

CS 520

What is a Knowledge Graph?



Dr. Mikhail Galkin

TU Dresden & Fraunhofer IAIS
Dresden, Germany

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 \mathcal{E} , relations \mathcal{R} , KG is a directed multi-relational graph \mathcal{G} that comprises triples (s, p, o)

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

“Abstract schema and instances”

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

“Every RDF / LPG / RDF* graph is a knowledge graph”

On the definition of a Knowledge Graph

Given entities \mathcal{E} , relations \mathcal{R} , KG is a directed multi-relational graph \mathcal{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

“Abstract schema and instances”

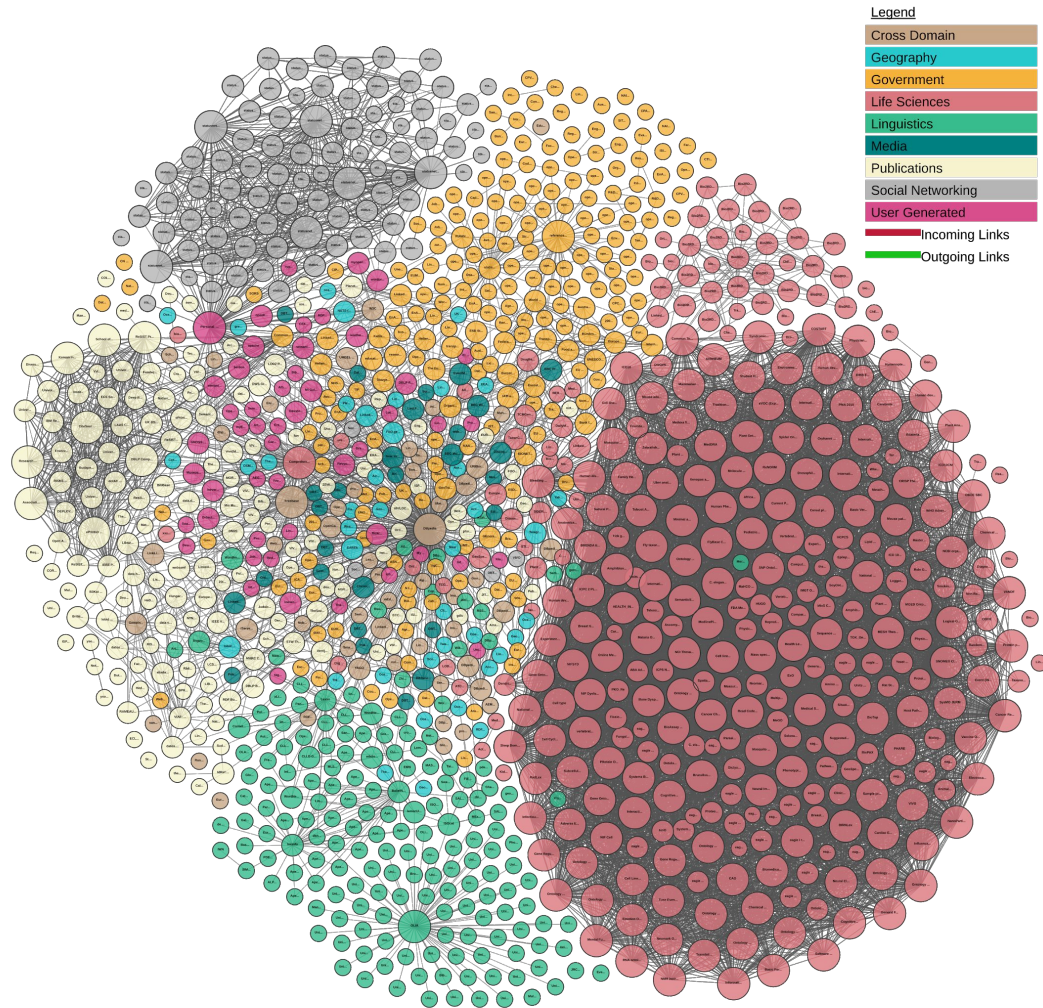
“Every RDF / LPG / RDF* graph is a knowledge graph”

Graph-structured world model

World models?

Entities and
relations define our
domain of discourse

How to encode it?



