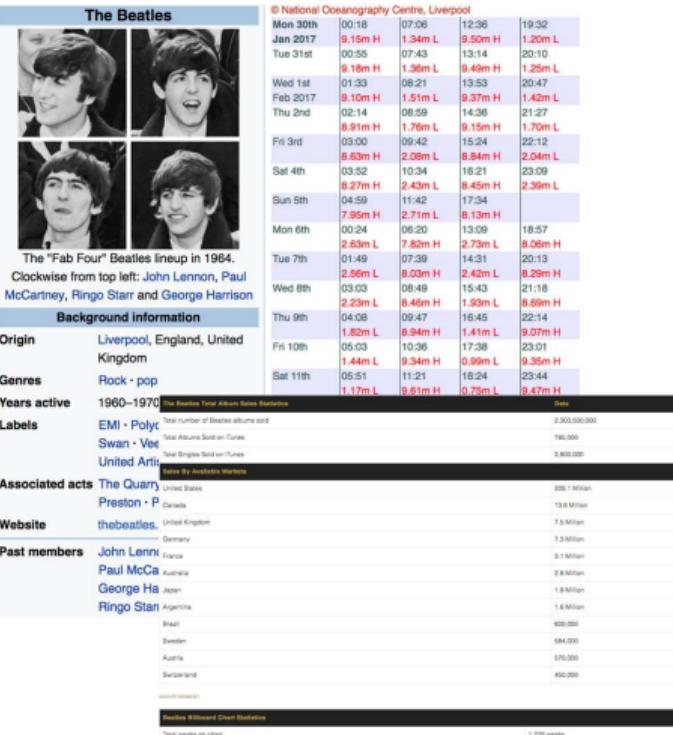


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Where do knowledge graphs come from?

- Structured Text

- Wikipedia Infoboxes, tables, databases, social nets

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Where do knowledge graphs come from?

- Structured Text
 - Wikipedia Infoboxes, tables, databases, social nets

- Unstructured Text
 - WWW, news, social media, reference articles

Beatles last live performance

Published: Thursday, January 26th 2017, 5:24 am PST

Updated: Monday, January 30th 2017, 4:06 am PST

Written by Jim Eftink, Producer [CONNECT](#)



(KFVS) - How about a little Beatles history.

It was on this date in 1969, the band performed their last live public performance.

Allan Williams, First Manager of the Beatles, Dies at 86

(SOURCE: Stock photo) By ALLAN KOZINN DEC. 31, 2016

The Beatles
January 19 at 10:00am - 4h
The Harrison family is pleased to announce the release of George Harrison - 1, the first ever box set featuring all of George Harrison's solo studio albums in one collection for the first time.

GEORGE HARRISON - THE VINYL COLLECTION
Released on 24th February, 2017, the vinyl box set includes all twelve of George's solo studio albums, plus his first solo single, plus his first solo tour diary and artwork. Also included in the box set are George's classic live album Live in Japan (2... See More

George Harrison - The Vinyl Collection - Released February 24th 2017
George Harrison - The Vinyl Collection, available to pre-order now, features an exclusive & limited edition...

Like 0 Comment 0 Share

828 shares

Write a comment...

Jeffrey Smith What I would really be interested in is an "All Things Paul" Press... Released "Gone" with just the basic tracks without Phil Spector's Wall of Sound. I would like to see the original songs and the ones that were cut. Like Reply · 1 day ago · January 17 at 10:00am · Edited

Dave Standard I think the greedy Harrison family and the greedy music industry make it difficult for us to buy records. I mean, I can't even afford to buy a CD or a download. Like Reply · 1 day ago · January 17 at 10:00am · Edited

anager of the Beatles in 1960, he sent them on a stint in Germany tagcraff. Press Association, via Associated Press

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- Images



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Where do knowledge graphs come from?

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- Unstructured Text
 - WWW, news, social media, reference articles
- Images
- Video
 - YouTube, video feeds

The Beatles - Topic

Home Videos Playlists Channels About

Top Tracks - The Beatles

 The Beatles - Hey Jude
TheBeatlesVEVO 63
44,642,725 views • 1 year ago

 The Beatles - Don't Let Me Down
TheBeatlesVEVO 69
48,399,211 views • 1 year ago

 The Beatles - A Day In The Life
TheBeatlesVEVO 68
3,132,900 views • 1 year ago

 The Beatles - Hello, Goodbye
TheBeatlesVEVO 63
3,298,211 views • 1 year ago





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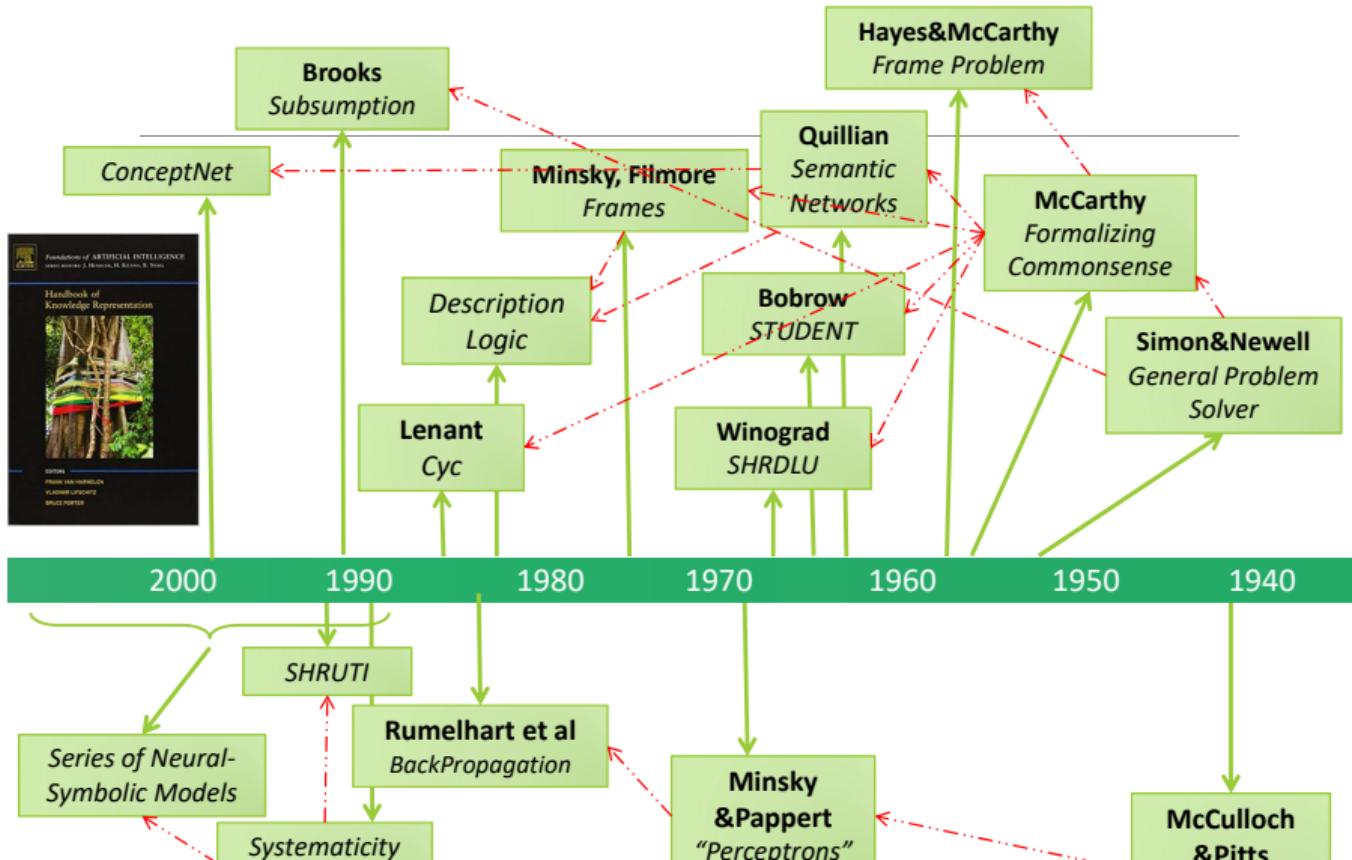
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History of Knowledge Representation (KR)

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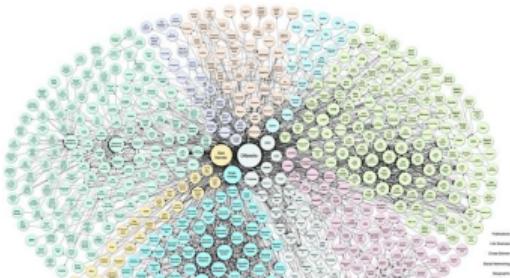
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Knowledge Representation

- Decades of research into knowledge representation
- Most knowledge graph implementations use RDF triples
 - <rdf:subject, rdf:predicate, rdf:object> : r(s,p,o)
 - Temporal scoping, reification, and skolemization...
- ABox (assertions) versus TBox (terminology)
- Common ontological primitives
 - rdfs:domain, rdfs:range, rdf:type, rdfs:subClassOf, rdfs:subPropertyOf, ...
 - owl:inverseOf, owl:TransitiveProperty, owl:FunctionalProperty, ...

Semantic Web

- Standards for defining and exchanging knowledge
 - RDF, RDFa, JSON-LD, schema.org
 - RDFS, OWL, SKOS, FOAF
- Annotated data provide critical resource for automation
- Major weakness: annotate everything?



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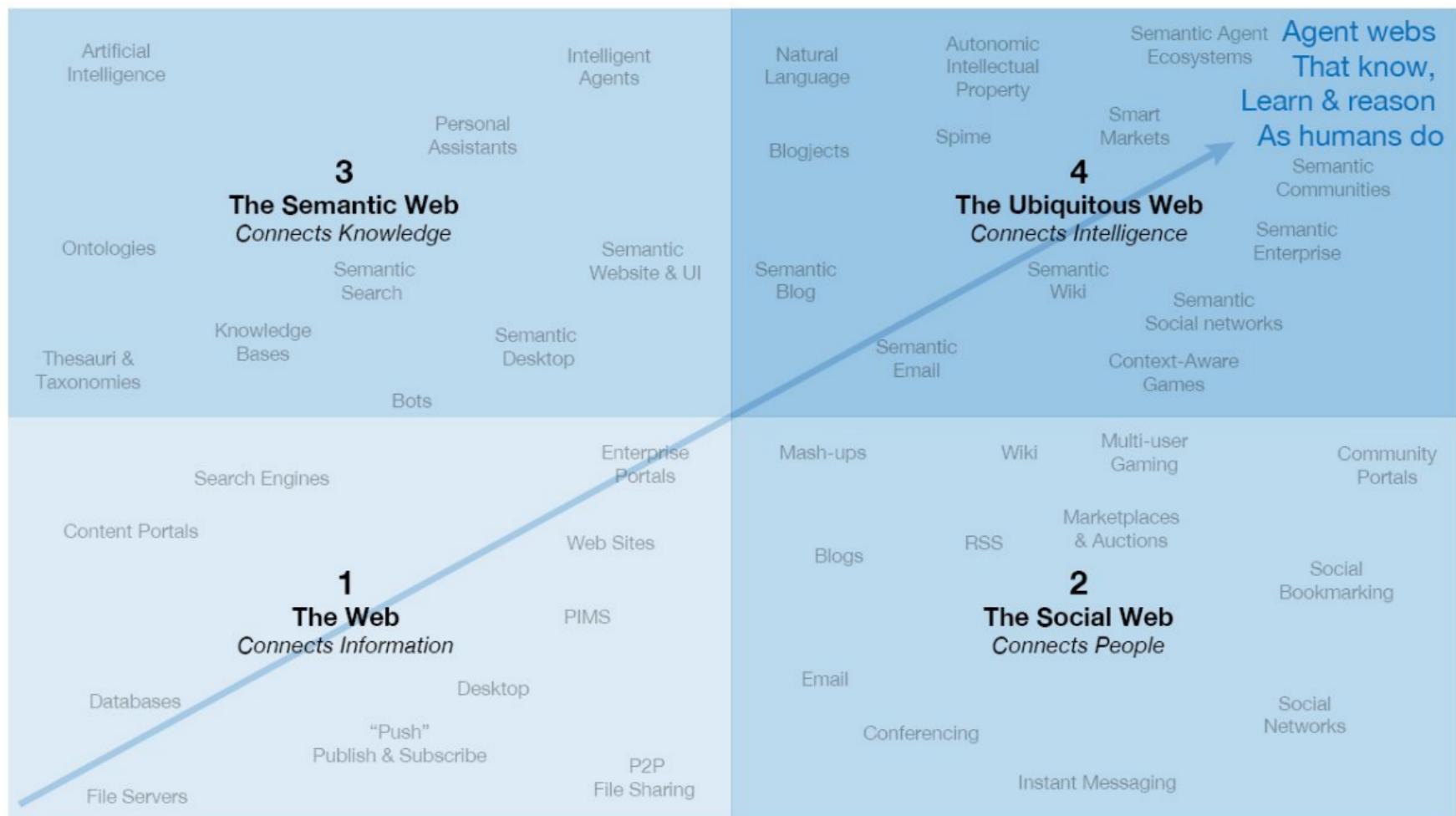
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Increasing Knowledge Connectivity & Reasoning

