CS 520
What is a Knowledge Graph?

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Outline

- On the definition
- On representation
- Point of View: Logic
- Point of View: Databases
- Point of View: CV
- Point of View: NLP
- What is a KG?

On the definition of a Knowledge Graph

Given entities E, relations R, KG is a directed multi-relational graph G that comprises triples (s, p, o)

$$\mathcal{G} \subseteq \mathcal{E} \times \mathcal{R} \times \mathcal{E}$$
$$(s, p, o) \in \mathcal{G}$$

* describes entities and relations
* defines a schema
* interrelating arbitrary entities
* various topical domains

"Every RDF / LPG / RDF* graph is a knowledge graph"

"Schema (TBox) with instances (ABox)"

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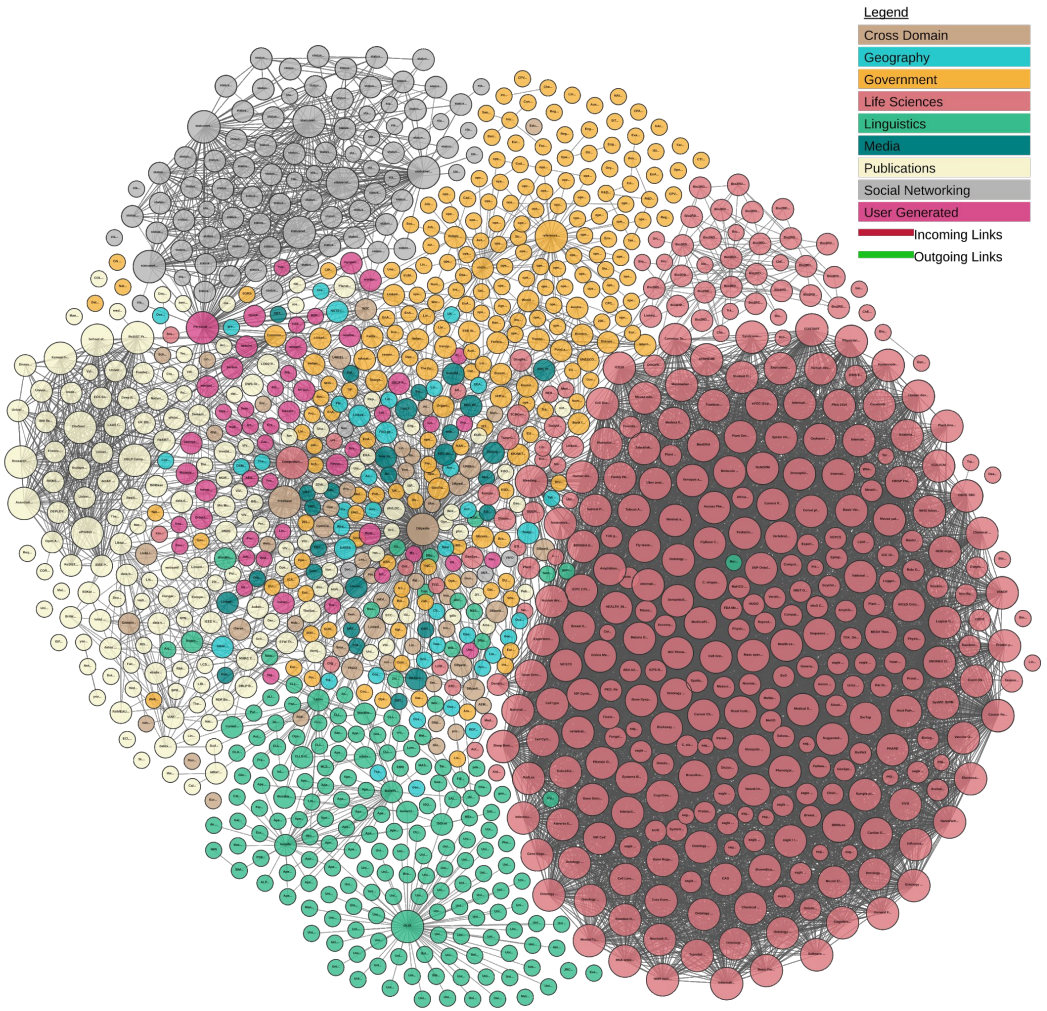
Graph-structured world model

World models?