On representation of Knowledge Graphs



Symbolic

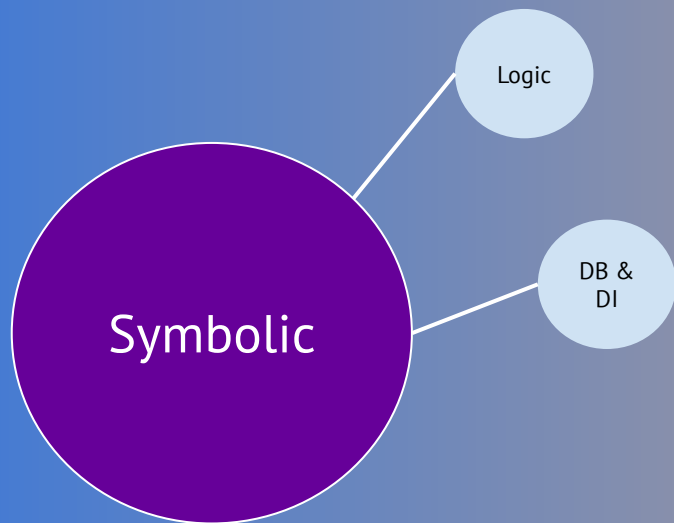
s, p, o
 $p(s, o)$
 (s, p, o)



Vector

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

On representation of Knowledge Graphs

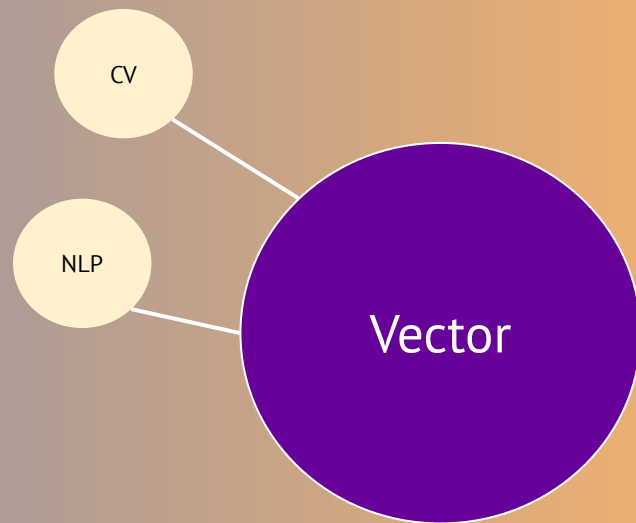


s, p, o
 $p(s, o)$
 (s, p, o)