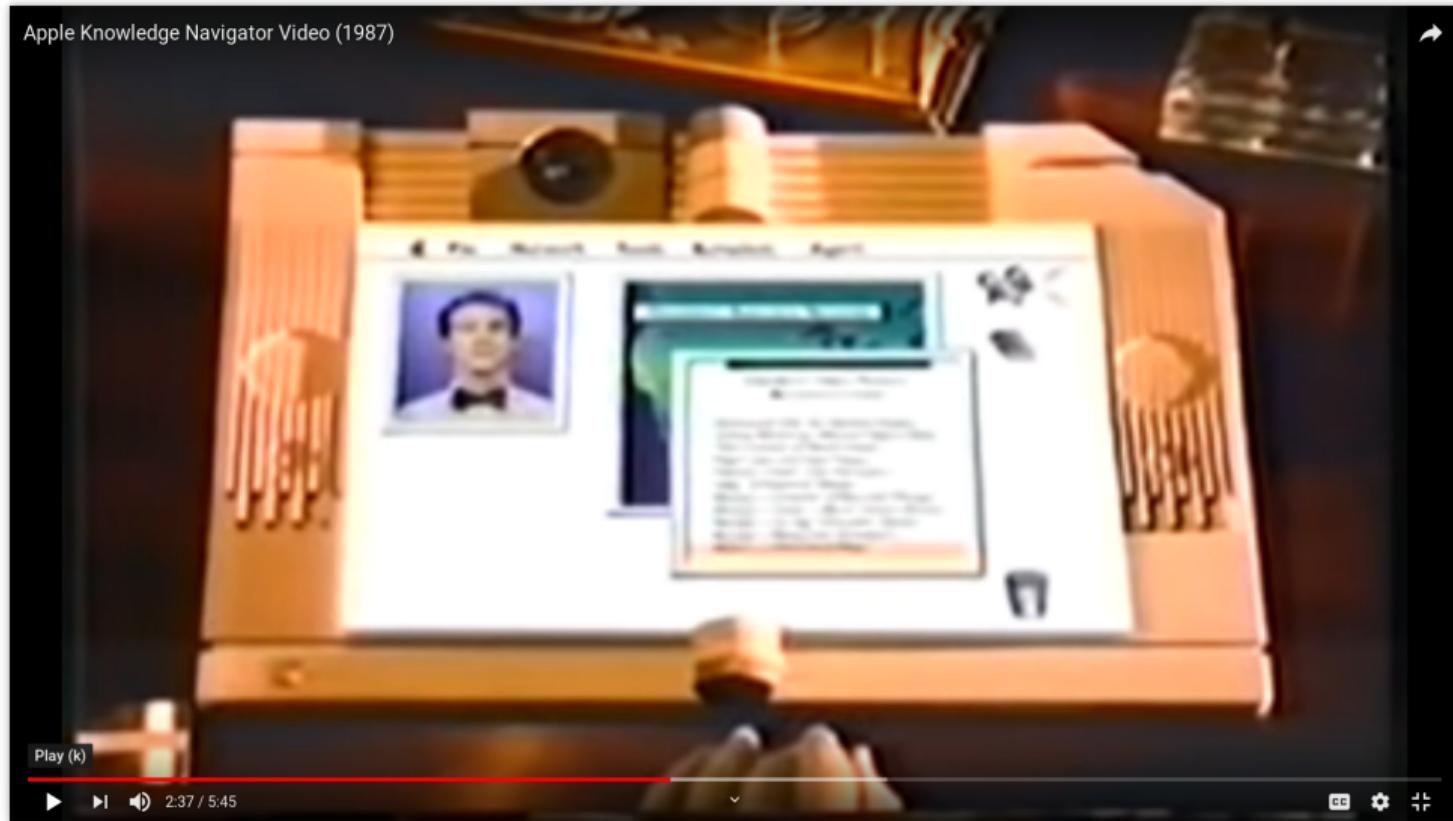


Increasing Social Connectivity

Apple's "Knowledge Navigator" Vision (1987)

René Witte

Apple Knowledge Navigator Video (1987)



<https://www.youtube.com/watch?v=umJsITGzXd0>



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From 1950–2020...

- Concepts have been around for a long time (Semantic Networks, Frames, Description Logic, ...)

1980s/90s

- AI/IS systems suffer from the *Knowledge Acquisition Bottleneck*
- One of the reasons for the *AI Winter* at that time

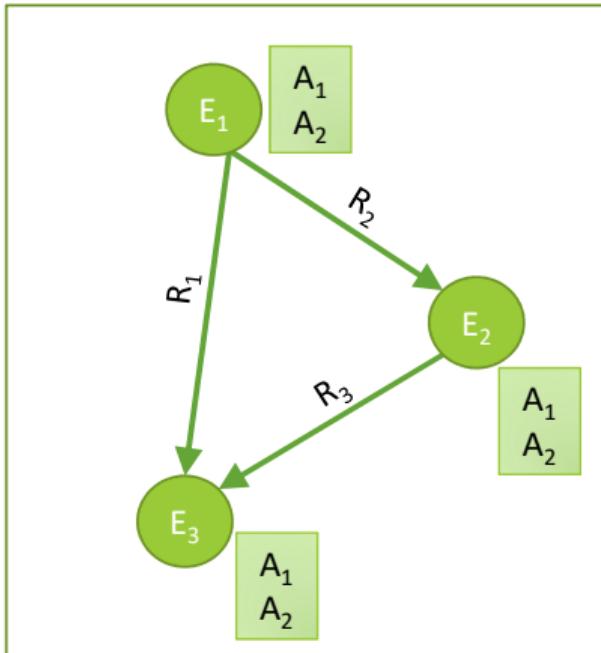
Technology

- Open standards, based on W3C recommendations, e.g., [RDF](#)
- Proprietary products, e.g., [Neo4J](#) or [Oracle Spatial and Graph](#)
- We now have substantial [knowledge bases](#) available, both proprietary (e.g., Facebook Graph Search, Google Knowledge Graph) and open access (e.g., Wikidata, DBpedia, YAGO)

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- Knowledge in graph form!
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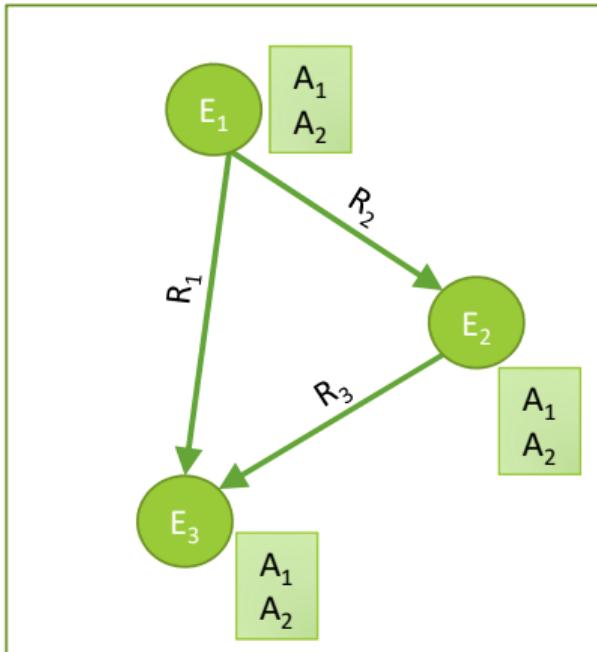
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Basic problems

- **Who** are the entities (nodes) in the graph?
- **What** are their attributes and types (labels)?
- **How** are they related (edges)?



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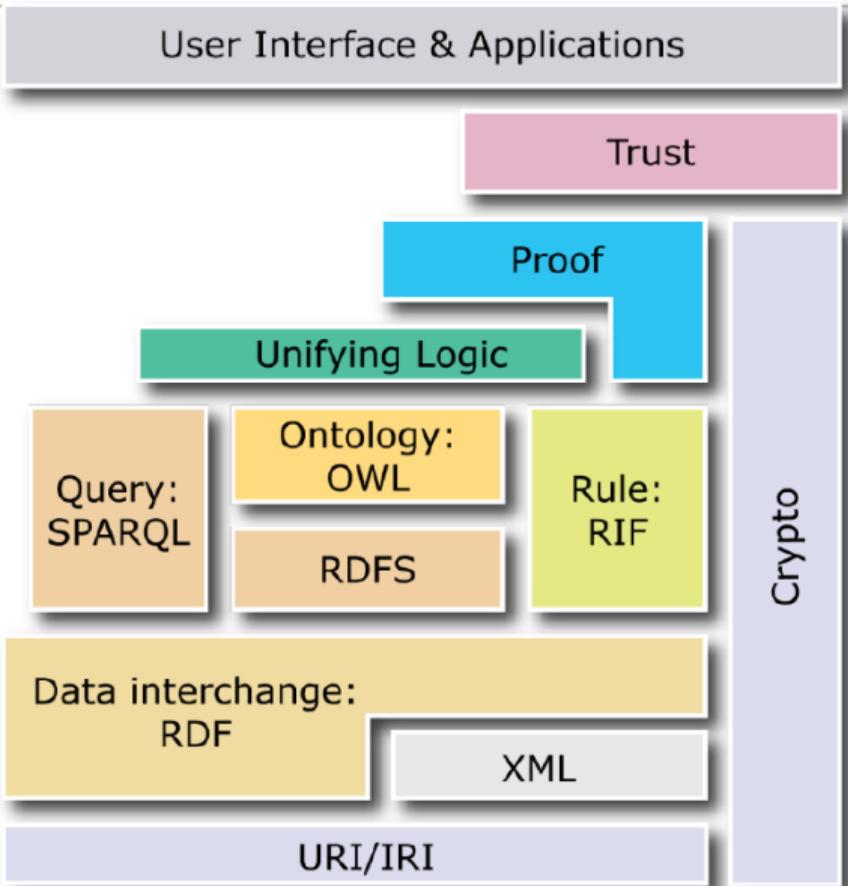
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The Basis: RDF

The W3C “Layer Cake”

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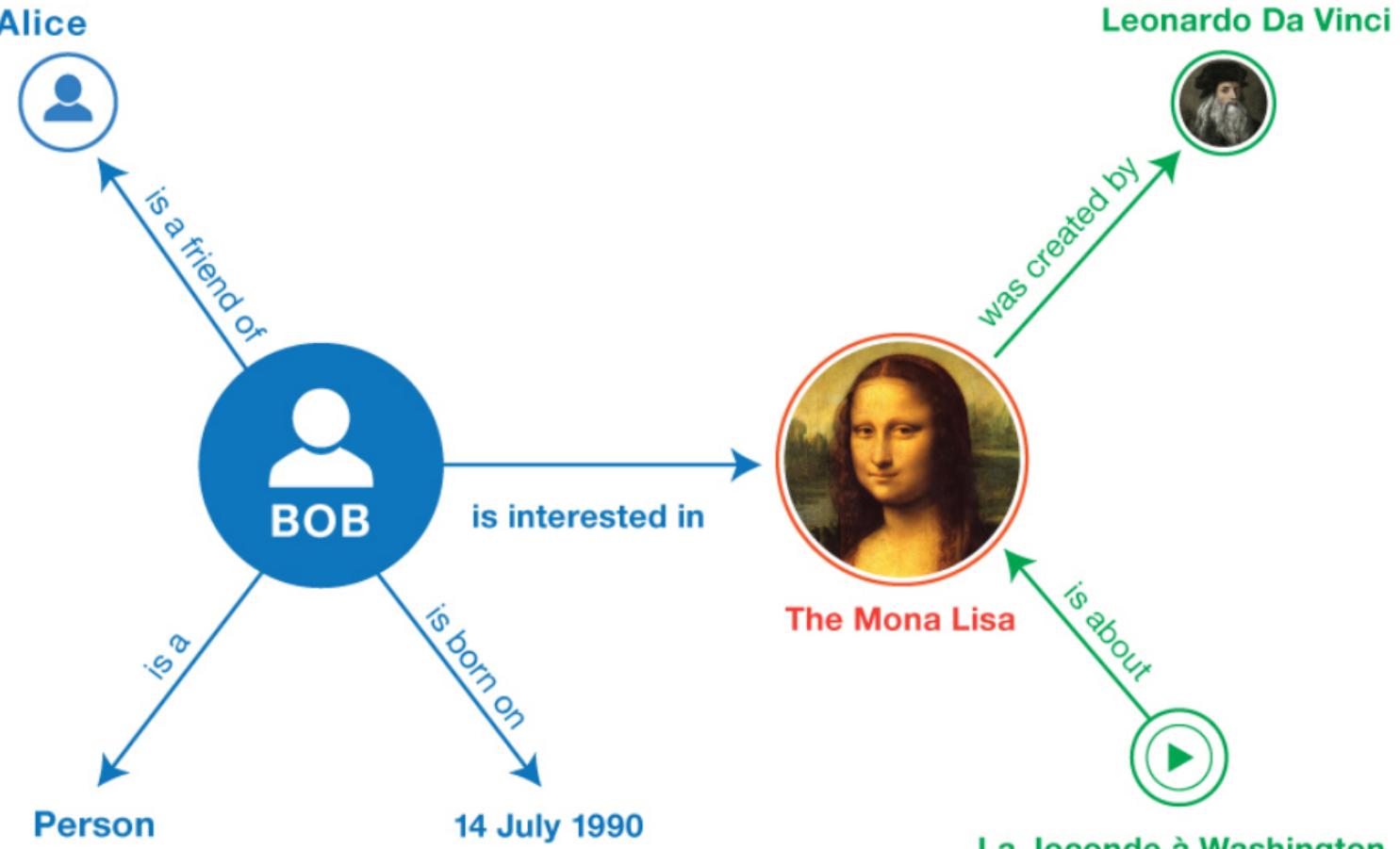
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Knowledge as Graphs

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Representation of Knowledge Graphs

In a system, we represent graphs in form of **triples**:

<subject> <predicate> <object>

(The *predicate* is sometimes called *property*.)