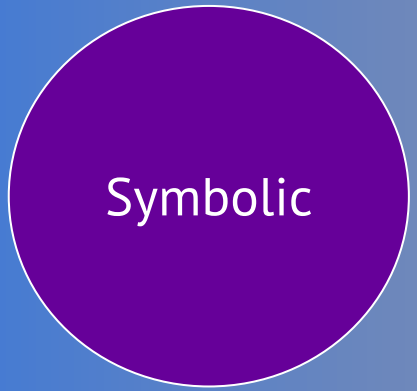
Entities and relations define our **domain of discourse**

How to encode it?

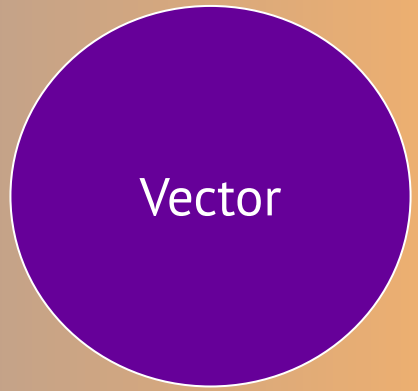


Source: https://lod-cloud.net/

On representation of Knowledge Graphs

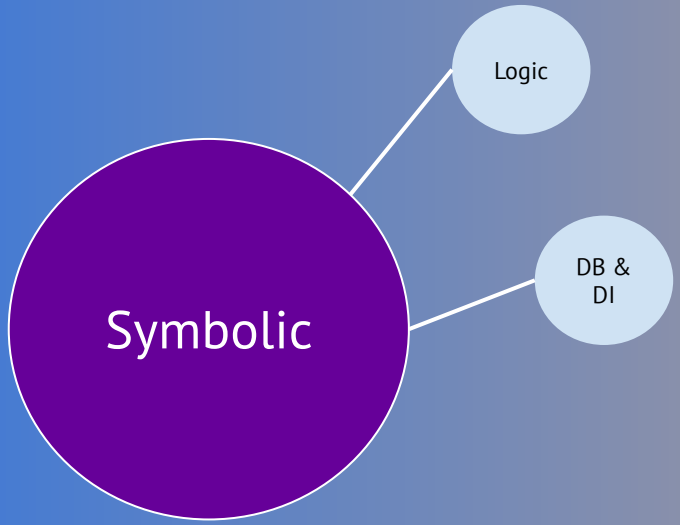


s,p,o
p(s,o)
(s,p,o)



$$s, p, o \in \mathbb{R}^d$$

On representation of Knowledge Graphs

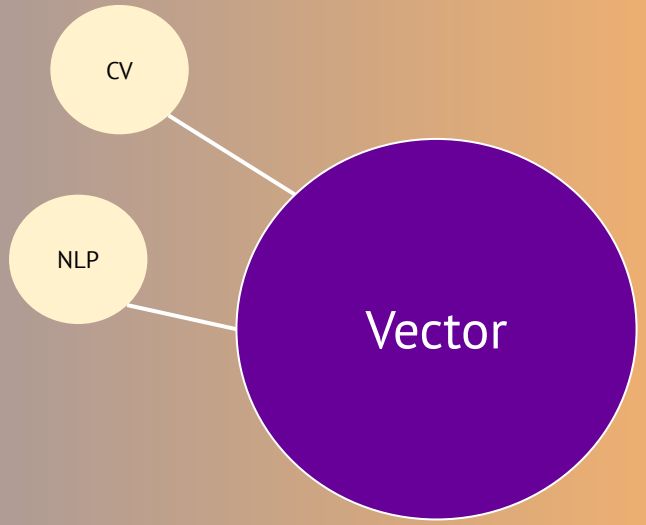


s,p,o
p(s,o)
(s,p,o)

