CS520: KNOWLEDGE GRAPHS

Data Models, Knowledge Acquisition, Inference, Applications

Lectures and Invited Guests

Spring 2021, Tu/Thu 4:30-5:50, cs520.Stanford.edu

Learn about the basic concepts,
latest research & applications

Organizers

Vinay

Naren

Mike

Motivation for the Seminar

- Knowledge Graphs are being used in
  - Web search
  - Answering questions
  - Data integration
- Knowledge Graphs are also target of output for
  - NLP and computer vision algorithms
  - ML algorithms more generally
- Knowledge Graphs are a topic of a major program from NSF
  - https://www.nsf.gov/od/oia/convergence-accelerator/Award%20Listings/track-a.jsp

Seminar Outline
Knowledge Graph

- What is it?
- How do create it?
- How do we reason with it?
- How do we use it with modern AI algorithms?
- Where is the research?

Course Design

- Two 80-minute sessions each week (Tue/Thu)
  - Tuesday sessions based on the synthesis of key points from the 2020 series
    - The synthesis points are also available as written notes on the course website
    - Some Tuesday sessions will also have invited guests
  - Thursday sessions will feature invited guests
    - (Generally) two 30-minute presentations
    - Followed by Q & A
- Recordings will be available on the course web site

For Stanford Students

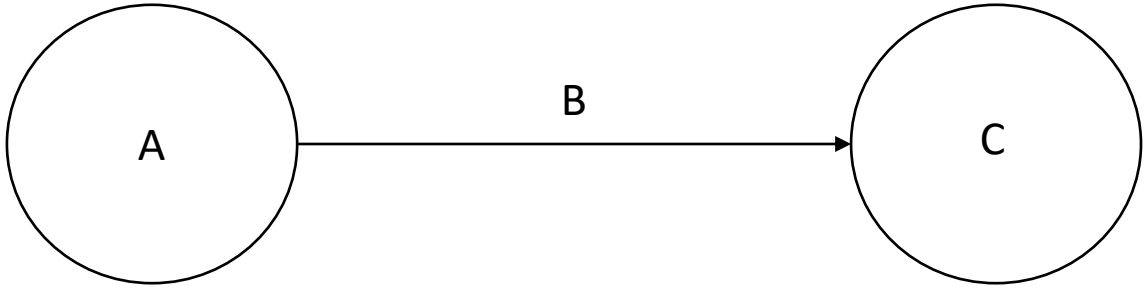
- Complete a quiz for all 10 of the Tuesday sessions
- Submit a written summary for any 8 of the 10 Thursday sessions

What is a Knowledge Graph?

Outline

- Knowledge Graph
- Resurgence of interest in Knowledge Graphs
  - Search engines
  - Data integration
  - Artificial Intelligence
- What is new and different?

What is a Knowledge Graph?



Directed Labeled Graph
Nodes and edges have well-defined meanings

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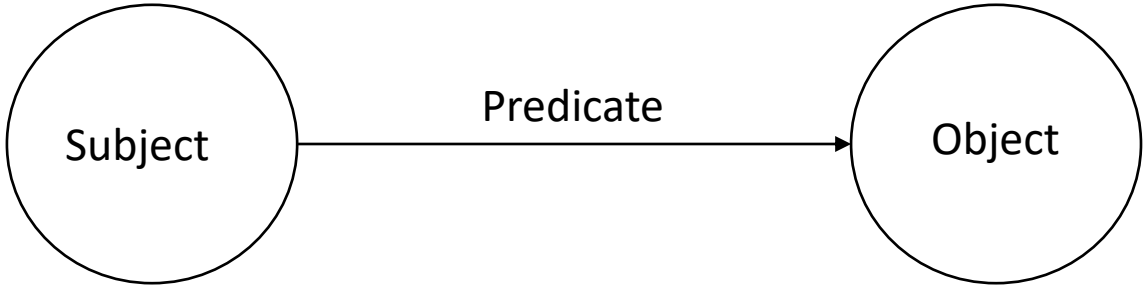

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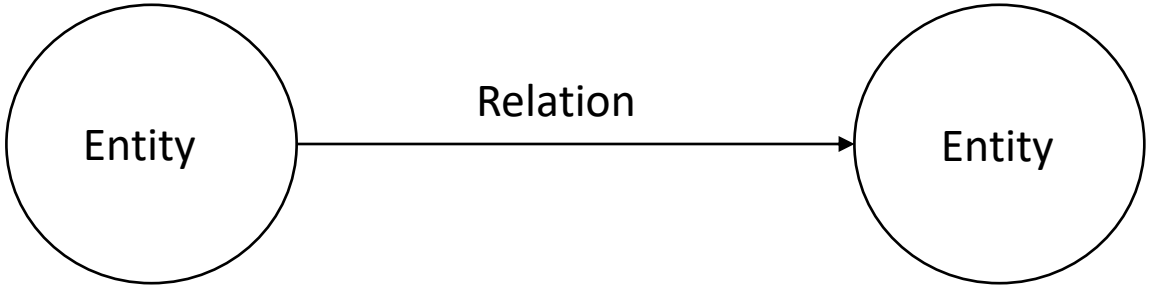

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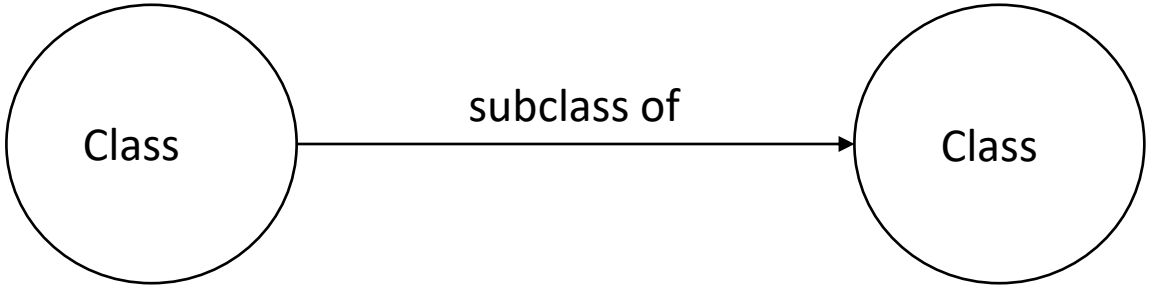