Open-world
assumption

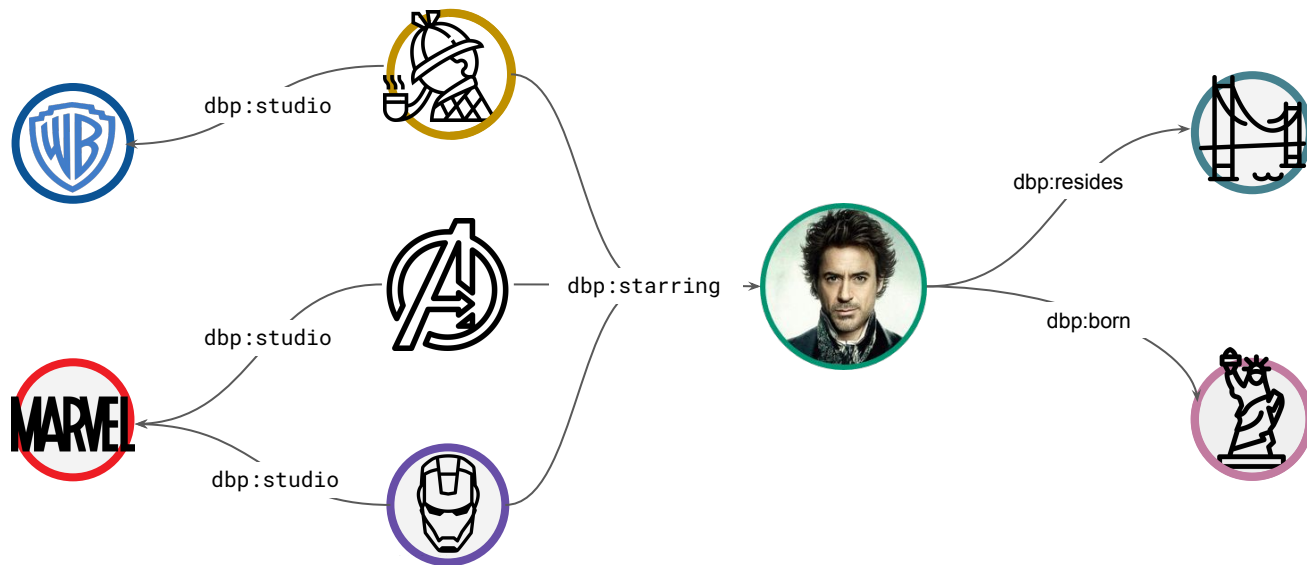
Closed-world
assumption

Temporal /
evolving



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

Symbolic: Triples



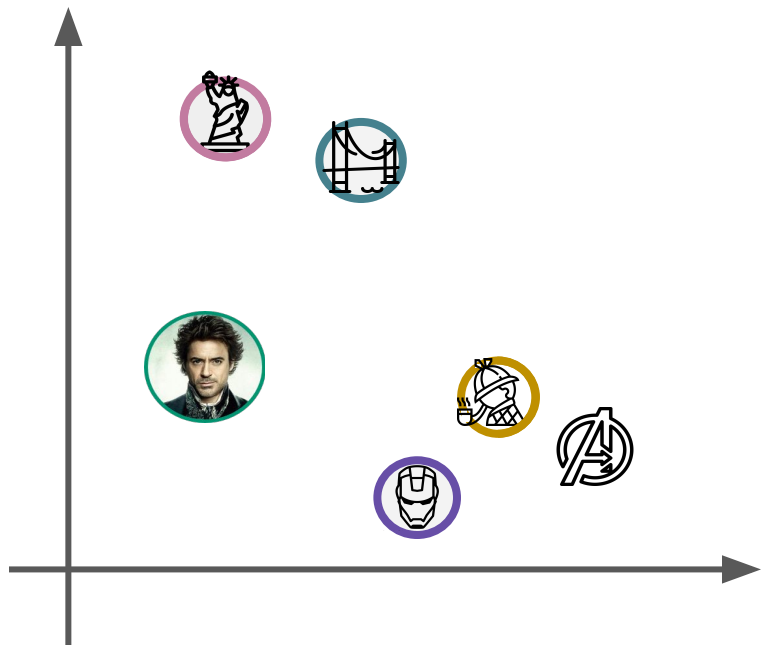
RDJ
 RDJ
 Sherlock_Holmes
 Sherlock_Holmes

dbp:resides SF .
 dbp:born NY .
 dbp:studio WB .
 dbp:starring RDJ .

Avengers
 Avengers
 Iron_Man
 Iron_Man

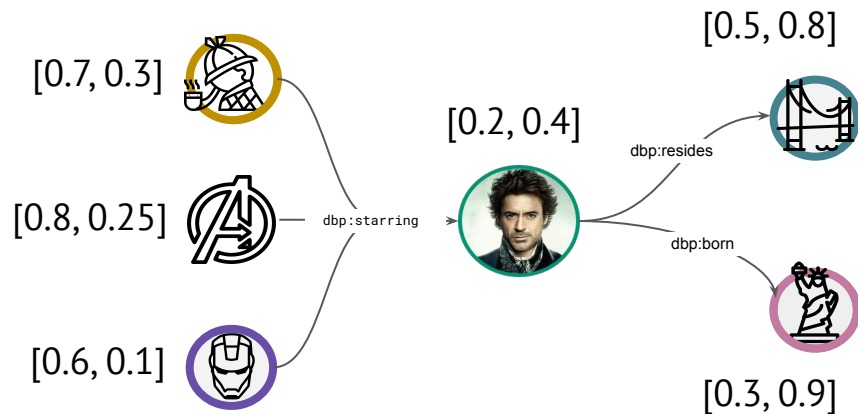
dbp:studio Marvel1 .
 dbp:starring RDJ .
 dbp:studio Marvel1 .
 dbp:starring RDJ .

