



Building Spatial Knowledge Graphs

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Center on Knowledge Graphs

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PhD Student



DIG
Technologies for building domain-specific knowledge graphs



Karma
A data integration tool



Semantic Modeling
Automatically building semantic descriptions of sources



WTNIC
Extract information to find relationship among 500,000 initiatives and public firms



PRINCESS
Automatically adapting to changes and failures in sensors



EFFECT
Predicting Cyber attacks by mining online sources.



THOR
Text-enabled Humanitarian Operations in Real-time



ELICIT
A novel knowledge organization system that integrates comments of



Linked Maps
Exploiting Context in Cartographic Evolutionary Documents to Extract and



SpaceAware
Multi-Source Data Fusion for Space Situational Awareness



Model Integration
Model Integration through Knowledge-Rich Data and Reverse Composition



Extracting and Interpreting Time Series
Extracting and Interpreting Time Series for Causal

Masters Students







Abhishek...
MS Student

Aditya Sun...
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Aneesh KA...
MS Student

Anika Jain...
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Anurag Kumar...
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Daye Nam...
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Erding Hu...
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Fan Pin...
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Fiona Khatri...
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Hong Su...
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Haotian Zh...
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Haosin Wang...
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Hong Xu...
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Jeet Mody...
MS Student

Jayaram Ding...
MS Student

Jing Peng...
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Kaushal S...
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Karan Sek...
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Muzahib...
MS Student

Micaela El...
MS Student

Nikhita Br...
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Nicole Pro...
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Oussif Saba...
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Pallavi Tan...
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Pragati Jan...
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Qingyuan...
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Rahul Gupta...
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Rahul Kap...
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Rubith Yer...
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Shreya Ven...
MS Student

Tianxin Zhao...
MS Student






Timothy R...
MS Student

Yeo Gu...
MS Student

Yuan Shi...
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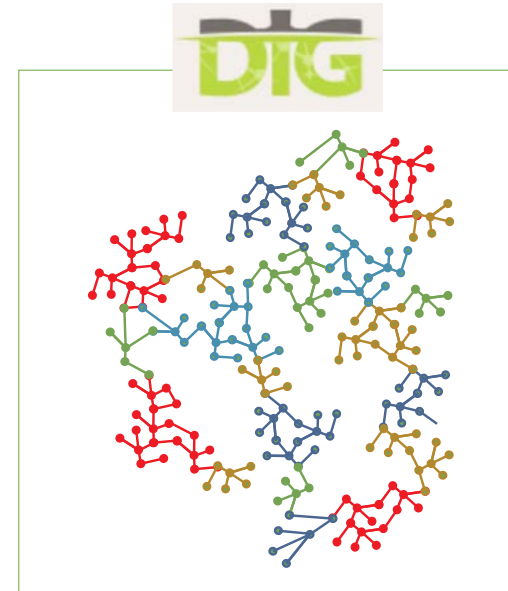
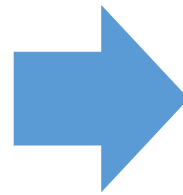
Zhenya Kore...
MS Student

Goal of a Knowledge Graph



raw ♦ messy ♦ disconnected

hard to query, analyze & visualize



clean ♦ organized ♦ linked

easy to query, analyze & visualize

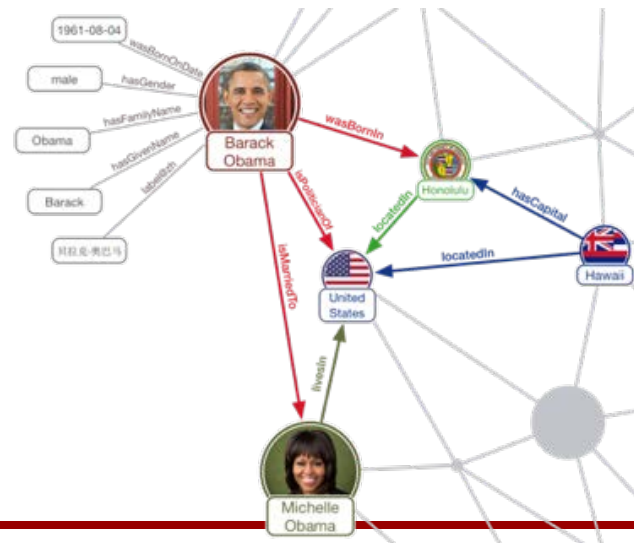
What is a Knowledge Graph?