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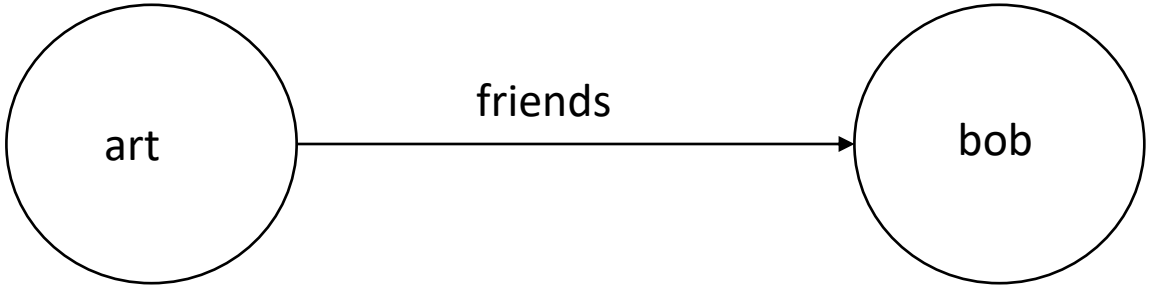

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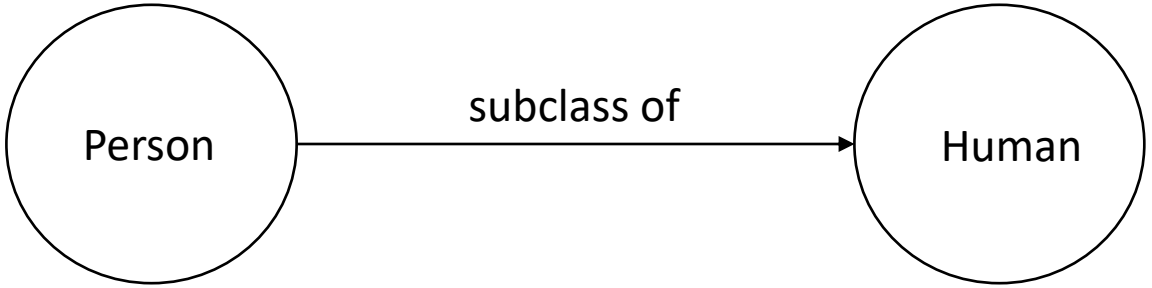

Directed Labeled Graph
Nodes and edges have well-defined meanings

Different ways to define meaning

- Based on a user's actions
  - *friend* relationship
- Explanation in a human understandable language
  - E.g., linguistic resource Wordnet
- Logical Specification
  - Using a set of axioms
- Associating examples
  - Defining a cat using a set of images
- Embeddings
  - Statistics on a corpus of text

Rich History of work on Knowledge Graphs

- Knowledge Representation
  - Semantic networks
  - Description logics
  - Conceptual graphs
- Database systems
  - Network databases
  - Triple stores

Outline

- Graphs in Computer Science
- Resurgence of interest in Knowledge Graphs
  - Search engines
  - Data integration
  - Artificial Intelligence
- What is new and different?

Knowledge Graphs in Search

- The *Winterthur* example
  - This example was introduced by Denny Vrandečić
    - For more details
      - Visit his Spring 2020 presentation
      - A story linked to the course website

Knowledge Graphs in Web Search

Google

Wintherthur zurich

All Maps News Images Shopping More Settings Tools

About 12,000,000 results (0.60 seconds)

Showing results for ***Winterthur*** zurich
Search instead for Wintherthur zurich

en.wikipedia.org › wiki › Winterthur

Winterthur - Wikipedia

Winterthur is a city in the canton of **Zürich** in northern Switzerland. With over 110,000 residents it is the country's sixth-largest city by population, and is the ...

Country: Switzerland
Highest elevation (Hulmen): 687 m (2,254 ft)
Lowest elevation (Kläranlage Hard): 393 ...
Elevation (Bahnhofplatz): 439 m (1,440 ft)

Battle of Winterthur · Winterthur, Delaware · Winterthur District · FC Winterthur

Top sights in Winterthur

Swiss Science Center Technorama
Science museum with hands-on exhibits

Castle Kyburg
11th-century castle with history museum

Oskar Reinhart collection Am
Art collection in a historic mansion

Kunst Museum Winterthur | Beim
Art museum, vincent van gogh, museum,...

Winterthur

City in Switzerland

Winterthur is a Swiss city northeast of Zurich, near the German border. Its museums include Fotomuseum Winterthur, with its photography exhibits, and the Swiss Science Center Technorama. Museum Oskar Reinhart shows artworks from antiquity to the 1900s. Kunstmuseum Winterthur exhibits modern art, including Picasso and Klee. The Rosengarten is a hilltop garden with hundreds of rose varieties and views of the old town.

Area: 26.28 mi²

Elevation: 1,440'

Weather: 62°F (17°C), Wind E at 2 mph (3 km/h), 76% Humidity

Local time: Tuesday 2:22 AM

WIKIPEDIA
The Free Encyclopedia

Main page
Contents
Current events
Random article
About Wikipedia
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Tools
What links here
Related changes
Special pages
Permanent link
Page information
Cite this page
Wikidata item

Print/export
Download as PDF

Winterthur

From Wikipedia, the free encyclopedia

Coordinates: 47°29′56″N 8°43′43″E

For other uses, see Winterthur (disambiguation).

Winterthur (/ˈvɪntərtʊər/ *VIN-tər-toor*, German: [ˈvɪntɐtuːɐ̯]; French: *Winterthour*) is a city in the canton of Zürich in northern Switzerland. With over 110,000 residents it is the country's sixth-largest city by population, and is the ninth-largest agglomeration with about 140,000 inhabitants.[3] Located about 20 kilometres (12 mi) northeast of Zürich, Winterthur is a service and high-tech industrial satellite city within Greater Zürich.

The official language of Winterthur is Swiss Standard German, but the main spoken language is the local variant of the Alemannic Swiss German dialect. Winterthur is usually abbreviated as *Winti* in the local dialect and by its inhabitants.