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

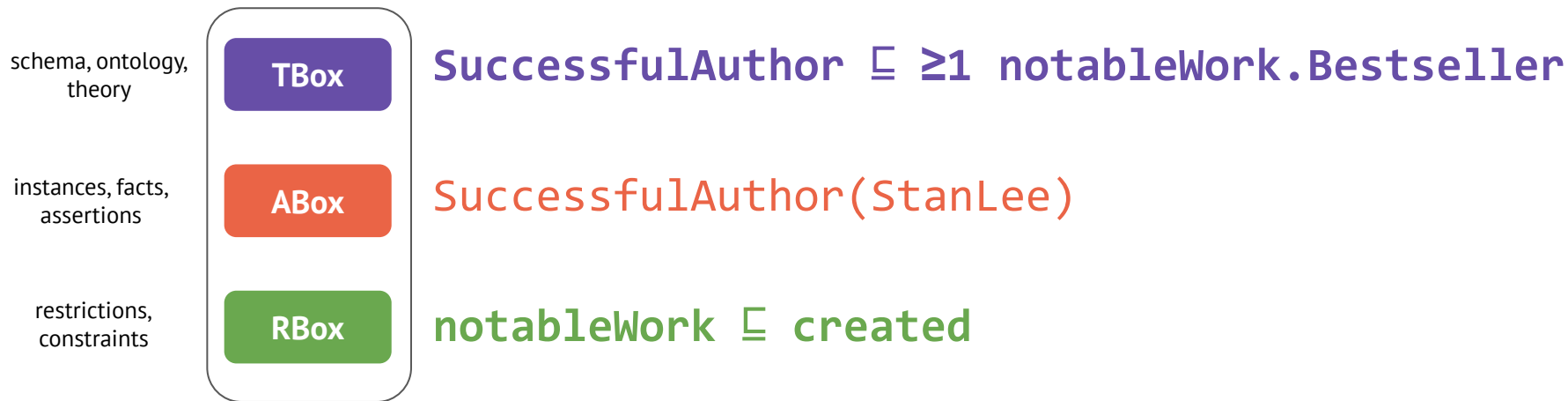
Predicates lives/2, born/2

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



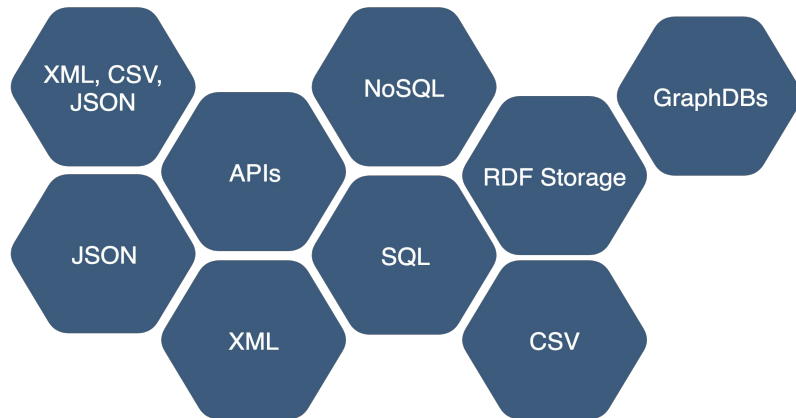
Logically consistent collection of axioms

POV: Databases and Data Integration

Knowledge Graph

Semantic Data Integration (Physical / Virtual)