Open-world assumption

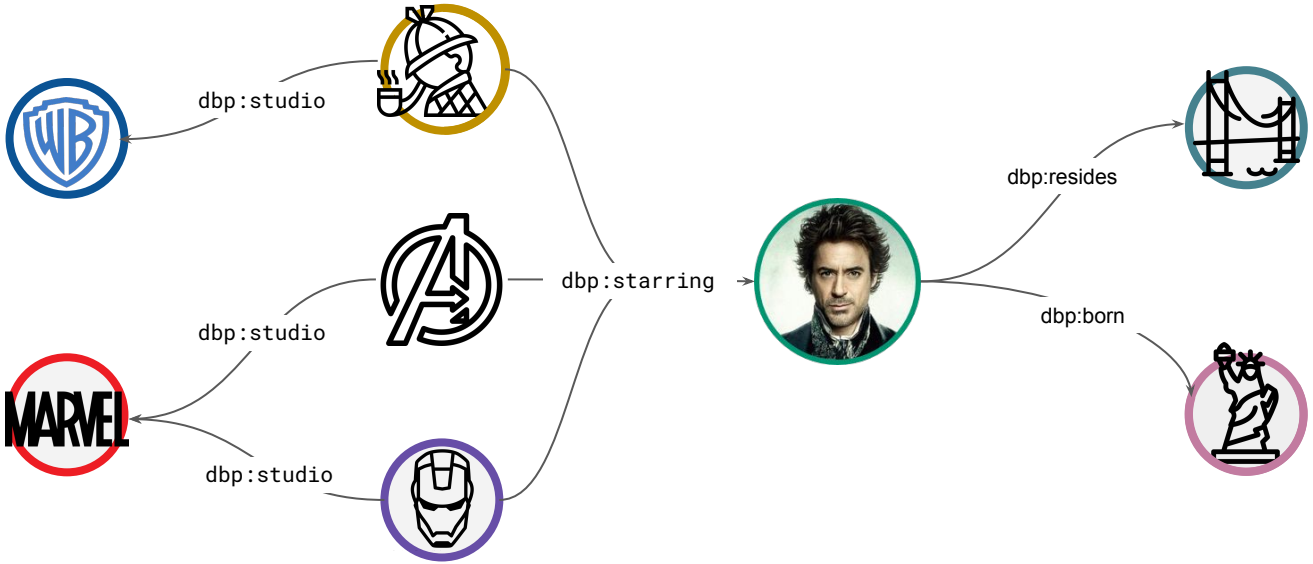
Closed-world assumption

Temporal / evolving



$s, p, o \in \mathbb{R}^d$

Symbolic: Triples

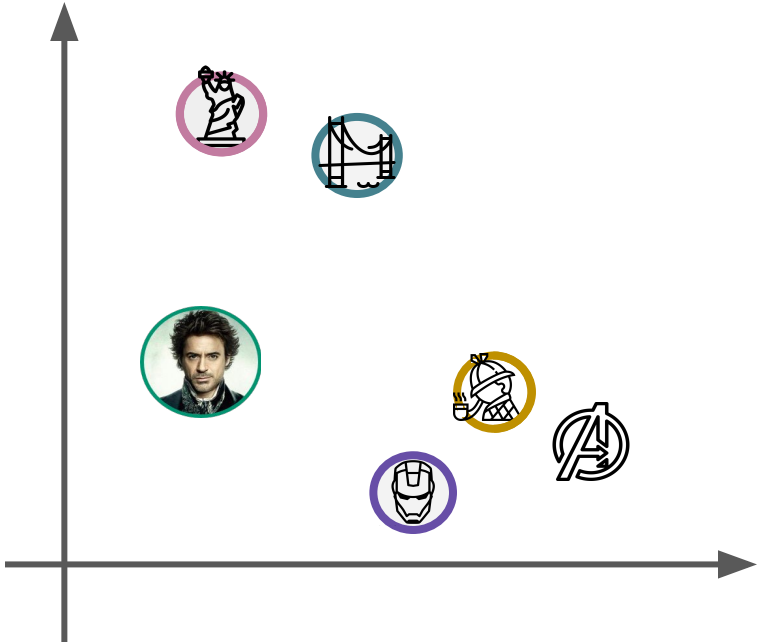


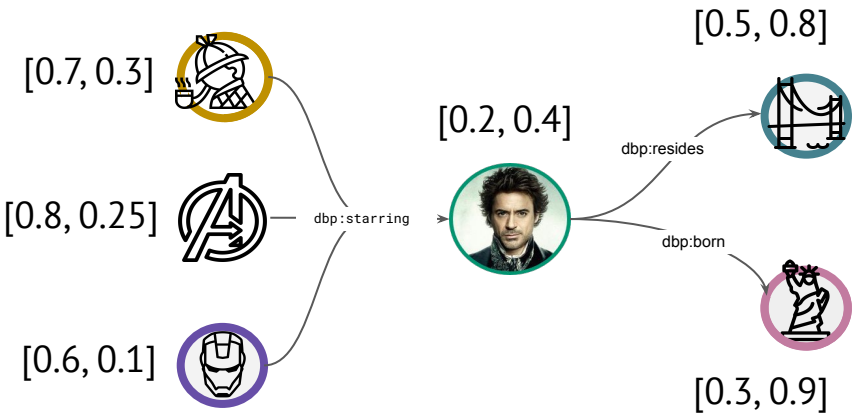

```
RDJ              dbp:resides   SF .      Avengers         dbp:studio     Marvel .
RDJ              dbp:born      NY .      Avengers         dbp:starring   RDJ .
Sherlock_Holmes  dbp:studio    WB .      Iron_Man         dbp:studio     Marvel .
Sherlock_Holmes  dbp:starring  RDJ.      Iron_Man         dbp:starring   RDJ .
```