Examples

<Bob> <is a> <person>.

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

<Bob> <is born on> <the 14th of July 1990>.

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

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

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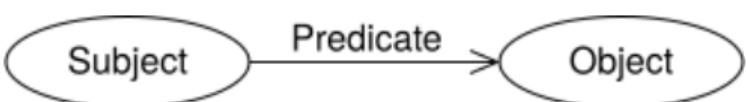
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<subject> <predicate> <object>



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The Resource Description Framework (RDF)

W3C (World Wide Web Consortium) standard (“recommendation”)

- first public draft 1997
- RDF 1.0 in 1999; revised in 2004
- RDF 1.1 in 2014 (current version)

Family of standards: RDF, RDFS, RDFa, Turtle, N3, SPARQL, ...

Format of triples

In RDF,

- Subject and predicate must be URIs (IRIs)
- Object can be IRI or **literal**

文字的

Examples

```
<http://www.wikidata.org/entity/Q12418>
  <http://purl.org/dc/terms/title>
  "Mona Lisa" .
```

```
<http://www.wikidata.org/entity/Q12418>
  <http://purl.org/dc/terms/creator>
  <http://dbpedia.org/resource/Leonardo_da_Vinci> .
```

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"Mona Lisa"

In this triple

```
<http://www.wikidata.org/entity/Q12418>
    <http://purl.org/dc/terms/title> "Mona Lisa" .
```

"Mona Lisa" is a **string literal**

Things to know about literals

- Literals have a **datatype**, e.g., string or int
- Strings can have a **language tag**, e.g.,
 "Leonardo da Vinci"@en
 "Léonard de Vinci"@fr
- Strings are often used to provide human-readable **labels**
 "Hey, how did you like the movie Q168154?"
- For strings only, datatype can be omitted:
 "Mona Lisa" is equivalent to "Mona Lisa"^^xsd:string
- Again, literals can **only** appear in the **object** position of a triple `<s> <p> <o>`



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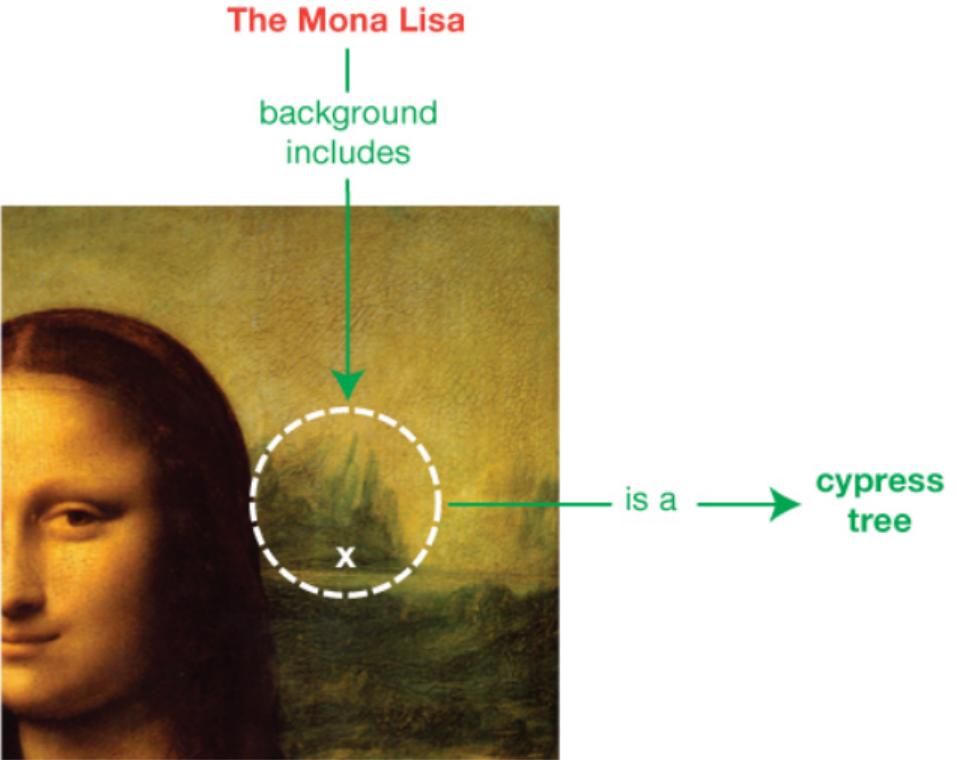
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```
<http://dbpedia.org/resource/Mona_Lisa> <lio:shows> _:x .
```

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About: Leonardo da Vinci

An Entity of Type : person, from Named Graph : <http://dbpedia.org>, within Data Space : dbpedia.org

Leonardo di ser Piero da Vinci (Italian: [leo'nardo di ser 'pjero da (v)intʃi] (); 14/15 April 1452 – 2 May 1519), known as Leonardo da Vinci (English: LEE-ə-NAR-doh də VIN-chee, LEE-oh-, LAY-oh-), was an Italian polymath of the Renaissance who is widely considered one of the greatest painters of all time (despite less than 25 of his paintings having survived). He is also known for his , in which he made drawings and notes on science and invention; these involve a variety of subjects including anatomy, cartography, and paleontology.

Property	Value
dbo:abstract	■ Leonardo di ser Piero da Vinci (Italian: [leo'nardo di ser 'pjero da (v)intʃi] (); 14/15 April 1452 – 2 May 1519), known as Leonardo da Vinci (English: LEE-ə-NAR-doh də VIN-chee, LEE-oh-, LAY-oh-), was an Italian polymath of the Renaissance who is widely considered one of the greatest painters of all time (despite less than 25 of his paintings having survived). He is also known for his , in which he made drawings and notes on science and invention; these involve a variety of subjects including anatomy, cartography, and paleontology.

DBpedia URIs

Make sure you use the correct URI:

- [http://dbpedia.org/resource/...](http://dbpedia.org/resource/Leonardo_da_Vinci) is the canonical URI
- The DBpedia server returns either
 - [http://dbpedia.org/page/...](http://dbpedia.org/page/Leonardo_da_Vinci) (HTML data, for a human)
 - [http://dbpedia.org/data/...](http://dbpedia.org/data/Leonardo_da_Vinci) (RDF data, for an AI)

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Shortening URIs

Instead of always writing full URIs (IRIs), we can split them into a **prefix** and **suffix**,
e.g.: <http://dbpedia.org/resource/Leonardo_da_Vinci>

- We define a prefix dbpedia:

```
PREFIX dbpedia: <http://dbpedia.org/resource/>
```

- and now we can simple write:

```
dbpedia:Leonardo_da_Vinci 在此行不使用<>
```

- Note: angle brackets <> only for full IRIs

→ reduces dataset sizes, easier to read

Conventions

Commonly used URLs use the same namespace prefix

- E.g., FOAF (friend-of-a-friend):

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
```

- Lookup a prefix at <https://prefix.cc/>

→ Worksheet #1: Tasks 8 & 9

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Formats

There is no single format .rdf (like .xml), commonly used are:

RDF/XML for data exchange (somewhat deprecated)

RDFa for embedding RDF into web pages

N-Triples (N3) for streaming RDF data and bulk dataset up-/download

Turtle for human-readable files

JSON-LD for web applications

plus some variations/extensions.

N-Triples

So far, we've mostly used the N-Triples format: 在N-Triples中用一行来表示

```
<http://www.wikidata.org/entity/Q12418> ←  
<http://purl.org/dc/terms/title> "Mona Lisa" .
```

each line in a file is one triple, full IRIs only (no namespace prefixes) and ended by a period '.'

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```

BASE <http://example.org/>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema>
PREFIX schema: <http://schema.org/>
PREFIX dcterms: <http://purl.org/dc/terms/>
PREFIX wd: <http://www.wikidata.org/entity/>
```

<bob#me> 此处bob是subject

```

    a foaf:Person ;
    foaf:knows <alice#me> ;
    schema:birthDate "1990-07-04"^^xsd:date ;
    foaf:topic_interest wd:Q12418 .
```

此处是省略用法

bob与这四个都形成triples

wd:Q12418

```

        dcterms:title "Mona_Lisa" ;
        dcterms:creator <http://dbpedia.org/resource/Leonardo_da_Vinci> .
```

```

<http://data.europeana.eu/item/04802/243FA8618938F4117025F17A8B813C5F9AA4D619>
        dcterms:subject wd:Q12418 .
```

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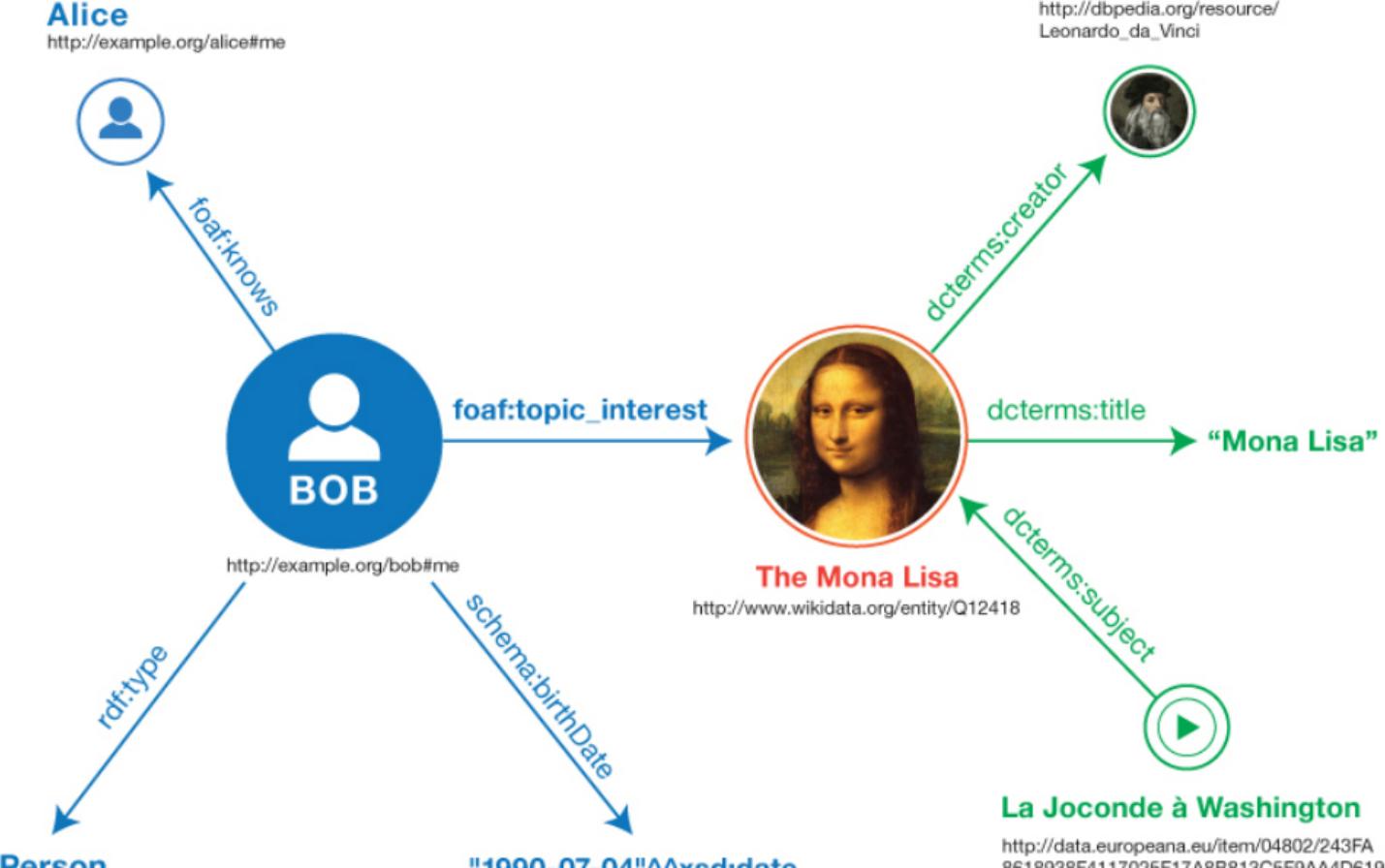
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Graph corresponding to the Turtle example

René Witte



RDF in programming practice

René Witte



- ▶ For example, using Python+RDFLib:
 - a “Graph” object is created
 - the RDF file is parsed and results stored in the Graph
 - the Graph offers methods to retrieve (or add):
 - triples
 - (property,object) pairs for a specific subject
 - (subject,property) pairs for specific object
 - etc.
 - the rest is conventional programming...
- ▶ Similar tools exist in Java, PHP, etc.

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Python example using RDFLib