Winterthur is connected to Germany by direct trains and has links to Zurich Airport. It is also a regional transport hub: the A1 motorway from Geneva through to St. Margrethen connects in Winterthur with the A4 motorway heading north toward Schaffhausen and the A7 motorway heading close to the Swiss-German border at Kreuzlingen. There are also roads leading to other places such as Turbenthal. The railway station is the fifth busiest railway station in Switzerland, and is 20 minutes away by train from Zürich.

Contents [hide]

‹ The template *Infobox settlement* is being considered for merging. ›

Winterthur

June 2009 view of the old town

Coat of arms

Location of Winterthur [show]

Knowledge Graphs in Web Search

Google

Wintherthur zurich

All | Maps | News | Images | Shopping | More | Settings | Tools

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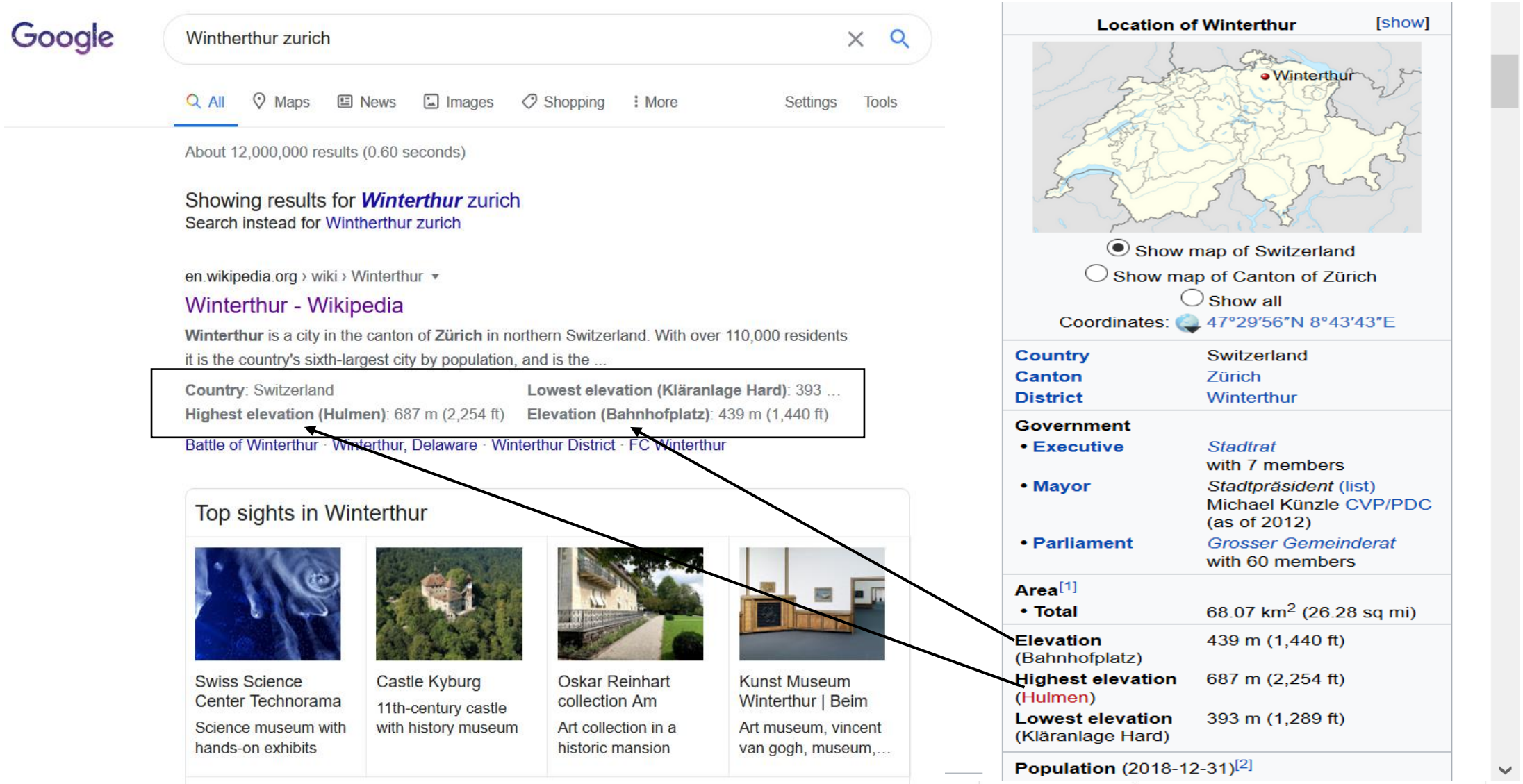


2022. Currently the Large Municipal Council consists of 18 members of the Social Democratic Party (SP/PS), 10 Swiss People's Party (SVP/UDC), 8 The Liberals (FDP/PLR), 7 Green Liberal Party (GLP/PVL), 5 Green Party (GPS/PES), 4 Evangelical People's Party (EVP), 3 Christian Democratic People's Party (CVP/PDC), 2 Alternative List (AL), one representative each of the Conservative Democratic Party (BDP/PBD), Federal Democratic Union (EDU/UDF), and the Pirate Party.[9]

The *Grosse Gemeinderat* of Winterthur for the mandate period of 2018-2022

- AL (3.3%)
- Piraten (1.7%)
- SP (30%)
- GPS (8.3%)
- glp (11.7%)
- EVP (6.7%)
- CVP (5%)
- FDP (13.3%)
- BDP (1.7%)
- SVP (16.7%)
- EDU (1.7%)

National Elections [edit]

National Council [edit]

In the 2019 federal election for the Swiss National Council the most popular party was the PS which received 22.6% (-3.4) of the vote. The next six most popular parties were the SVP (17.8%, -5.6), the Green Party (17.8%, +9), the glp (14.3%, +5.5), FDP (10.6%, -1.5), the EVP (5.0%, 0), and the CVP (4.2%, +0.2).[11] In the federal election a total of 32,907 votes were cast, and the voter turnout was 47.0%.[12]

In the 2015 election for the Swiss National Council the most popular party was the SPS which received 26.1% of the vote. The next most popular parties were the SVP (23.4%), the FDP (12.1%), the Green Party (8.8%), the glp (8.8%), the EVP (5.0%), the CVP (4.0%), and BDP (3.5%). In the federal election, a total of 33,426 voters were cast, and the voter turnout was 49.3%.[13] In the 2011, federal election the most popular party was the SP which received 22.5% of the vote. The next three most popular parties were the SVP (21.8%), the Green Liberals (11.1%) and the Green Party (10.1%).