Vector: Embeddings

$$E \in \mathbb{R}^{N_e \times d}$$

$$R \in \mathbb{R}^{N_r \times d}$$





POV: Logic - Logic Programming

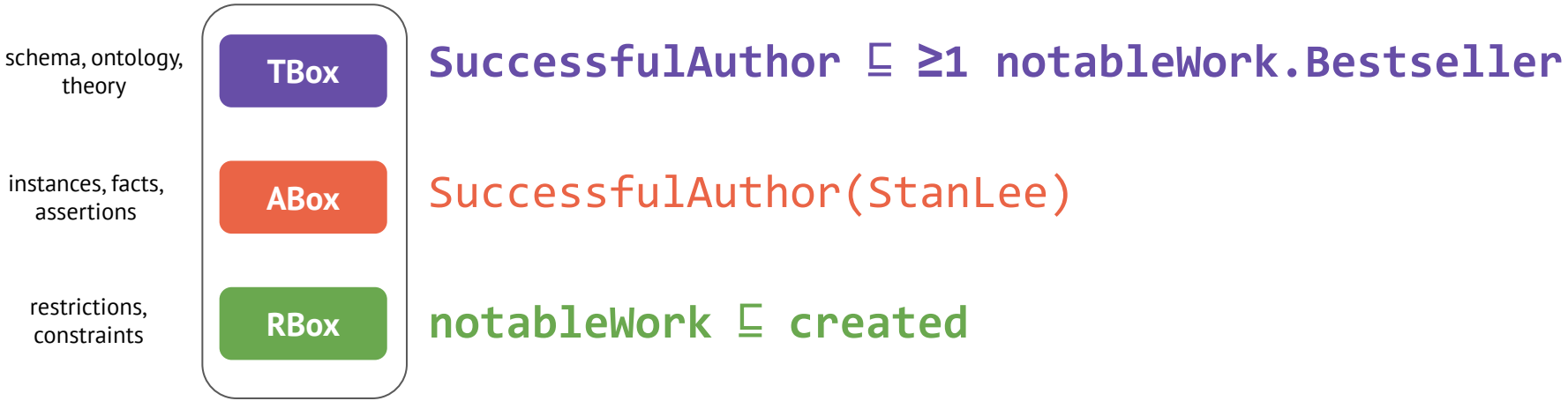
In Datalog / Prolog / Epilog style

Symbols	`RobertDowneyJr, NewYork, SanFrancisco`
Predicates	`lives/2, born/2`
Dataset	`lives(RobertDowneyJr,SanFrancisco)` `born(RobertDowneyJr,NewYork)`