```
# create a graph from a file
graph = rdflib.Graph()
graph.parse("filename.rdf", format="rdfformat")
# take subject with a known URI
subject = rdflib.URIRef("URI_of_Subject")
# process all properties and objects for this subject
for (s,p,o) in graph.triples((subject,None,None)) :
    do_something(p,o)
```

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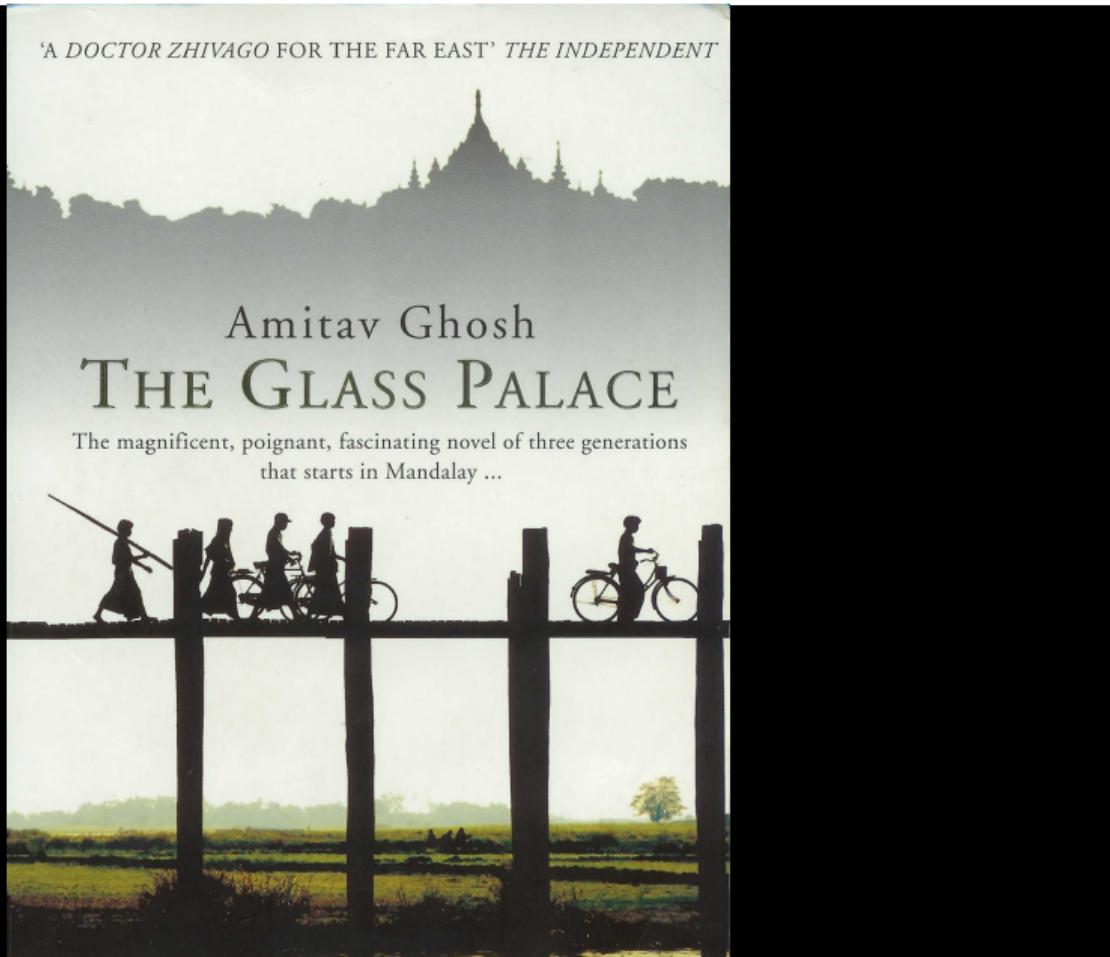
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A simplified bookstore data (dataset “A”)

ISBN	Author	Title	Publisher	Year
0006511409X	id_xyz	The Glass Palace	id_qpr	2000

ID	Name	Homepage
id_xyz	Ghosh, Amitav	http://www.amitavghosh.com

ID	Publisher's name	City
id_qpr	Harper Collins	London

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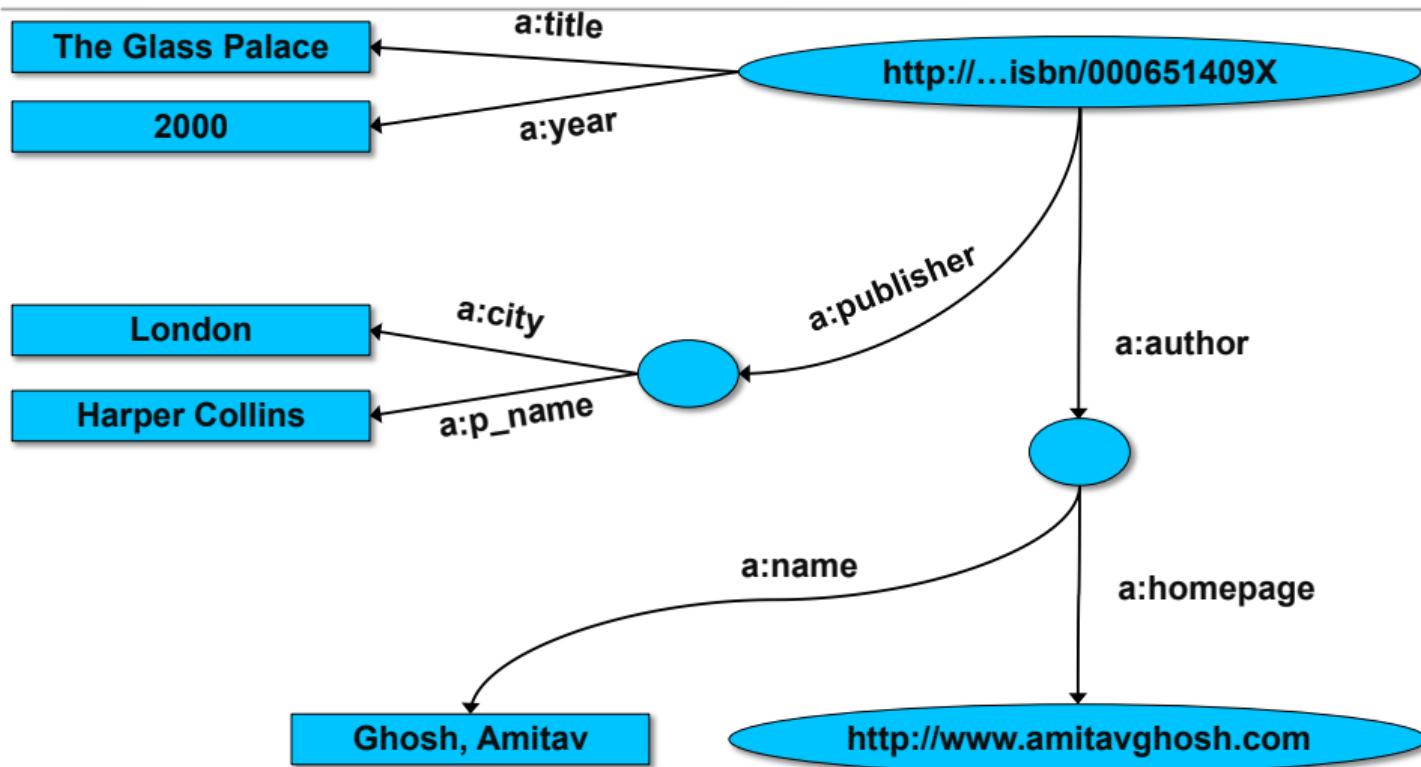
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1st: export your data as a set of relations



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Some notes on the exporting the data

- ▶ Relations form a graph
 - the nodes refer to the “real” data or contain some literal
 - how the graph is represented in machine is immaterial for now

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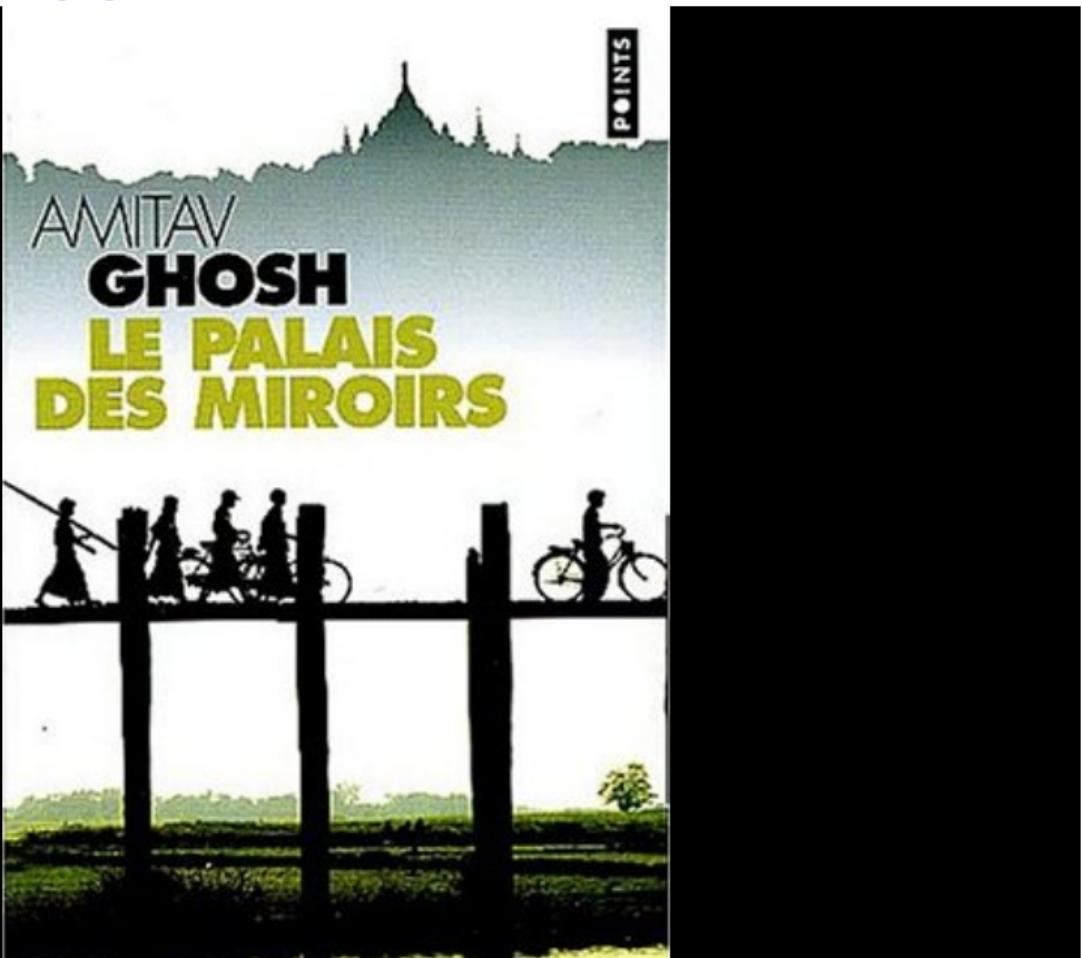
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Now the same book in French...

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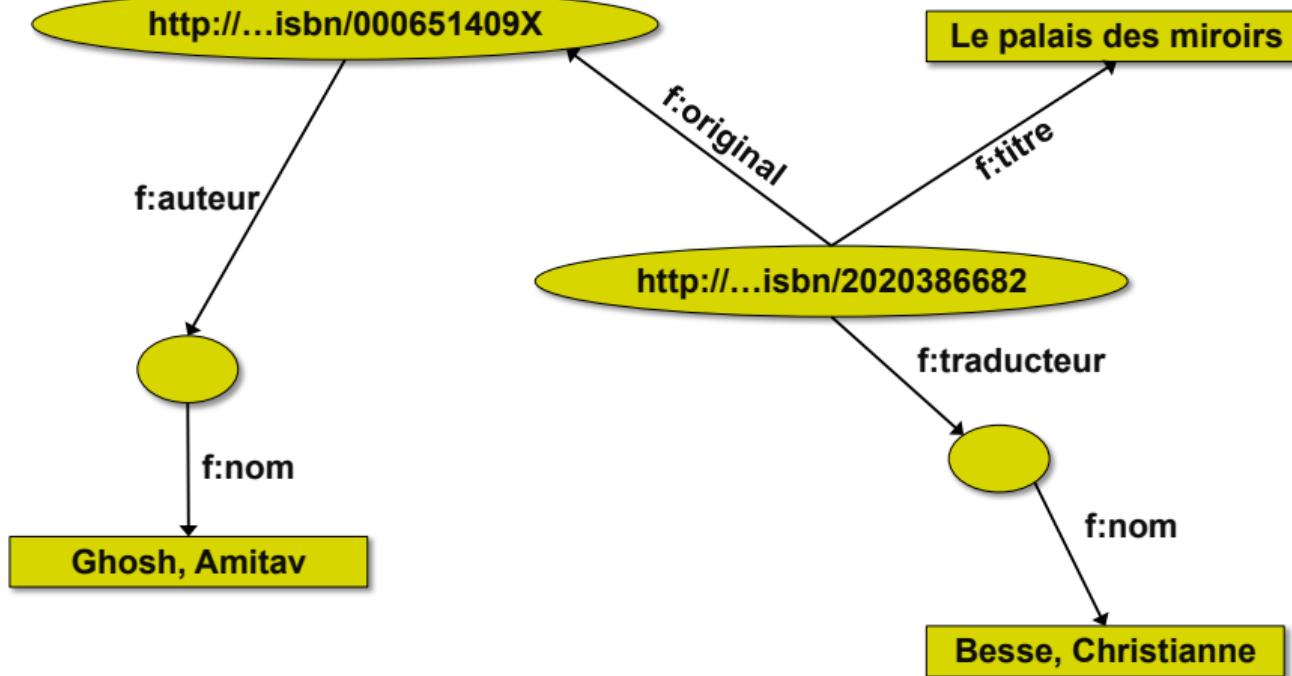
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Another bookstore data (dataset “F”)

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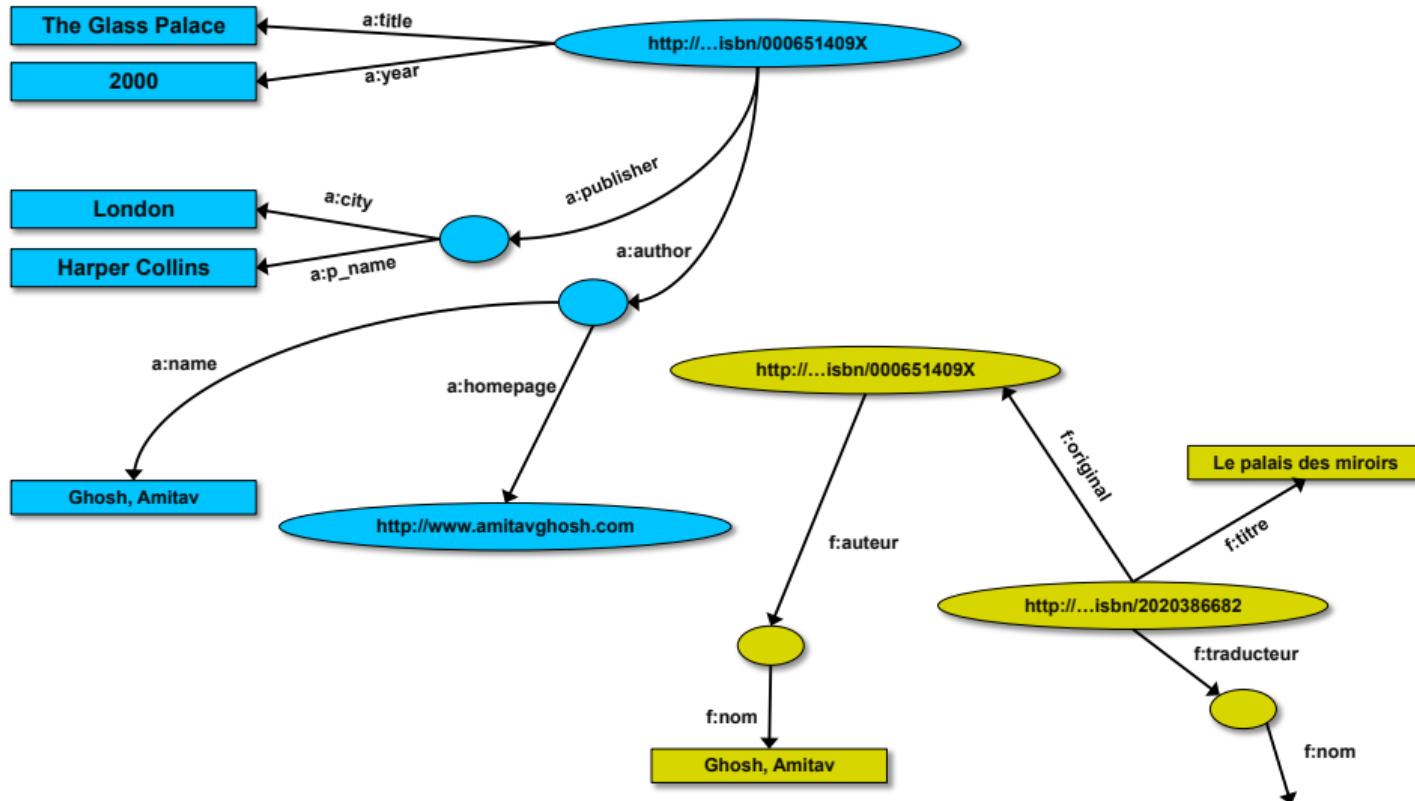
A	B	C	D
1	ID	Titre	Traducteur
2	ISBN 2020286682	Le Palais des Miroirs	\$A12\$
3			ISBN 0-00-6511409-X
4			
5			
6	ID	Auteur	
7	ISBN 0-00-6511409-X	\$A11\$	
8			
9			
10	Nom		
11	Ghosh, Amitav		
12	Besse, Christianne		

2nd: export your second set of data



3rd: start merging your data

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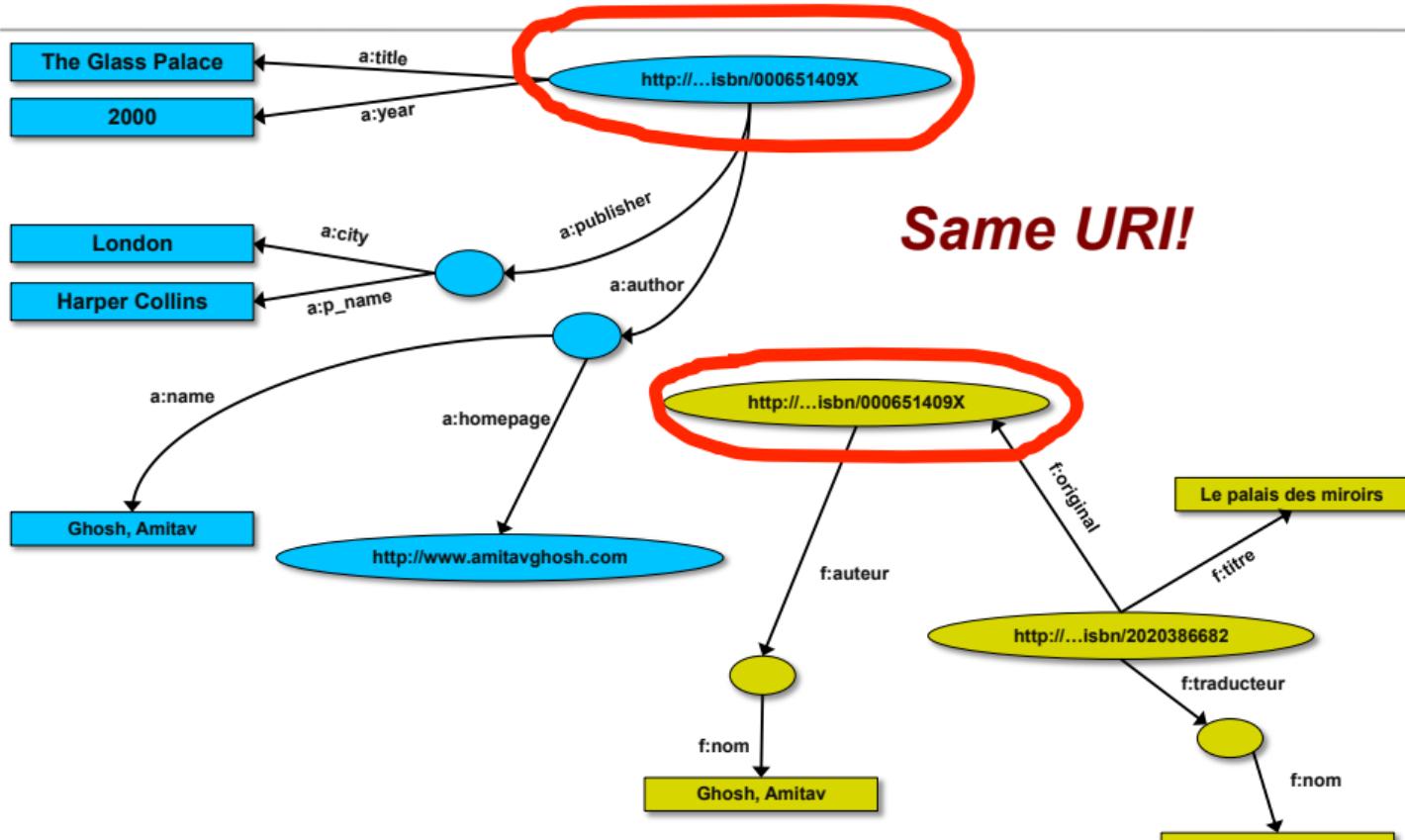
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3rd: start merging your data (cont)



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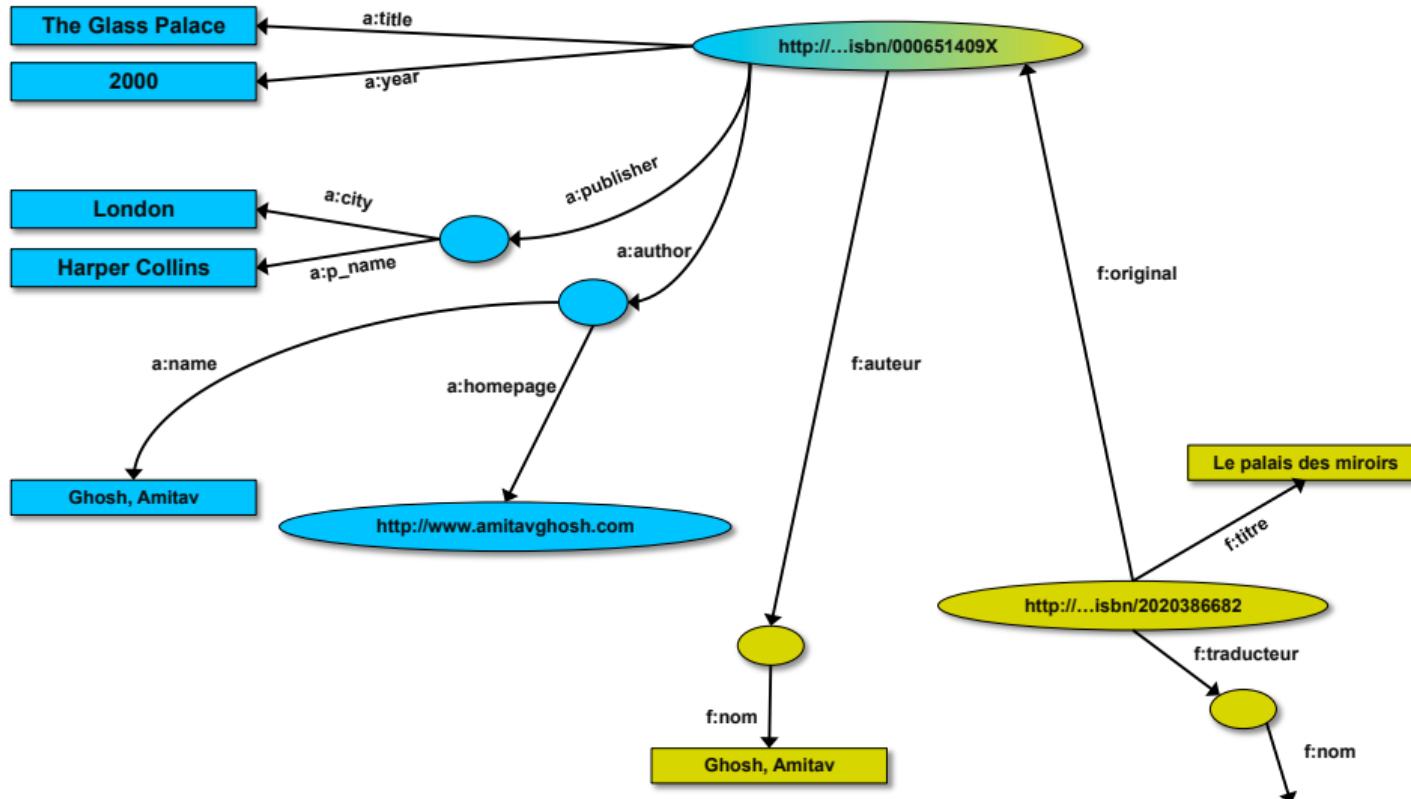
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3rd: start merging your data

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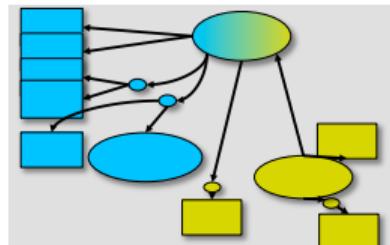
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Start making queries...

- ▶ User of data “F” can now ask queries like:
 - “give me the title of the original”
 - well, ... « donnez-moi le titre de l’original »
- ▶ This information is not in the dataset “F”...
- ▶ ...but can be retrieved by merging with dataset “A”!



However, more can be achieved...

- ▶ We “feel” that a:author and f:auteur should be the same
- ▶ But an automatic merge does not know that!
- ▶ Let us add some extra information to the merged data:
 - a:author same as f:auteur
 - both identify a “Person”
 - a term that a community may have already defined:
 - a “Person” is uniquely identified by his/her name and, say, homepage
 - it can be used as a “category” for certain type of resources

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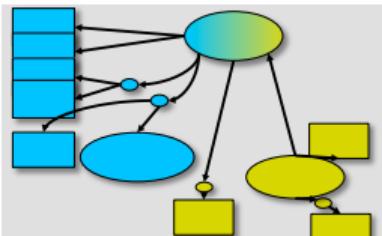
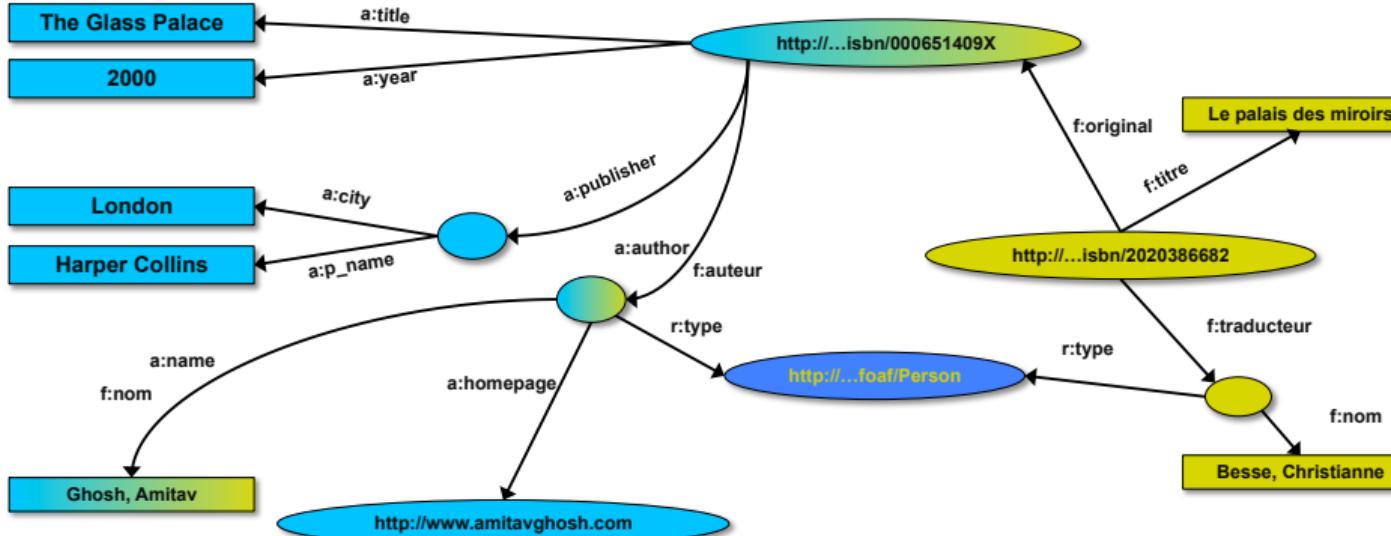
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3rd revisited: use the extra knowledge

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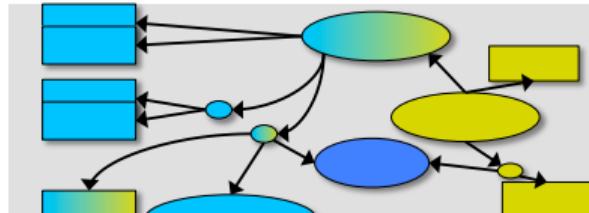
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Start making richer queries!

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- ▶ User of dataset “F” can now query:
 - “donnes-moi la page d'accueil de l'auteur de l'original”
 - well... “give me the home page of the original's ‘auteur’”
- ▶ The information is not in datasets “F” or “A”...
- ▶ ...but was made available by:
 - merging datasets “A” and datasets “F”
 - adding three simple extra statements as an extra “glue”



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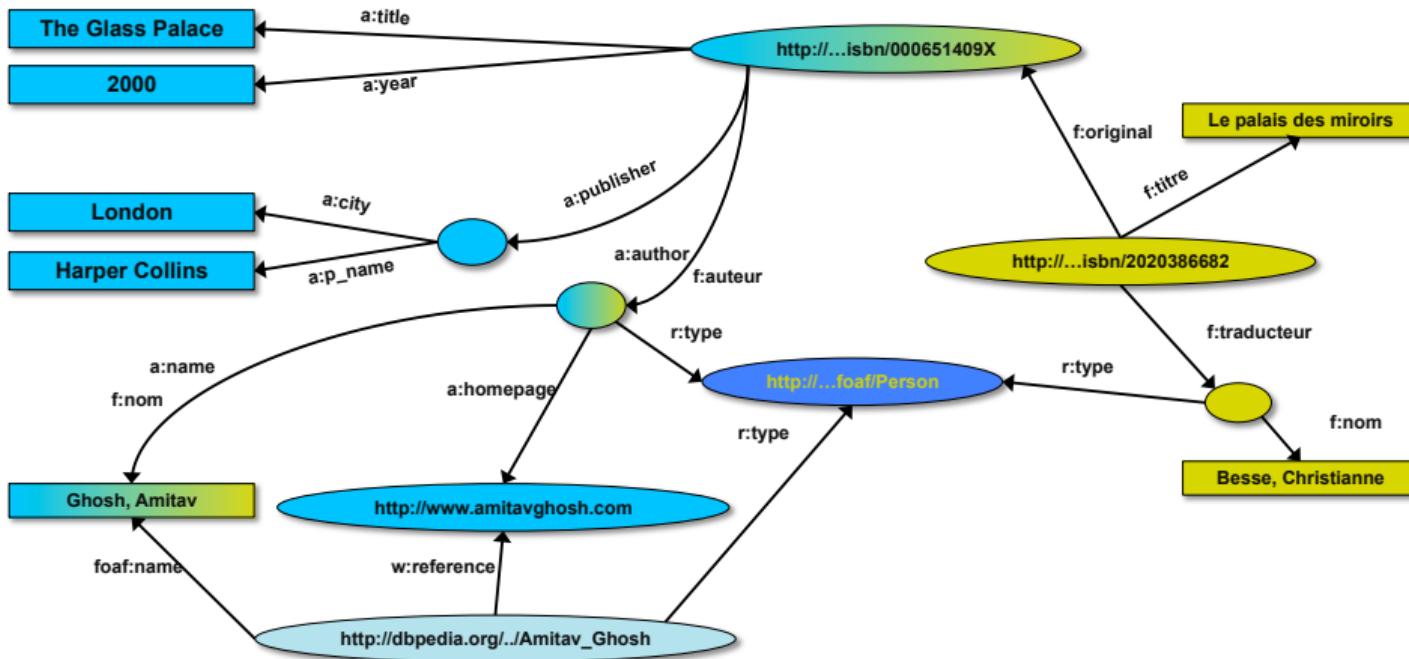
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Combine with different datasets

- ▶ Using, e.g., the “Person”, the dataset can be combined with other sources
- ▶ For example, data in Wikipedia can be extracted using dedicated tools
 - e.g., the “[dbpedia](#)” project can extract the “infobox” information from Wikipedia already...

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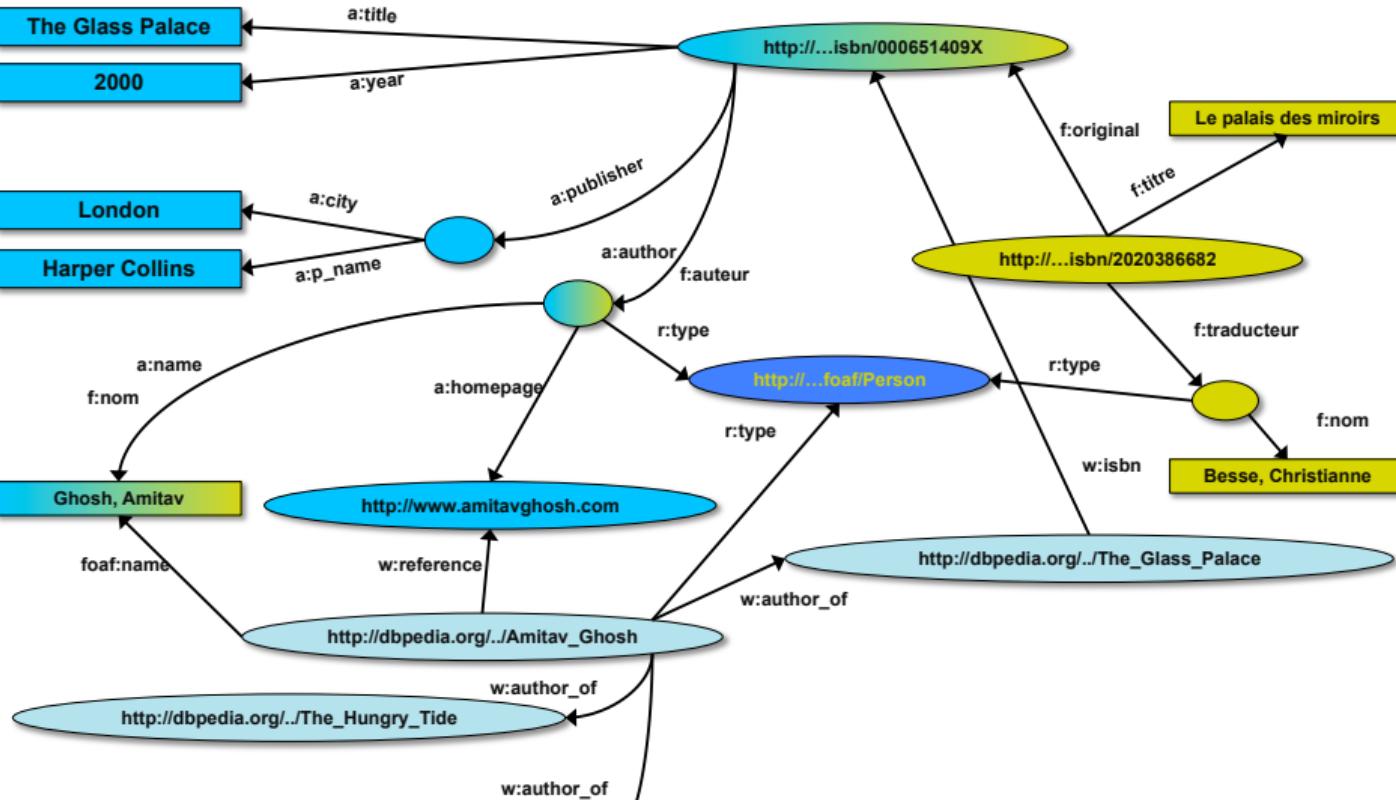
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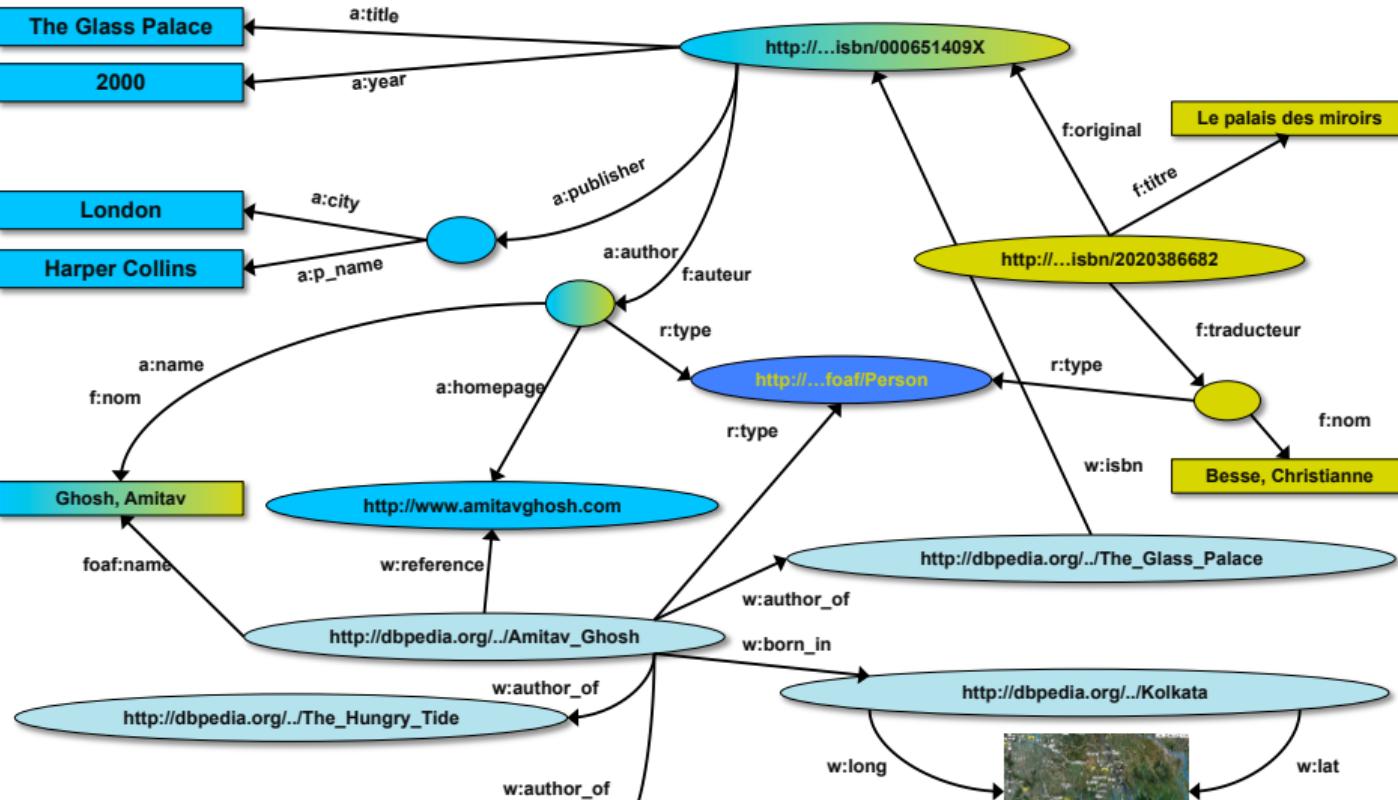
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Is that surprising?

- ▶ It may look like it but, in fact, it should not be...
- ▶ What happened via automatic means is done every day by Web users!
- ▶ The difference: a bit of extra rigour so that machines could do this, too

→ **Worksheet #1: Task 10**

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What did we do?