International relations [edit]

See also: List of twin towns and sister cities in Switzerland

Twin towns [edit]

Winterthur is twinned with two Swiss and two international towns and coordinates its international relations together with the Swiss towns Frauenfeld, St. Gallen, and Schaffhausen:[14]

- Yverdon-les-Bains, Switzerland[15]
- La Chaux-de-Fonds, Switzerland
- Pilsen, Czech Republic
- Hall in Tirol, Austria

Ontario, California

Go to a page with this exact name if it ex

From Wikipedia, the free encyclopedia

Coordinates: 34°03′10″N 117°37′40″W

"Ontario, CA" redirects here. For the Canadian province, see Ontario.

Ontario is a city located in southwestern San Bernardino County, California, 35 miles (56 km) east of downtown Los Angeles and 23 miles (37 km) west of downtown San Bernardino, the county seat. Located in the western part of the Inland Empire metropolitan area, it lies just east of Los Angeles County and is part of the Greater Los Angeles Area. As of the 2010 Census, the city had a population of 163,924, up from 158,007 at the 2000 census.

Ontario is bordered by Upland and Rancho Cucamonga to the north, Fontana to the east, Montclair to the west and Chino to the southwest.

The city is home to the Ontario International Airport, which is the 15th-busiest airport in the United States by cargo carried. Ontario handles the mass of freight traffic between the ports of Los Angeles and Long Beach and the rest of the country.[11]

It takes its name from the Ontario Model Colony development established in 1882 by the Canadian engineer George Chaffey and his brothers William Chaffey and Charles Chaffey.[12] They named the settlement after their home province of Ontario.

Contents [hide]

‹ The template *Infobox settlement* is being considered for merging. ›

Ontario, California

City

Downtown Ontario in November 2018

Flag

Seal

CITY OF ONTARIO SOUTHERN CALIFORNIA

Sister cities [edit]

Ontario has five sister cities around the world.[50] They are:

- **Brockville**, Ontario, Canada *(since 1977)*
- **Guamúchil**, Sinaloa, Mexico *(since 1982)*
- **Mocorito**, Sinaloa, Mexico *(since 1982)*
- **Los Mochis**, Sinaloa, Mexico *(since 1988)*
- **Winterthur**, Canton of Zürich, Switzerland[note 1][51]

See also [edit]

California portal

- *Inland Valley Daily Bulletin* (newspaper)
- Ontario and San Antonio Heights Railroad Company
- *The Daily Report* (newspaper)

Notes and references [edit]

Notes [edit]

1. ^ However, according to the official website by the city of Winterthur, Ontario is not one of its partner cities.

References [edit]

1. ^ a b "City Facts". City of Ontario. Retrieved February 26, 2015.
2. ^ "Public Officials". City of Ontario, California. Retrieved February 24, 2020.
3. ^ "City Treasurer". City of Ontario, California. Retrieved
16. ^ City History Retrieved 2017-10-21
17. ^ a b "City of Ontario CAFR".
18. ^ Ken Bensinger (April 5, 2008). "Road for electric car makers full of potholes". *Los Angeles Times*. Retrieved December 3, 2011
35. ^ "Ontario Mills' Big Food gets much, much smaller". December 31, 2011. Retrieved October 7, 2012.
36. ^ "Greater Ontario Visitors and Convention Bureau". *www.discoverontariocalifornia.org*. Retrieved December 30, 2015

Problem

- *Twin Towns* and *Sister Cities* are identical concepts
  - The reference to *Winterthur* in the *Ontario* Page appears in text description
  - There is no easy way to resolve the differences

Solution

- Wikidata: Publicly curated Knowledge Graph

Winterthur (Q9125)

city in the canton of Zürich, Switzerland edit

Winterthur ZH

In more languages

Configure

Language	Label	Description	Also known as
English	Winterthur	city in the canton of Zürich, Switzerland	Winterthur ZH
Spanish	Winterthur	ciudad y comuna suiza del cantón de Zúrich	
Traditional Chinese	溫特圖爾	瑞士的城市	
Chinese	温特图尔	No description defined	

All entered languages

Statements

instance of — municipality of Switzerland edit

0 references

+ add reference

city of Switzerland edit

Main page
Community portal
Project chat
Create a new Item
Create a new Lexeme
Recent changes
Random Item
Query Service
Nearby
Help
Donate

Tools

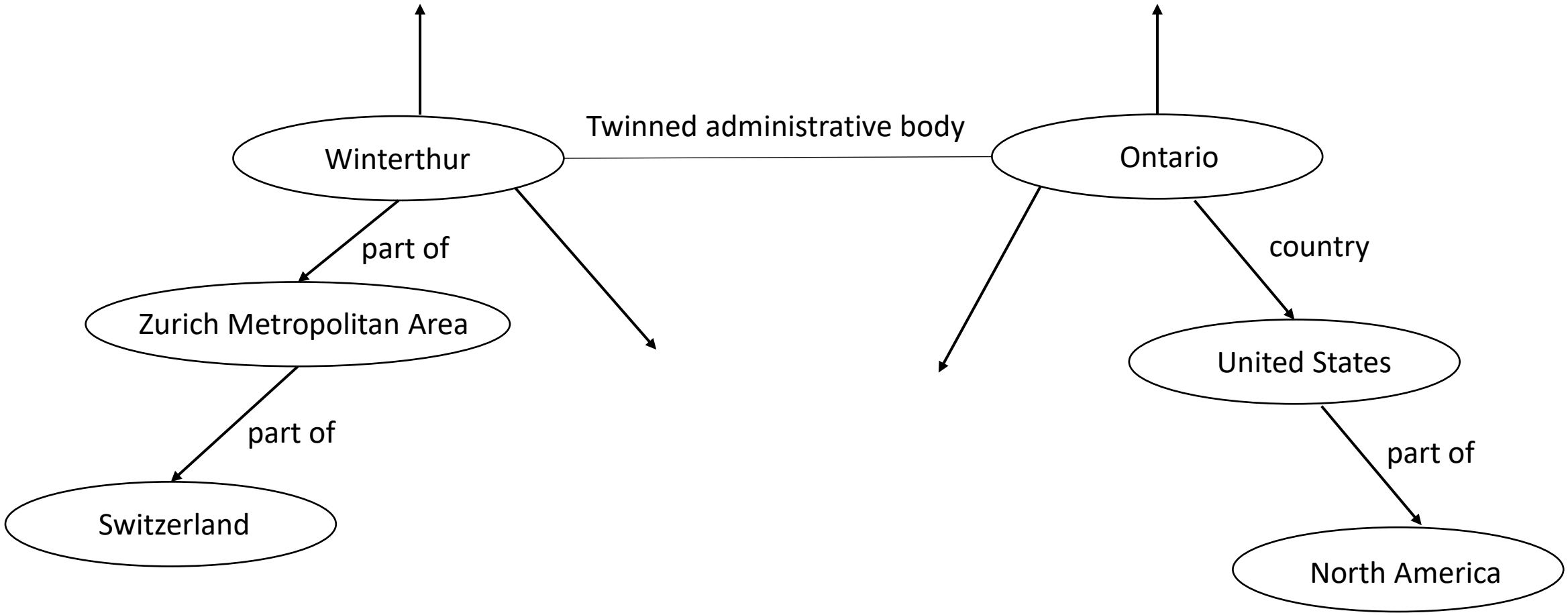
What links here
Related changes
Special pages
Permanent link
Page information
Cite this page
Concept URI