Logically consistent collection of facts

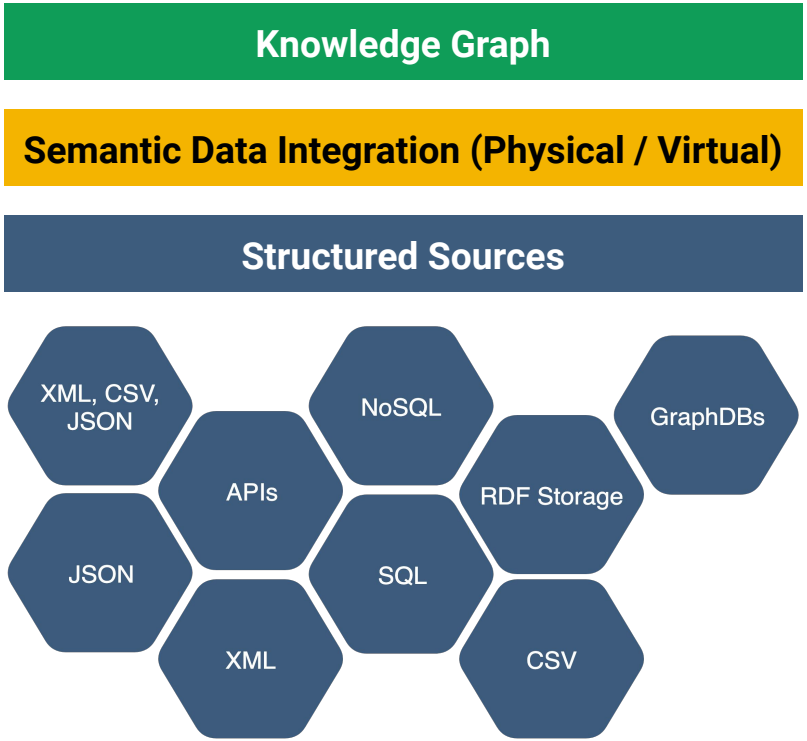
POV: Logic - Description Logics

Based on logical formalisms, e.g., Description Logics (DL), RDFS, OWL



Logically consistent collection of axioms

POV: Databases and Data Integration



Entities

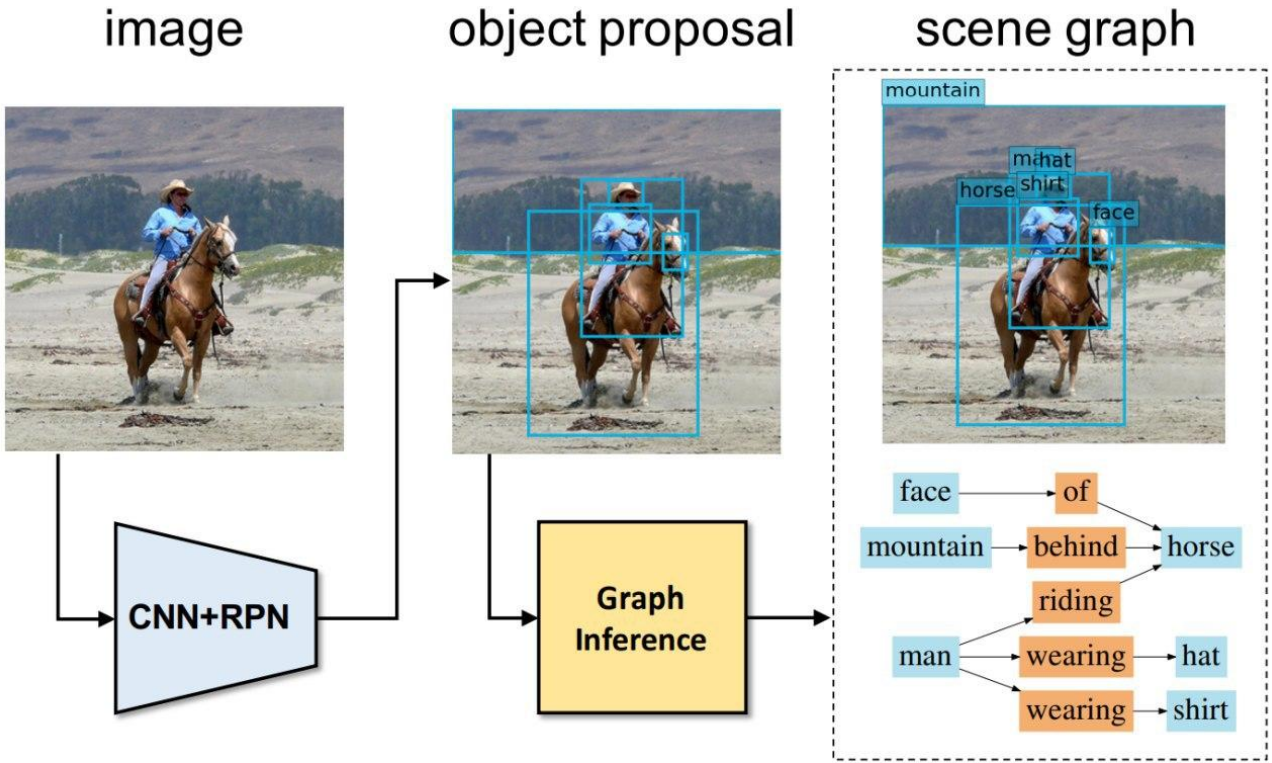
Cells - classes, instances

Relations

Column headers

Author	Notable work	Date of birth
Stan Lee	Iron Man	12/28/1922
Bob Kane	Batman	10/24/1915