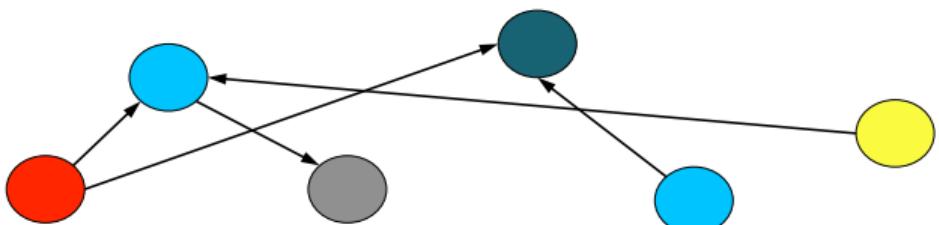
René Witte



Applications

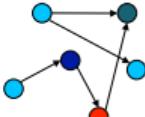
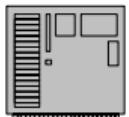


Manipulate
Query
...



Data represented in abstract format

Map,
Expose,
...



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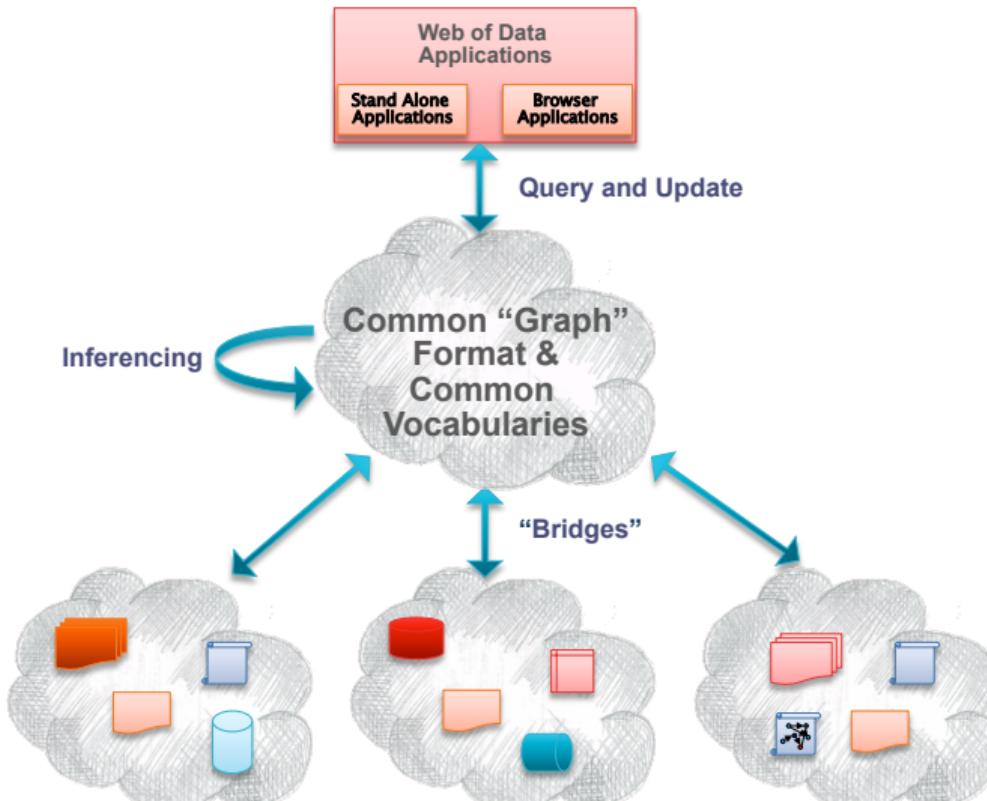
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What did we do? (alternate view)

René Witte



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Success story: OpenIE (ReVerb)

 **Open Information Extraction**

openie.allenai.org

Hosted by  Created at 

Argument 1:

Argument 2:

Relation:

All   Search

[all](#) [location \(21\)](#) [film location \(18\)](#) [statistical region \(16\)](#) [name source \(15\)](#) [travel destination \(14\)](#) [misc.](#)

[more types](#) ▾

were bigger than **Jesus** (100)

came to America (95)

appeared on **The Ed Sullivan Show** (88)

broke up in 1970 (56)

Here Comes the Sun (46)

came to America (45)

is for the future (44)

are a great band (42)

perform on **The Ed Sullivan Show** (39)

are a great band ➔ 

Extracted Synonyms:

were
is
was

Extracted from these sentences:

are **The Beatles** are the **best band** , hands down but Oasis did make a great cover . (via ClueWeb12)
The Beatles are a **great band** . (via ClueWeb12)
The Beatles are the **best band** . (via ClueWeb12)
The Beatles are the **greatest band** ... Started 1 month ago by georgedcc Yeah , Songs in the Key of Life is a bit much for 1 listen . (via ClueWeb12)
The Beatles , arguably , are the **greatest band** , and may or may not have the greatest name . (via ClueWeb12)
The Beatles , from the 1960s , are the **best band** ever . (via ClueWeb12)

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Success story: NELL

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NELL Knowledge Base Browser

CMU Read the Web Project

[Search](#)
[log in](#) | [preferences](#) | [help/instructions](#) | [feedback](#)
[categories](#)
[relations](#)

- everypromotedthing
- abstractthing
- event
 - convention
 - musicfestival
 - protestevent
 - meetingeventtitle
 - conference
 - mlconference
 - weatherphenomenon
 - sportsevent
 - sportsgame
 - race
 - olympics
 - grandprix
 - crimeorcharge
 - earthquakeevent
 - election
 - bombingevent
 - militaryeventtype
 - militaryconflict
 - productlauchevent
 - filmfestival
 - roadaccidentevent
 - meetingeventtype
 - eventoutcome
 - malgraphithm
 - physiologicalcondition