Structured Sources



Entities

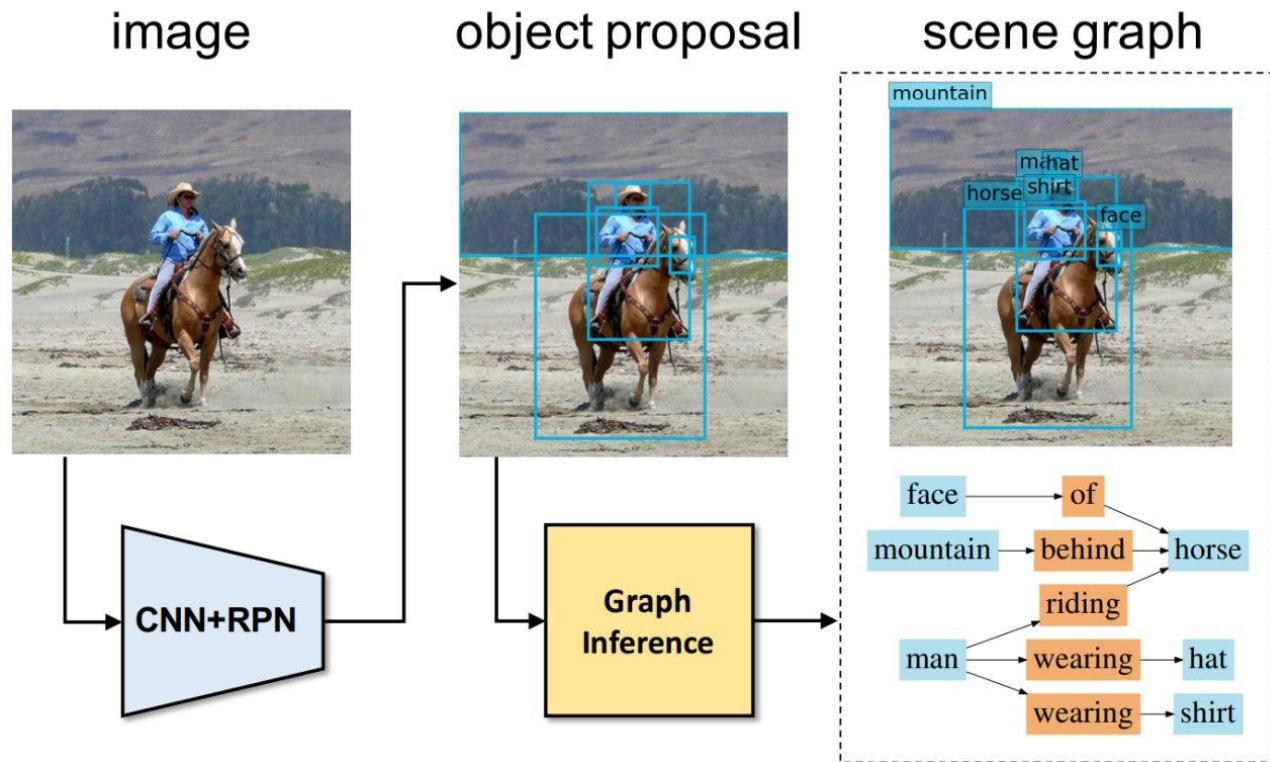
Cells - **classes**, **instances**

Relations

Column headers

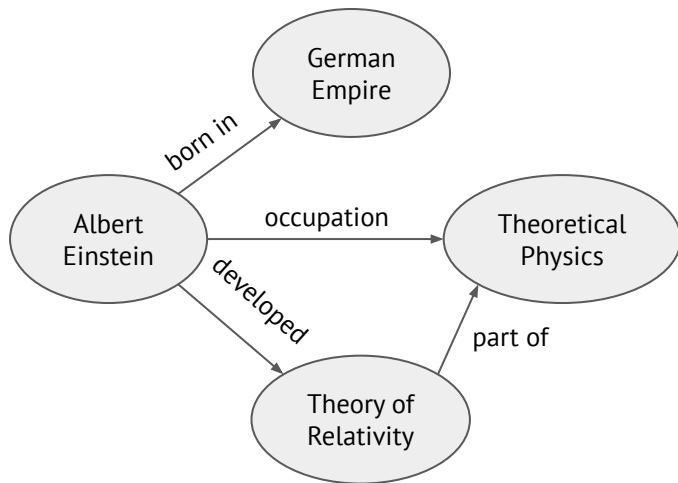
Author	Notable work	Date of birth
Stan Lee	Iron Man	12/28/1922
Bob Kane	Batman	10/24/1915

POV: Computer Vision



POV: NLP - Building KGs from texts

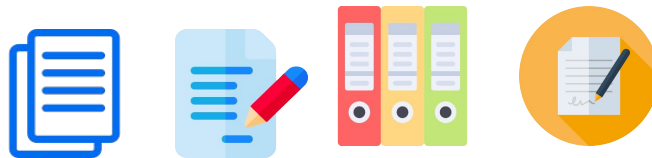
Albert Einstein was a German-born theoretical physicist who developed the theory of relativity.



Knowledge Graph

Information Retrieval

Unstructured Sources



POV: NLP - Named Entity Recognition

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?

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

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

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

Name all the movies in which Robert Downey Jr ^{wdt:P161}**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

All
marvel
movies

Every
thing
starring
RDJ

Find the
intersection

Count the
entities
left

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