POV: Computer Vision



Entities:

Identified objects

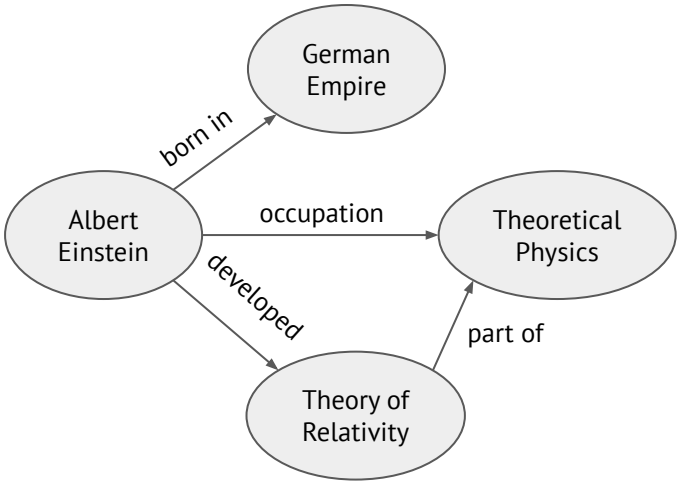
Relations:

Inferred as to objects arrangement

Xu et al. Scene Graph Generation by Iterative Message Passing. CVPR 2017

POV: NLP - Building KGs from texts

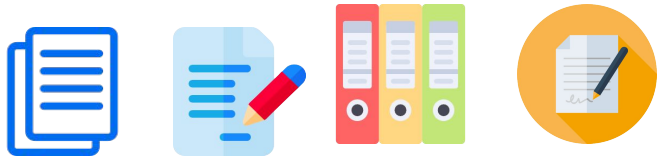
Albert Einstein was a German-born theoretical physicist who developed the theory of relativity.



Knowledge Graph

Information Retrieval

Unstructured Sources



POV: NLP - Named Entity Recognition

Entities in a Knowledge Graph

apple (Q89)

fruit of the apple tree
apples

Apple (Q1754545)

1990 album by Mother Love bone

Apple (Q213710)

UK international record label; imprint of Apple Corps Ltd.
LC 01074 | LC 1074 | Apple Records

Apple Inc. (Q312)

American producer of hardware, software, and services, based in Cupertino, California
Apple Computer, Inc. | Apple Computer | Apple Computer Inc | Apple | Apple Incorporated | Apple Computer Incorporated |

Who is the CEO of **Apple**?

Apple belongs to which genus?

movie character

Downey played **Iron Man** in which year?

Who is the alter ego of **Iron man**?

comic character

POV: NLP - Relation Linking

Relations in a Knowledge Graph

- List of known relations
- Surface forms (synonyms), easily multi-lingual
- Relations constraints
- Relations hierarchy
- Most used types of subjects and objects

wdt:P161

Name all the movies in which Robert Downey Jr **acted**?

Find me all the films **casting** Robert Downey Jr ?

List all the movies **starring** Robert Downey Junior?

RDJ **has acted** in which movies?

cast member (P161)

actor in the subject production |

starring | film starring | actor | actress | contestant or a play

performer (P175)

actor, musician, band or other performer associated with this role or musical work

artist | musician | played by | portrayed by | recorded by | recording by | dancer | actor | musical artist

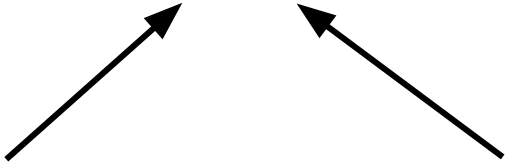
POV: NLP - Question Answering

How many Marvel movies was Robert Downey Jr. casted in?

```
SELECT COUNT(?uri) WHERE {
    ?uri dbp:studio dbr:Marvel_Studios.
    ?uri dbo:starring dbr:Robert_Downey_Jr
}
```

POV: NLP - Language Modeling

Robert Downey Jr. portrayed **[MASK]** in the Marvel movie in 2008.