set of triples, where each triple (h, r, t) represents a relationship r between head entity h and tail entity t

(Barack Obama, wasBornOnDate, 1961-08-04),
(Barack Obama, hasGender, male),

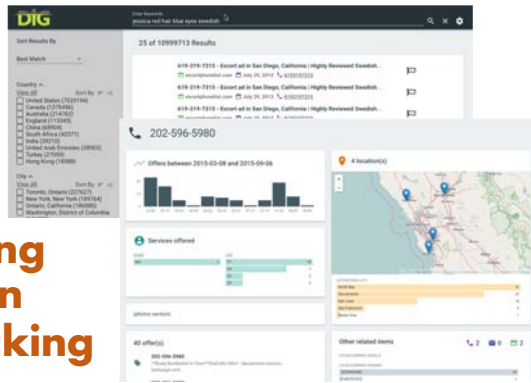
...
(Hawaii, hasCapital, Honolulu),

...
(Michelle Obama, livesIn, United States)



Applications of Knowledge Graphs

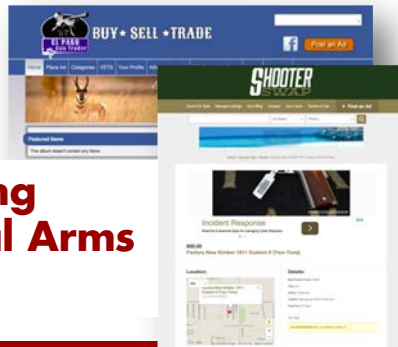
Fighting human trafficking



Forecasting Cyber Threats



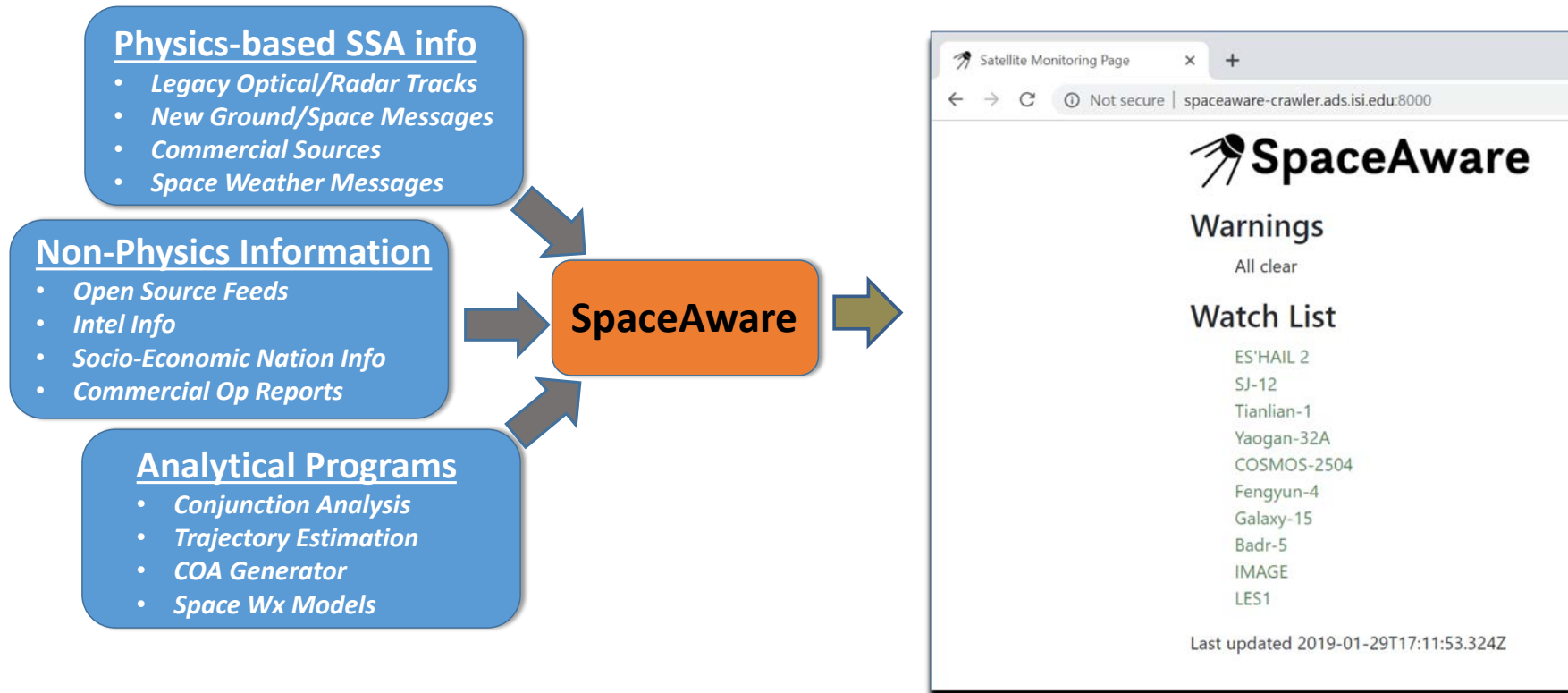
Finding Illegal Arms Sales



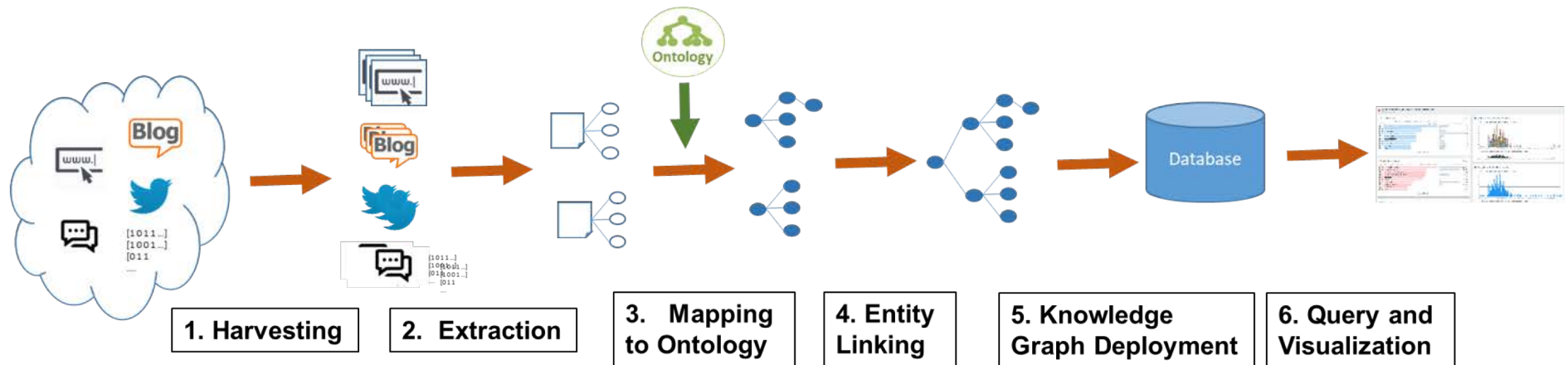
Identifying Threats in Space



Building a Knowledge Graph for Space Objects

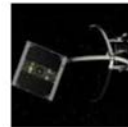


Steps To Build a KG



Harvesting

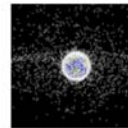
- Space Catalog
- SpaceTrack
- News
- Mailing lists
- Wikipedia
- Web sites
- FCC
- ...



Why technological innovation and increased cooperation regarding ...

The Space Review - Feb 26, 2018

Recently, the threats to **space** assets posed by the increasing number of uncontrolled **objects** in orbit have been poignantly demonstrated. In 2016, a millimeter-sized particle of **space** debris crashed into a solar panel of the European **Space Agency's** (ESA) Sentinel-1A **satellite** and a mysterious piece of ...



NASA's TESS Telescope May Spot Alien Geo-Satellites, Say ...

Forbes - Feb 24, 2018

In the last half-century of **space** flight, our planet's own orbits have become so littered with **space** junk, it gives pause to wonder if our orbital presence could be remotely ... The two main debris fields are the ring of **objects** in geosynchronous Earth orbit (GEO) and the cloud of **objects** in low Earth orbit (LEO).



Is China's space laser for real?

Popular Science - Feb 15, 2018

Laser-armed **satellites**, naturally, generate a lot of attention, and so the proposal of Quan Wen and his co-authors has made its way into several splashy headlines. But it's more than hype. The concept addresses a real (and growing) problem: there's something like 17,852 artificial **objects** orbiting earth ...



Tsunami Of Smallsats Creating Opportunities And Problems

Aviation Week - 17 hours ago

On Feb. 22, U.S. **Space** Command logged two more **satellites** into the growing catalog of **objects** orbiting Earth. Items 43216 and 43217 hitched a ride aboard a SpaceX Falcon 9 rocket that blasted off from Vandenberg AFB, California, with the Paz radar-imaging spacecraft, owned by Hisdesat, the Spanish ...