twinned administrative body	La Chaux-de-Fonds		edit
	start time	1984	
	0 references		
			+ add reference
	Yverdon-les-Bains		edit
	start time	1969	
	0 references		
			+ add reference
	Hall in Tirol		edit
	start time	1948	
	0 references		
			+ add reference
	Plzeň		edit
	start time	1994	
	0 references		
			+ add reference
	Ontario		edit
	start time	1982	

twinned administrative body	Brockville		edit
	0 references		+ add reference
	East Coast Bays		edit
	0 references		+ add reference
	Guamúchil		edit
	0 references		+ add reference
	Mocorito		edit
	0 references		+ add reference
	Winterthur		edit
	start time	1982	
	2 references		
	Ahome, Los Mochis		edit
	0 references		

Graph Underlying Wikidata

Graph Underlying Wikidata



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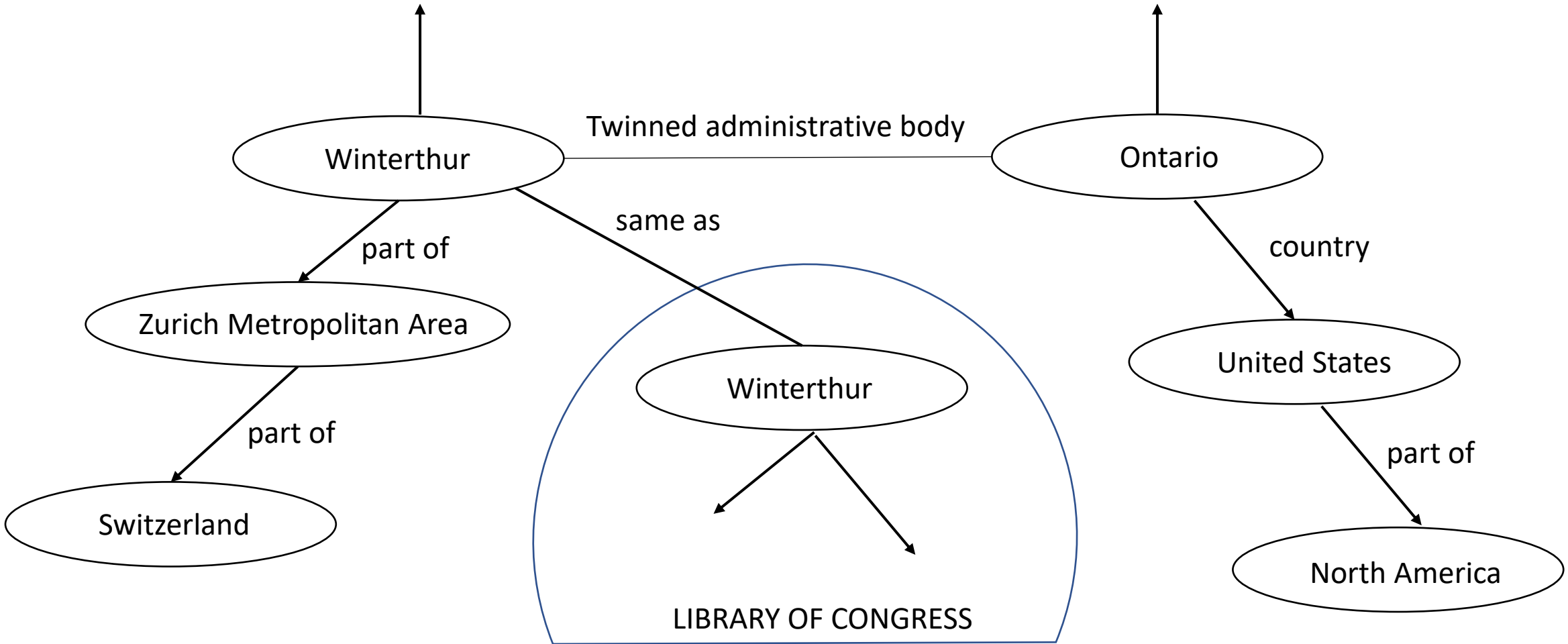