 - disease

beatles (musicartist)

 literal strings: [BEATLES](#), [Beatles](#), [beatles](#)

Help NELL Learn!

NELL wants to know if these beliefs are correct.
 If they are or ever were, click thumbs-up. Otherwise, click thumbs-down.

- [beatles](#) is a [musical artist](#)
- [beatles](#) is a musician in the [genre classic_pop](#) ([musicgenre](#))
- [beatles](#) is a musician in the [genre pop](#) ([musicgenre](#))
- [beatles](#) is a musician in the [genre rock](#) ([musicgenre](#))
- [beatles](#) is a musician in the [genre classic_rock](#) ([musicgenre](#))

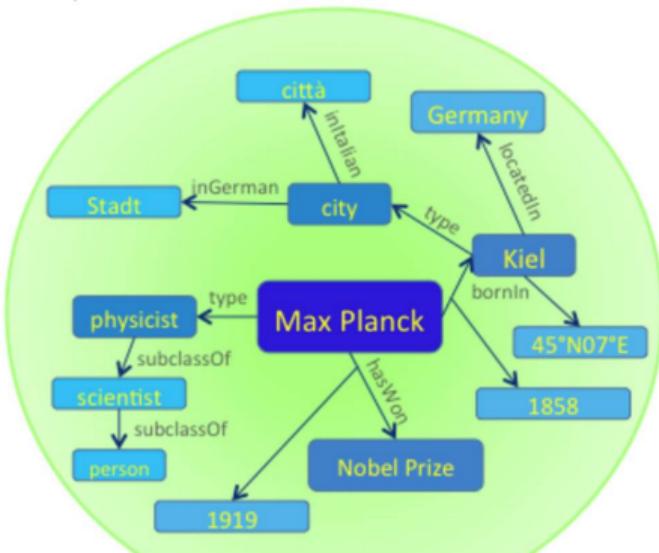
categories

- [musicartist](#)(100.0%)

- MBL @198 (100.0%) on 07-feb-2011 [Promotion of musicartist:beatles musicartist:genre musicgenre:classic_rock]
- CPI @1021 (80.9%) on 14-oct-2016 ["numerous other artists including _ "traducidas de _", incluidas en" _ had a guitar player" "early pioneers such as _ "controversial photo of _ "distressed image of _ "D-tracks of _ "Beatles Come Together" _ "ohne die _ "opening band for _ "American acts like _ "classic acts like _ "performance footage of _ " _ were the perfect band" _ "record label" "record album by _ "les paroles de _", never recorded the song" "such renowned artists as _ _ did a few songs" "Top artists include _ "crazy lives of _ "UK artists such as _ "Lennon started _ " musical talent" _ "Birthplace" _ "harmonies" "Tour , starring _ " _ last days" _ "fourth album" _ "sixth studio album" _ "original recordings" "They were also pushing _ "She Said by _ "Other artists featured include _ "Post general comments related to _ "track also shows _ "such major artists as _ "time favorite band is _ "past masters such as _ "pop hooks of _ "popular musicians like _ "pop icons such as _ "music artists like _ "music bands like _ "pop stars such as _ "pop influenced by _ "

Success story: YAGO

- **Input:** Wikipedia infoboxes, WordNet and GeoNames
- **Output:** KG with 350K entity types, 10M entities, 120M facts
- Temporal and spatial information



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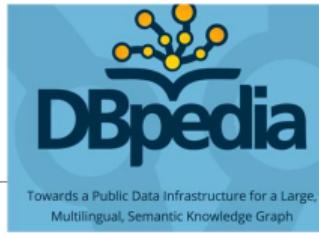
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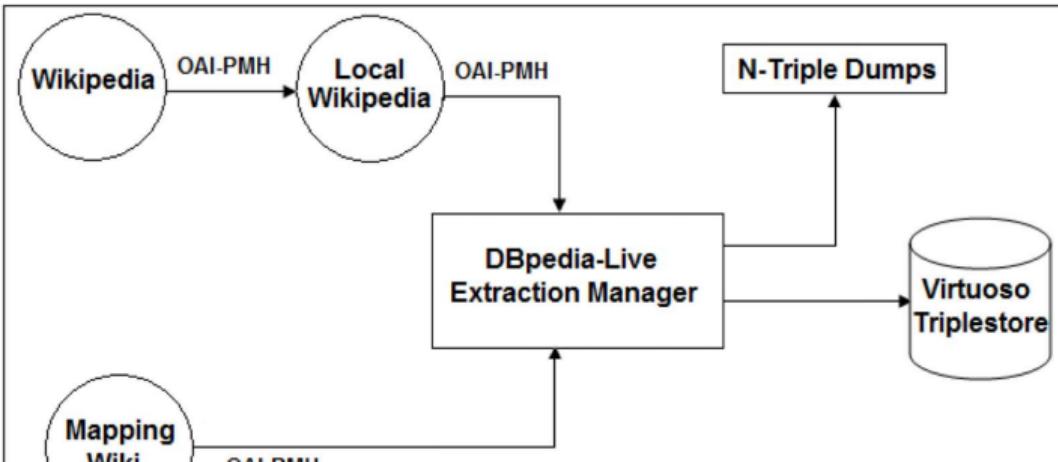
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Success story

- DBpedia is automatically extracted structured data from Wikipedia
 - 17M canonical entities
 - 88M type statements
 - 72M infobox statements