Knowledge Graph

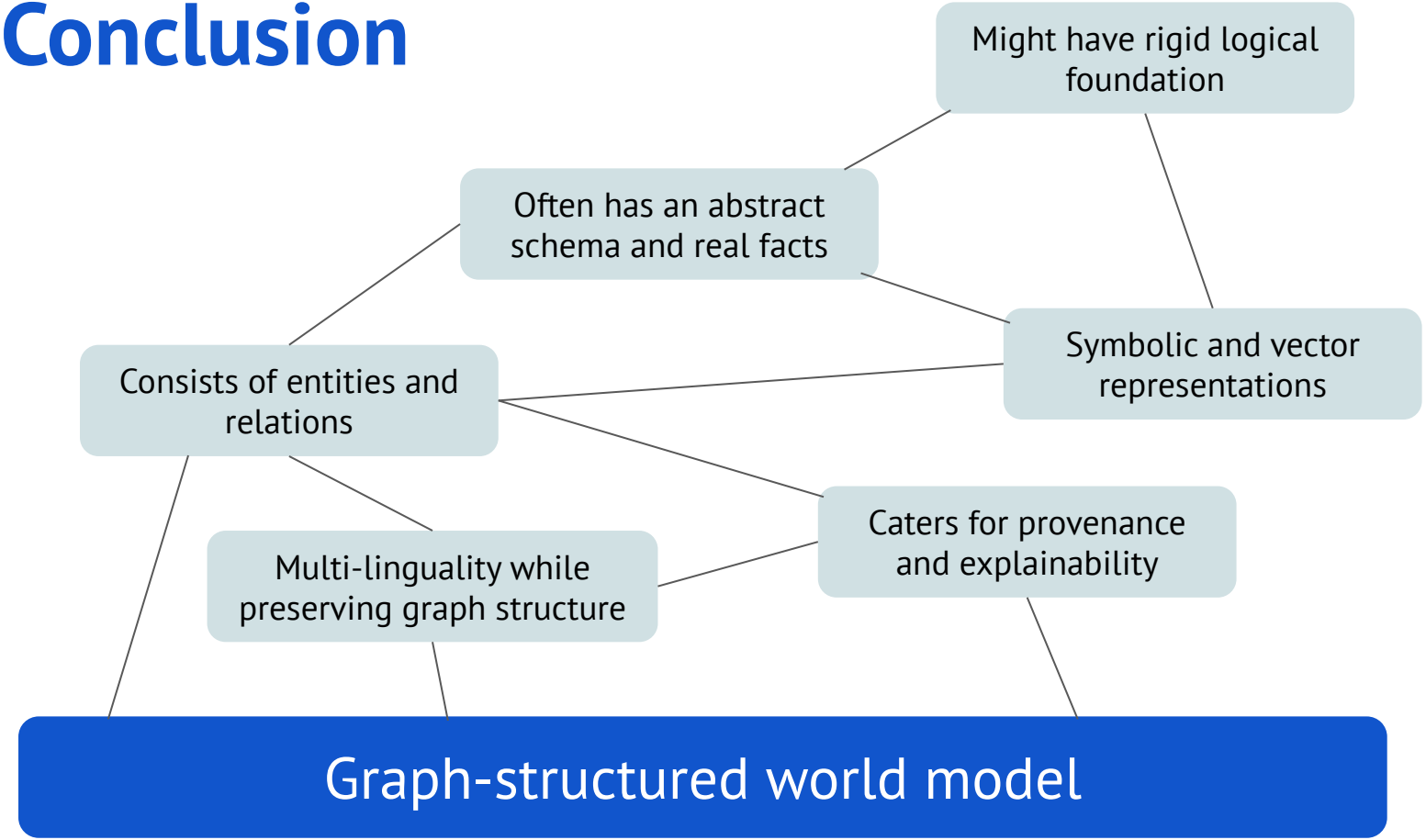
(Iron Man, cast member, Robert Downey Jr)
(Iron Man, production company, Marvel)
(Iron Man, released, 2008)
(Robert Downey Jr, character role, Tony Stark)
(Tony Stark, pseudonym, Iron Man)

Precise facts | Entities & relations | Explainability

Unstructured Sources

Large-scale text corpora
(Wikipedia, OpenBooks, Reddit, CommonCrawl, etc)

Conclusion


Might have rigid logical foundation
Often has an abstract schema and real facts
Symbolic and vector representations
Consists of entities and relations
Caters for provenance and explainability
Multi-linguality while preserving graph structure
Graph-structured world model