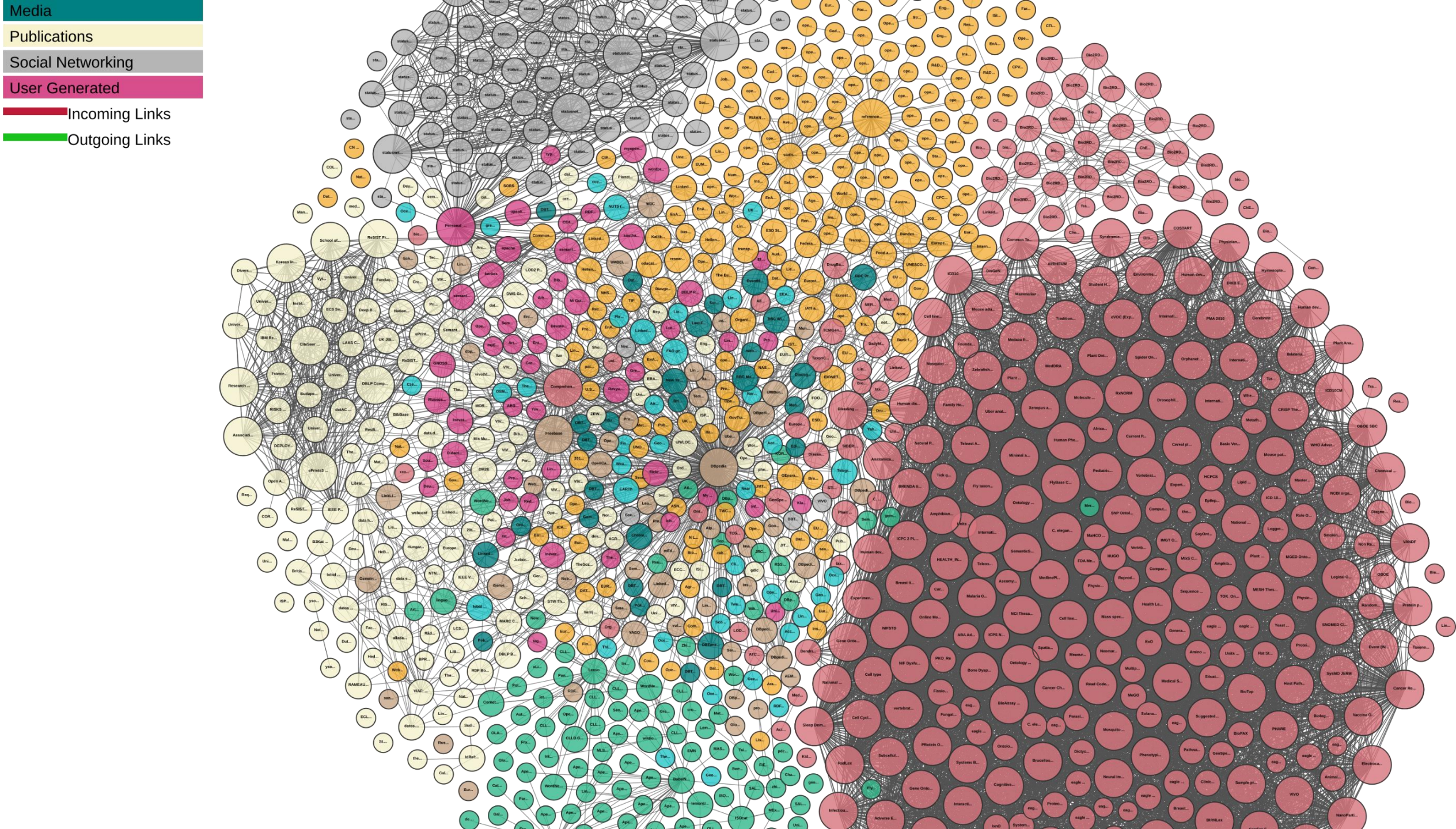
Media
Publications
Social Networking
User Generated
Incoming Links
Outgoing Links

We can also query the data

Display on a map the birth cities of people who died in Winterthour?

- Requires querying multiple data sources on the web
- Requires understanding their schemas
  - Schemas published using Schema.Org vocabulary
- Structured results can then be included in the search results on the web pages

Scale of Wikidata

80+ Million Objects

Scale of Wikidata

1+ Billion Relationships

Scale of Wikidata

4872+ Catalogs

Wikidata Knowledge Graph

- A graph of unprecedented scale
- Collaboratively created
- Data may be curated manually or automatically
- Semantic definitions in Schema.Org
- Compelling use case: Web Search

Outline

- Graphs in Computer Science
- Resurgence of interest in Knowledge Graphs
  - Search engines
  - Data integration
  - Artificial Intelligence
- What is new and different?

Example Use Case

- 360 Degree View of a Customer

Who is funding who?

Who supplies to who?

Who are my customers?

INTERNAL
COMPANY
DATA

Risk Analysis for Lending Decisions
Business Intelligence for Marketing

Data Integration

- Data reside in multiple sources
  - Company directory, product catalog, government database, weather report, …
- Answering queries requires combining data from multiple sources
  - We need to provide translations of data between multiple sources
    - Direct mappings
    - Shared schema

Data Integration

- Schema-free approach to data integration
  - Convert the relational data from multiple sources into triples
    - Stored in a graph database
      - Referred to as a knowledge graph
  - Deal with schema mappings/translations on “pay as you go” basis
    - Visualization
    - Optimized for graph traversals

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Artificial Intelligence

- Output representation for
  - Natural Language Processing
  - Computer Vision
- Input representation for machine learning
  - Language Models
  - Graph Models

Natural Language Processing

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

Natural Language Processing

- Entity Extraction

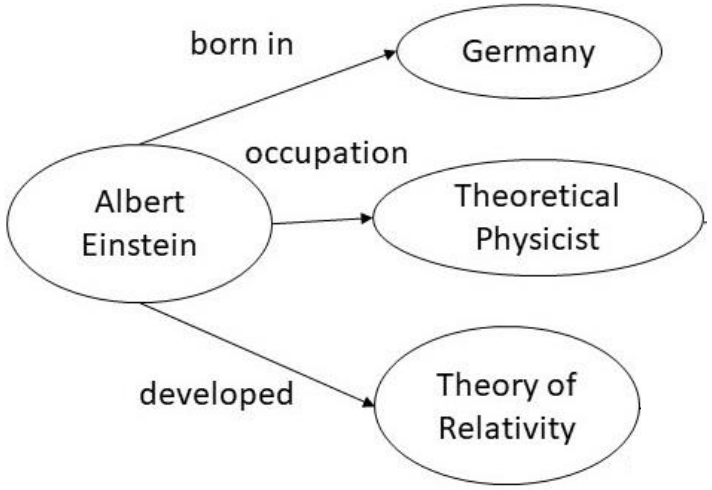
Albert Einstein was a **German-born theoretical physicist** who developed the **theory of relativity**.