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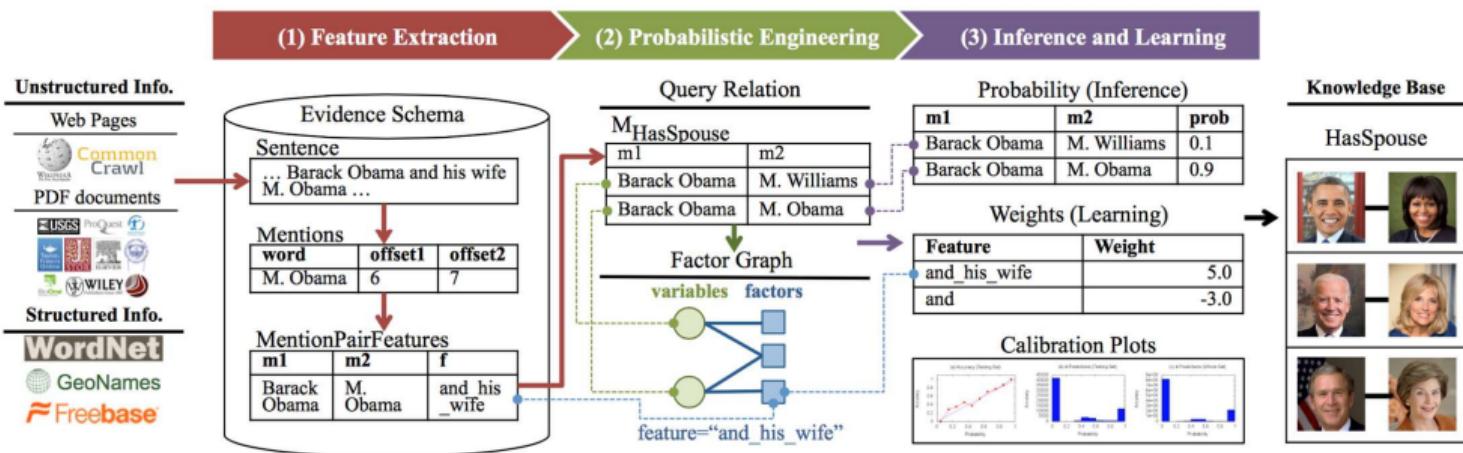
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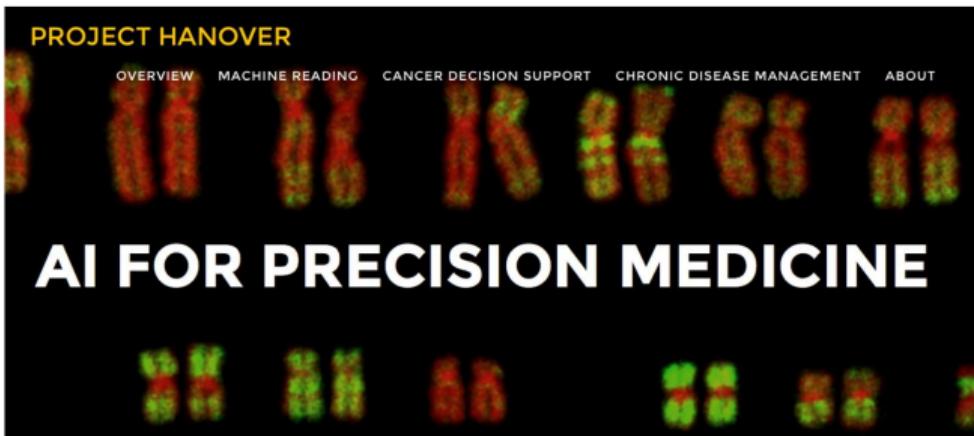
DeepDive



- Best Precision/recall/F1 in KBP-slot filling task 2014 evaluations (31 teams participated)

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Interesting application of Knowledge Graphs



Microsoft[®]
Research

Chronic disease management:

develop AI technology for predictive and preventive personalized medicine to reduce the national healthcare expenditure on chronic diseases

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Aristo Science QA challenge

- Science questions dataset

~5K 4-way multiple choice questions

Frogs lay eggs that develop into tadpoles and then into adult frogs. This sequence of changes is an example of how living things _____

- (A) go through a life cycle
- (B) form a food web
- (C) act as a source of food
- (D) affect other parts of the ecosystem

Science knowledge

frog's life cycle,
metamorphosis



Common sense
knowledge

frog is an animal,
animals have life cycle

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Knowledge Extraction

John was born in Liverpool, to Julia and Alfred Lennon.

Text

NLP

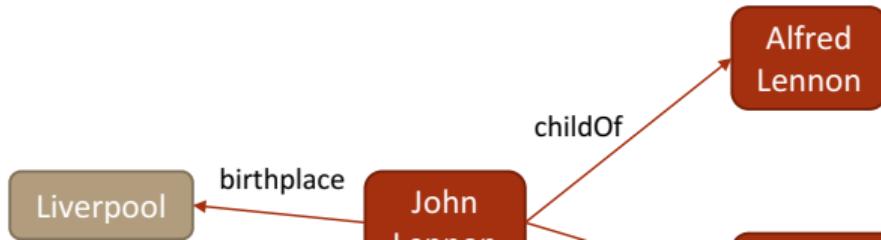


Annotated text

Information
Extraction

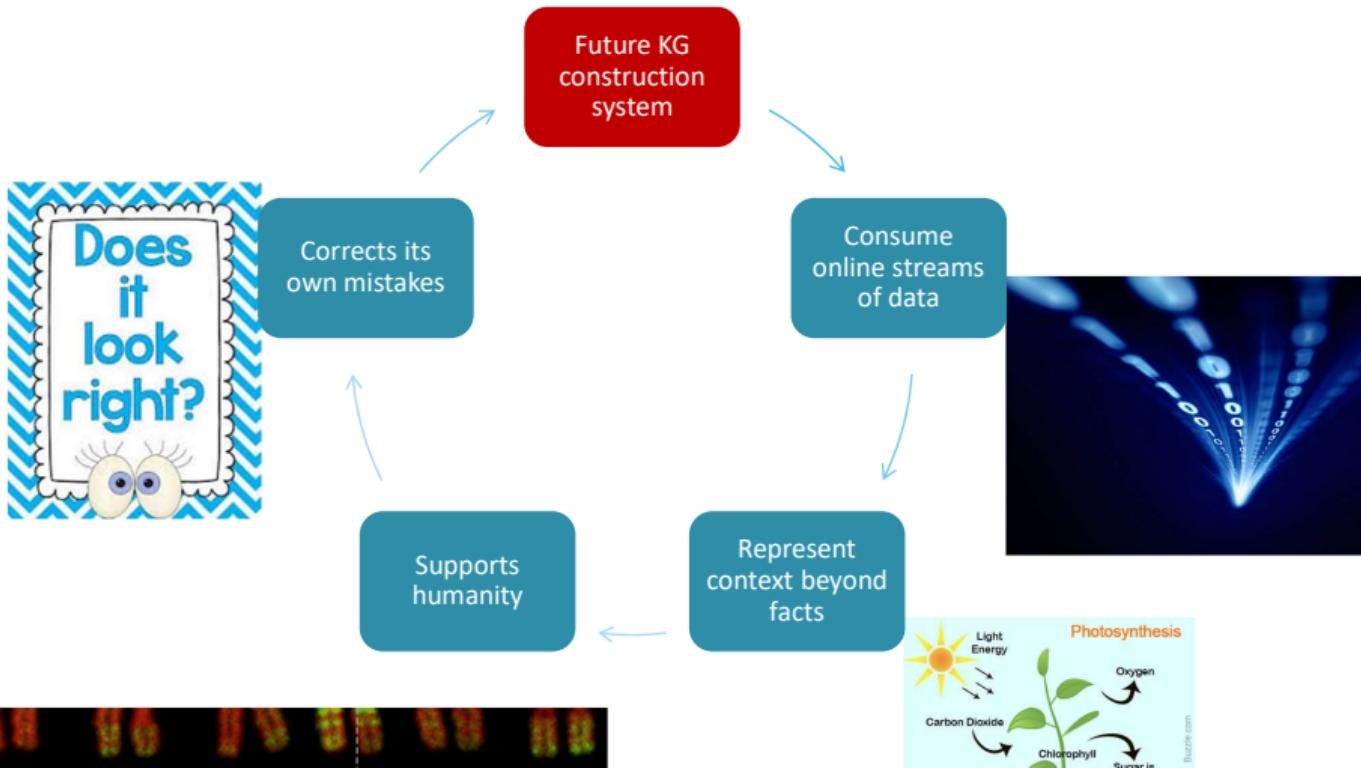


Extraction graph



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Required

- [Yu14, Chapters 1, 2] (Introduction, RDF)

Supplemental

- [Wor14] (RDF Primer)
- [RN10, Chapter 12] (Knowledge Representation)
- Graph databases: The best kept secret for effective AI,
<https://www.youtube.com/watch?v=2ZzGMzitNgo>

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- [Her] Ivan Herman.
Tutorial on Semantic Web Technologies.
[http://www.w3.org/People/Ivan/CorePresentations/RDFTutorial/.](http://www.w3.org/People/Ivan/CorePresentations/RDFTutorial/)
- [RN10] Stuart Russell and Peter Norvig.
Artificial Intelligence: A Modern Approach.
Prentice Hall, 3rd edition, 2010.
https://encore.concordia.ca/iii/encore/record/C__Rb2591108?lang=eng.
- [Wor14] World Wide Web Consortium (W3C).
RDF 1.1 Primer.
<http://www.w3.org/TR/rdf11-primer/>, 24 June 2014.
- [Yu14] Liyang Yu.
A Developer's Guide to the Semantic Web.
Springer-Verlag Berlin Heidelberg, 2nd edition, 2014.
Available online at
<https://concordiauniversity.on.worldcat.org/oclc/897466408.>

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