Elon Musk's red Roadster is now officially a celestial object: NASA ...

Daily Mail - Feb 8, 2018

Elon Musk's red Roadster is now officially a celestial **object**: NASA adds the orbiting sports car and 'space-suit wearing mannequin' to the log of ... and the 'spacesuit-wearing mannequin' have joined the ranks of all other **objects** being monitored in the solar system, from **satellites** to planets and asteroids.

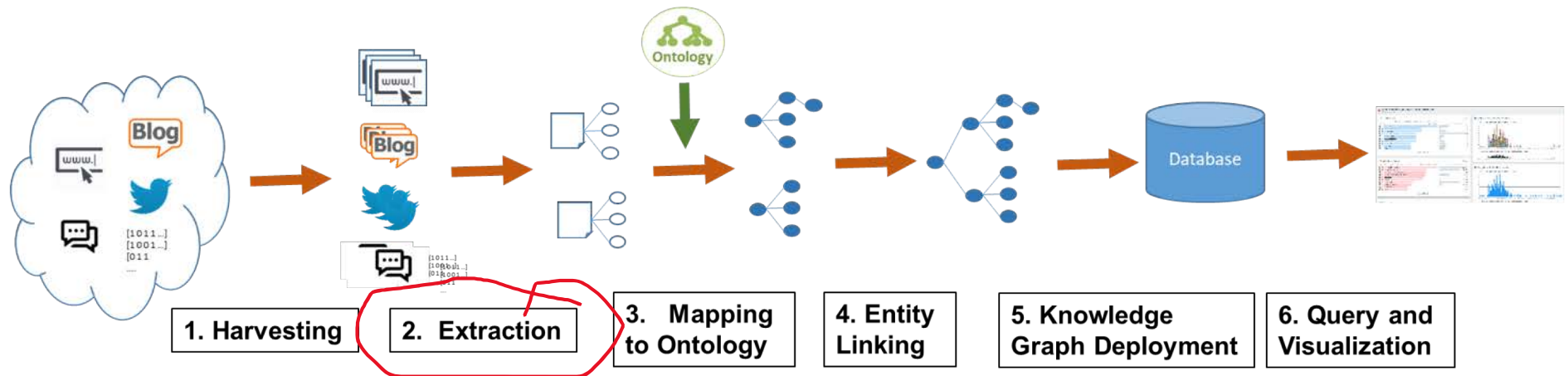


New Hubble Data Shows "New Physics" At Work in Space

Inverse - 3 hours ago

Besides taking glamorous photos of celestial objects, Hubble has the capability of ...

Steps To Build a KG




Extraction

IFL SCIENCE!

35.6K SHARES

Share on Facebook Share on Twitter +



SPACE

KIMIKA YING, VIA FLICKR, CC BY-NC-SA 2.0

A mysterious Russian object that was launched earlier this year has been performing some rather fishy maneuvers, prompting some to start panicking that the satellite could be some kind of secret space weapon.

The curious satellite, coined **Object 2014-28E** was put into orbit in May of this year as part of a launch that saw three communications satellites added to an existing military group. It was originally classed as **space debris**, but Russia didn't declare its launch. This, married with its peculiar orbital movements, has aroused suspicion in many. So much so that for the past few weeks, amateur astronomers and satellite trackers in both the **US** and **Russia** have been closely stalking its activity.

The object has been observed making highly precise maneuvers across the skies, such as gliding towards other Russian satellites and rendezvousing with the remnants of the stage that launched it. These complex movements prompted the US to re-classify the object as a satellite, but no one knows what it is really doing.

IFL STORE f t g+

Information Extraction from Text Documents

- Named entity extraction
 - Identify the locations, organizations, people, etc from the text
- Event extraction
 - Extract the events mentioned in the article
 - Launches, conjunctions, etc.
- Property extraction
 - Extract the details of individual satellites from text documents

Extraction

← → ↻ https://space.skyrocket.de/doc_sdat/astranis-unk.htm ☆ a ⓘ G B O E

"Astranis 1"

Home ▶ Spacecraft by country ▶ USA

Astranis builds a small geostationary high-throughput communications satellite to be used to provide broadband communications services for Alaska for Pacific Dataport. Astranis will be the owner and operator of the satellite.

The 300 kg satellite is to use electric propulsion to reach geostationary orbit. The Ku-band HTP communications payload will provide Alaska with a 7.5 gigabits per second capacity. Initially consumers will be able to utilize a 25 megabits downlink and a 3 megabit uplink.