Natural Language Processing

- Entity Extraction

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

- Relation Extraction

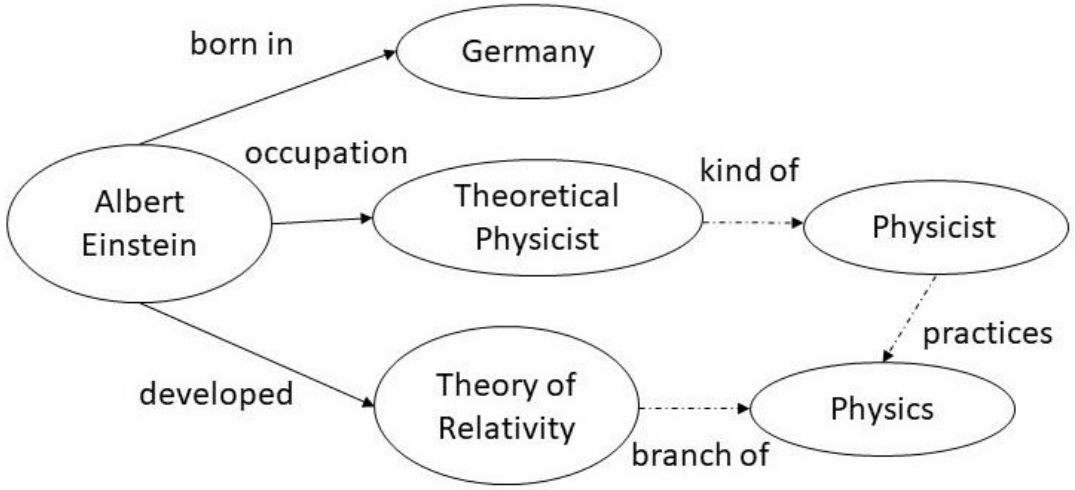


Natural Language Processing

- Entity Extraction

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

- Relation Extraction



Question Answering

Common Sense Reasoning

Computer Vision

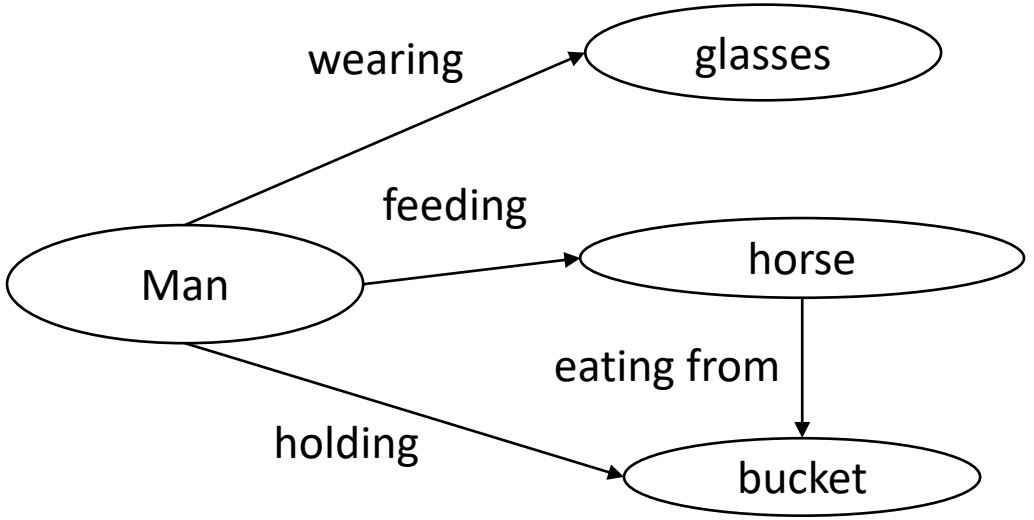
Computer Vision

Object Detection

Computer Vision

Object Detection

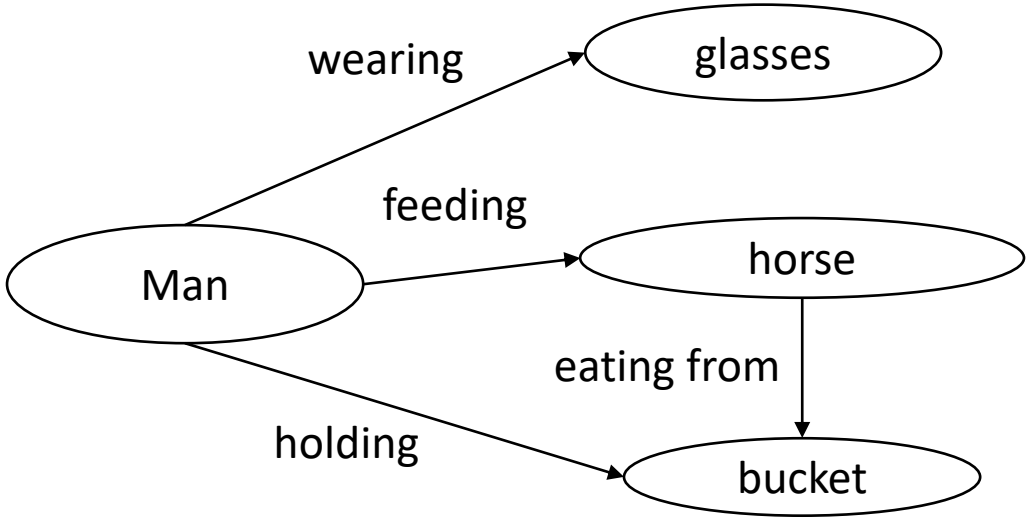
- Edge Detection



Computer Vision

Object Detection

- Edge Detection



Visual Question Answering

Input to Machine Learning

- Machine learning requires numerical input
  - Symbolic inputs must be converted to numerical input
    - A process known as embedding
      - Word Embeddings
      - Graph Embeddings

Word Embedding

- Primary use case is to calculate similarity between words
  - “like” is similar to “enjoy”
- But, generally useful for a variety of language understanding tasks
- Key idea: capture the meaning of a word by counting how often it occurs next to other words

Word Embedding

I like knowledge graphs.

I like databases.

I enjoy running.

Word Embedding

I like knowledge graphs.

I like databases.