Astranis will launch the satellite in the second half of 2020.

Nation:	USA
Type / Application:	Communications
Operator:	Astranis, Pacific Dataport
Contractors:	Astranis
Equipment:	Ku-band HTP payload
Configuration:	
Propulsion:	None
Power:	Solar cells, batteries
Lifetime:	7 years
Mass:	300 kg
Orbit:	GEO

Satellite	COSPAR	Date	LS	Launch Vehicle	Remarks
"Astranis 1"	-	2020			with ?

GUNTER'S SPACE PAGE

- Launch Vehicles
 - Upper Stages
 - Engines
- Launch Sites
- Chronology
- Spacecraft by nation
- Spacecraft by type
- S/C Platforms
- Manned Missions
- Astronauts
- News
- Links
- Books
- Unit Calculator
- Contact
- Search
- Gunter's Homepage

Quicksearch
Search

Structured Extraction

← → ↻ https://space.skyrocket.de/doc_sdat/astranis-unk.htm ☆ a ⓘ G B O E

"Astranis 1"

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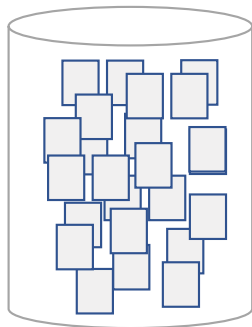
GUNTER'S SPACE PAGE

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- Search
- Gunter's Homepage

Quicksearch
Search

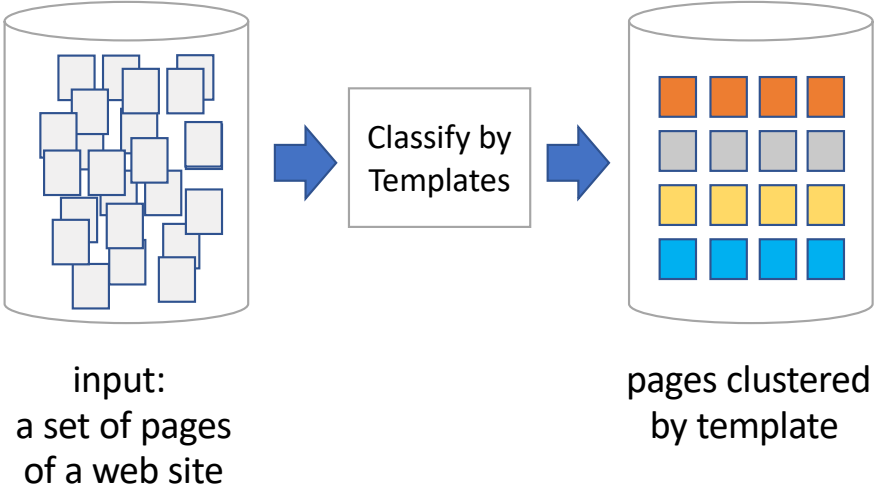
Automated Extraction

[Minton et al., Inferlink]

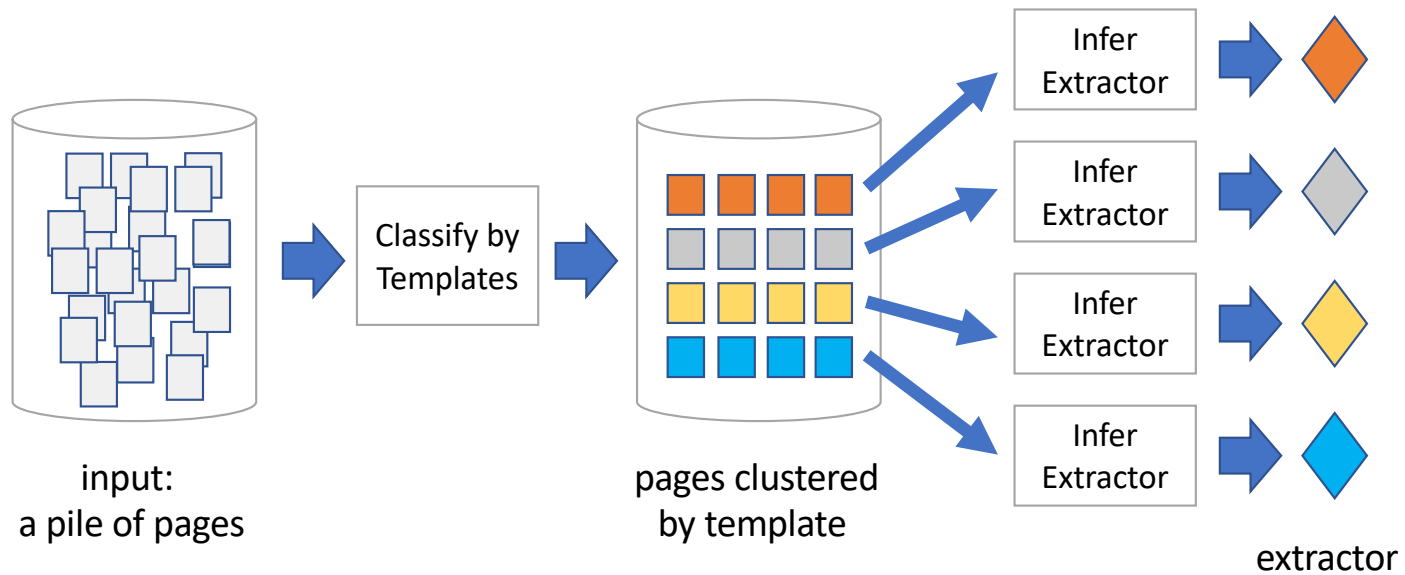


Input: A set of pages
of a web site

Automated Extraction



Automated Extraction



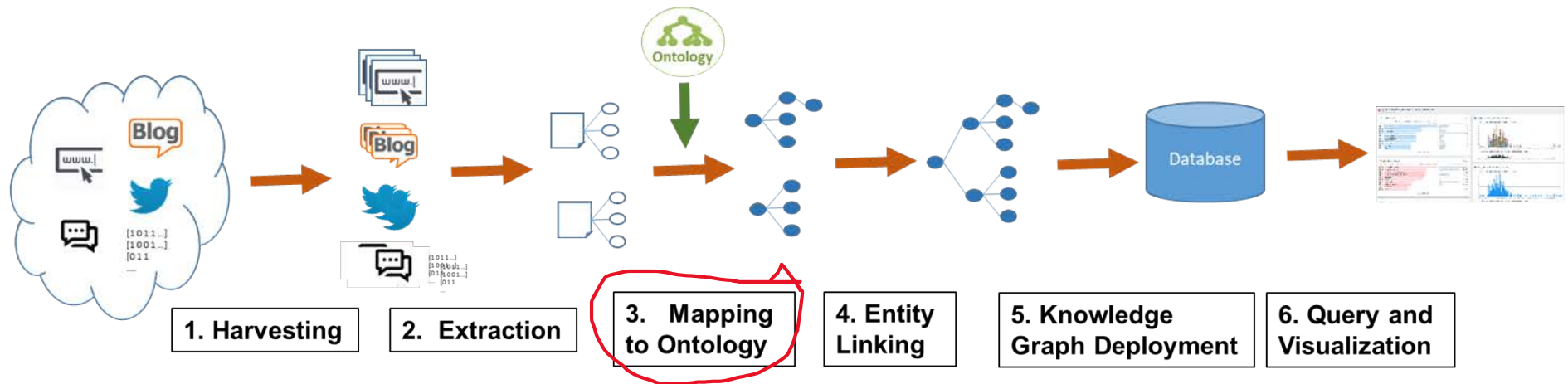
Extraction Evaluation

10 websites, 5 pages each

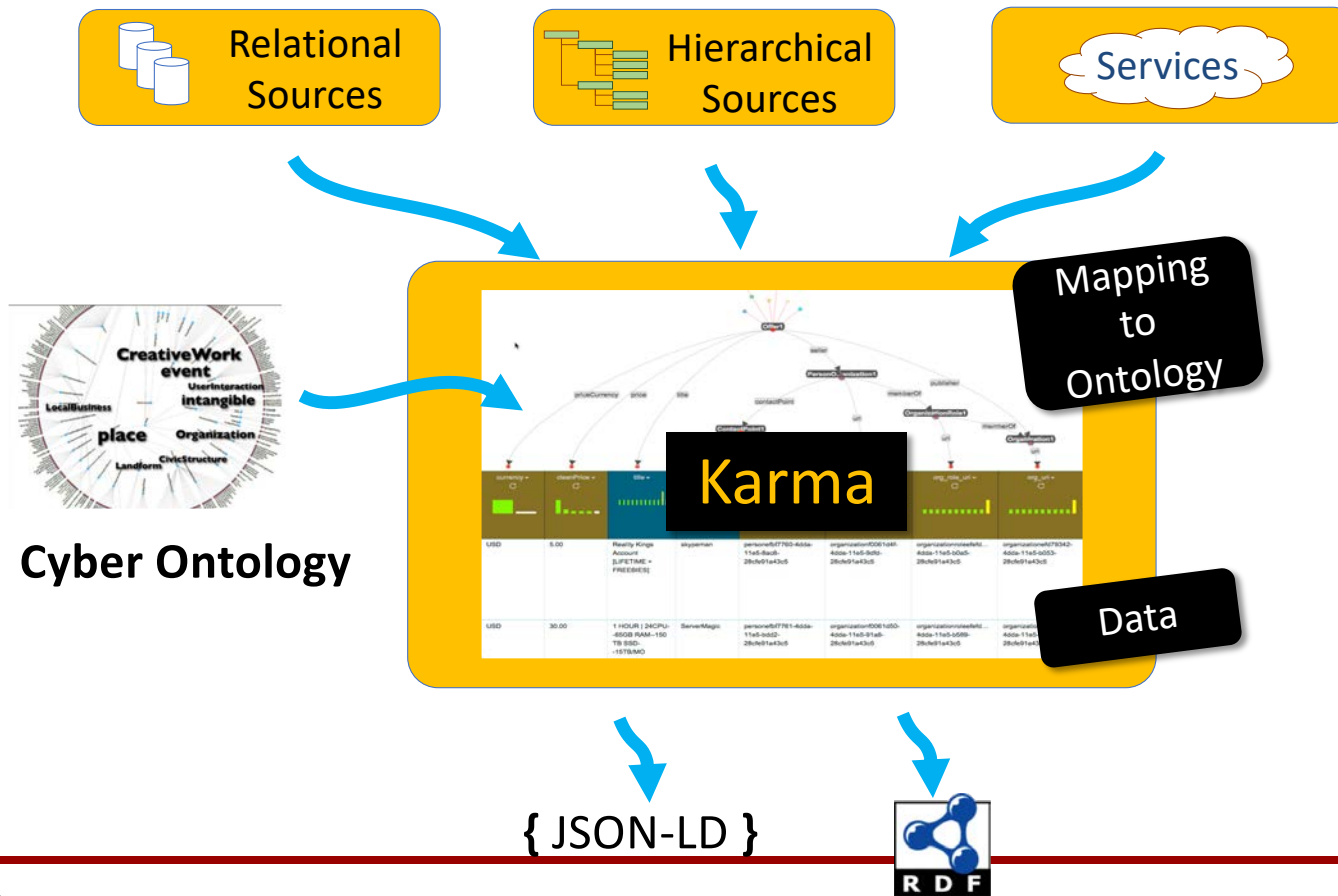
fields

	Title	Desc	Seller	Date	Price	Loc	Cat	Member Since	Expires	Views	ID
Perfect	1.0 (50/50)	.76 (37/49)	.95 (40/42)	.83 (40/48)	.87 (39/45)	.51 (23/45)	.68 (34/50)	1.0 (35/35)	.52 (15/29)	.76 (19/25)	.97 (35/36)
Including partial and extra data	1.0 (50/50)	.98 (48/49)	.95 (40/42)	.83 (40/48)	.98 (44/45)	.84 (38/45)	.88 (44/50)	1.0 (35/35)	.55 (16/29)	1.0 (25/25)	1.0 (36/36)