I enjoy running.

counts	I	like	enjoy	knowledge	graphs	databases	running	.
I	0	2	1	0	0	0	0	0
like	2	0	0	1	0	1	0	0
enjoy	1	0	0	0	0	0	1	0
knowledge	0	1	0	0	1	0	0	0
graphs	0	0	0	1	0	0	0	1
databases	0	1	0	0	0	0	0	1
running	0	0	1	0	0	0	0	1
.	0	0	0	0	1	1	1	0

Word Embedding

counts	I	like	enjoy	knowledge	graphs	databases	running	.
I	0	2	1	0	0	0	0	0
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knowledge	0	1	0	0	1	0	0	0
graphs	0	0	0	1	0	0	0	1
databases	0	1	0	0	0	0	0	1
running	0	0	1	0	0	0	0	1
.	0	0	0	0	1	1	1	0

Meaning of a word is captured by the vector corresponding to each row of co-occurrence counts

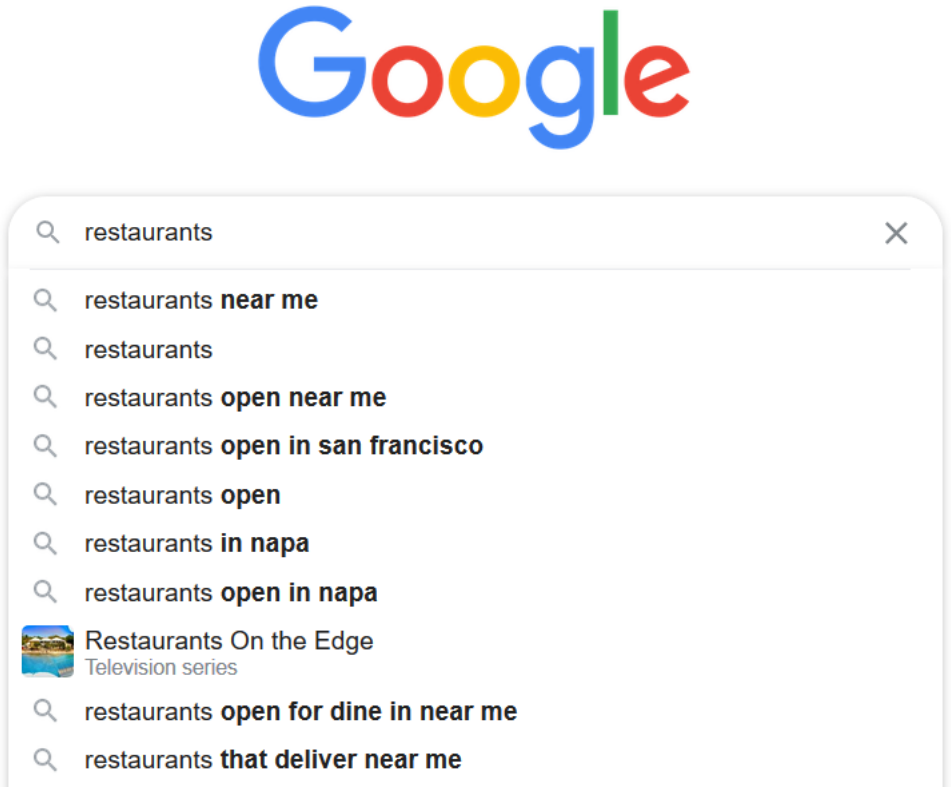
Word similarity can be calculated using the distance between the vectors

Word Embedding

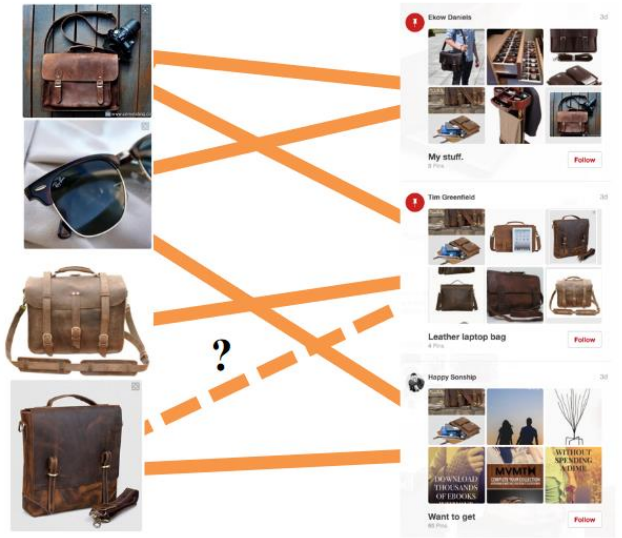
- A large-scale text corpus can have billion plus words
  - The storage requirement for the vectors blows up
    - Dimensionality reduction (typically in the range of 200)
    - Linear algebra techniques (e.g., Singular Value Decomposition)
    - Automatic learning of the necessary parameters

Word Embedding

- A popular application is to predict the next word



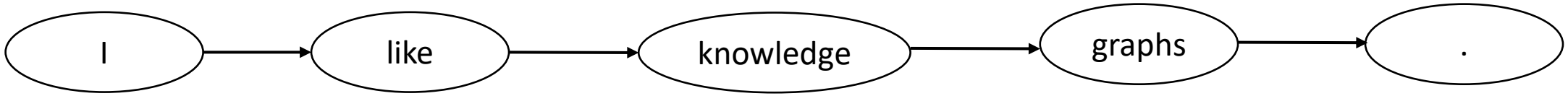
Graph Embedding



- Application areas
  - Recommendation engines
- Generalize what we did for word embeddings
  - Goal is still to reduce the nodes to vectors so that we can calculate the node similarity as a difference between the vectors

Word Embedding to Graph Embedding

- Word embeddings view the text as a linear graph
  - Word prediction is the instance of more general problem of link prediction



Graph Embedding

- Example encoding function
  - Randomly walk the graph
  - Compute the cooccurrence counts between the nodes
- Once nodes have been converted into vectors
  - calculate node similarity
- Optimize the encoding function

Knowledge Graphs and AI

- Output representation for
  - Natural language processing
  - Computer vision
- Input representation for machine learning
  - Language models
  - Graph models

Summary

- Graphs are a fundamental construct in discrete mathematics
  - Defining meaning is the crux of the problem for knowledge graphs
  - Rich history in knowledge representation and databases
- Recent surge of interest driven by
  - Use of structured data in web search results
  - Progress in NLP and vision
  - Progress in ML to perform predictive tasks
- What's new?
  - Scale
  - Bottom-up development
  - Multiple modes of construction

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What are Knowledge Graphs and why do we need them?

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