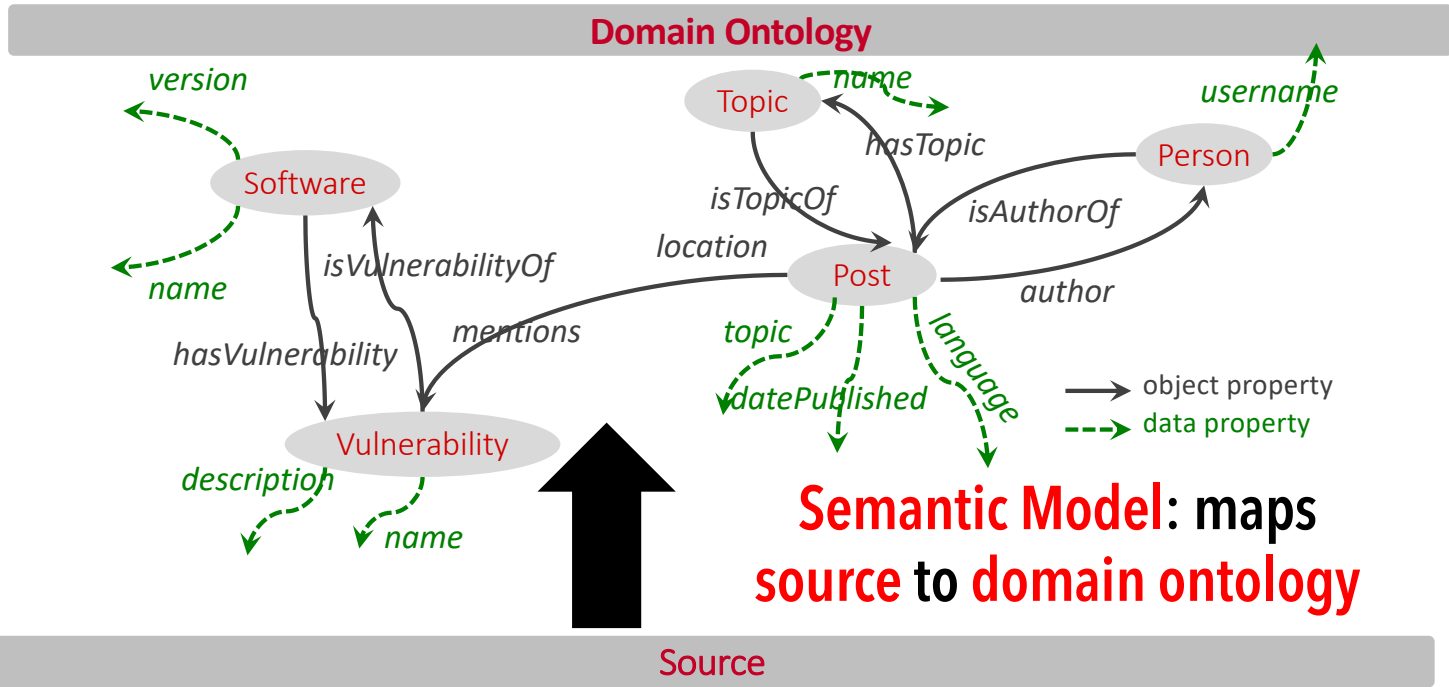
Steps To Build a KG



Karma: Mapping Data to Ontologies

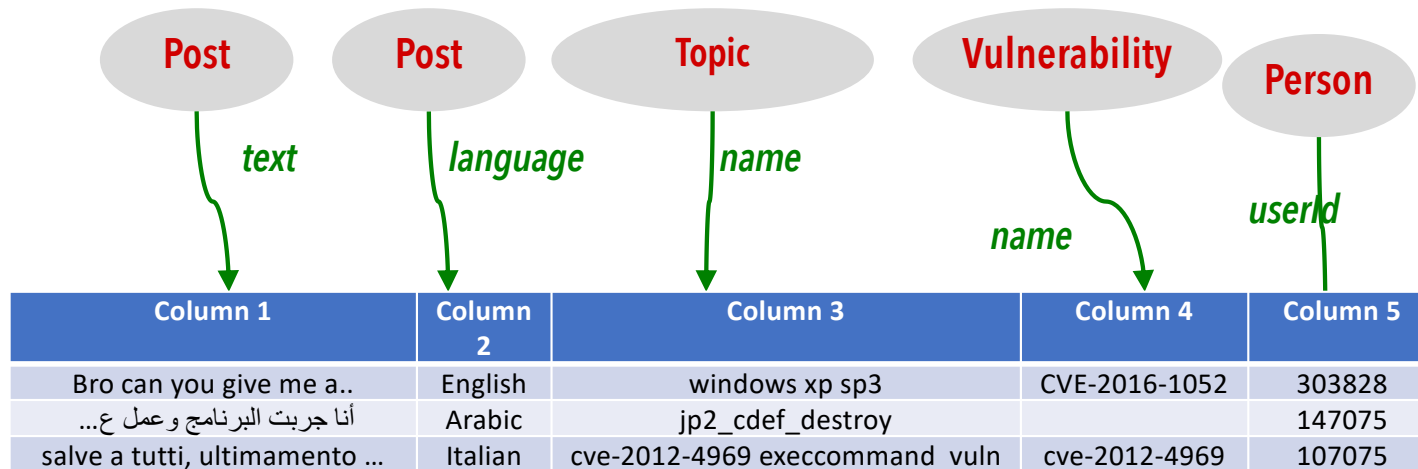


Map Source to Domain Ontology

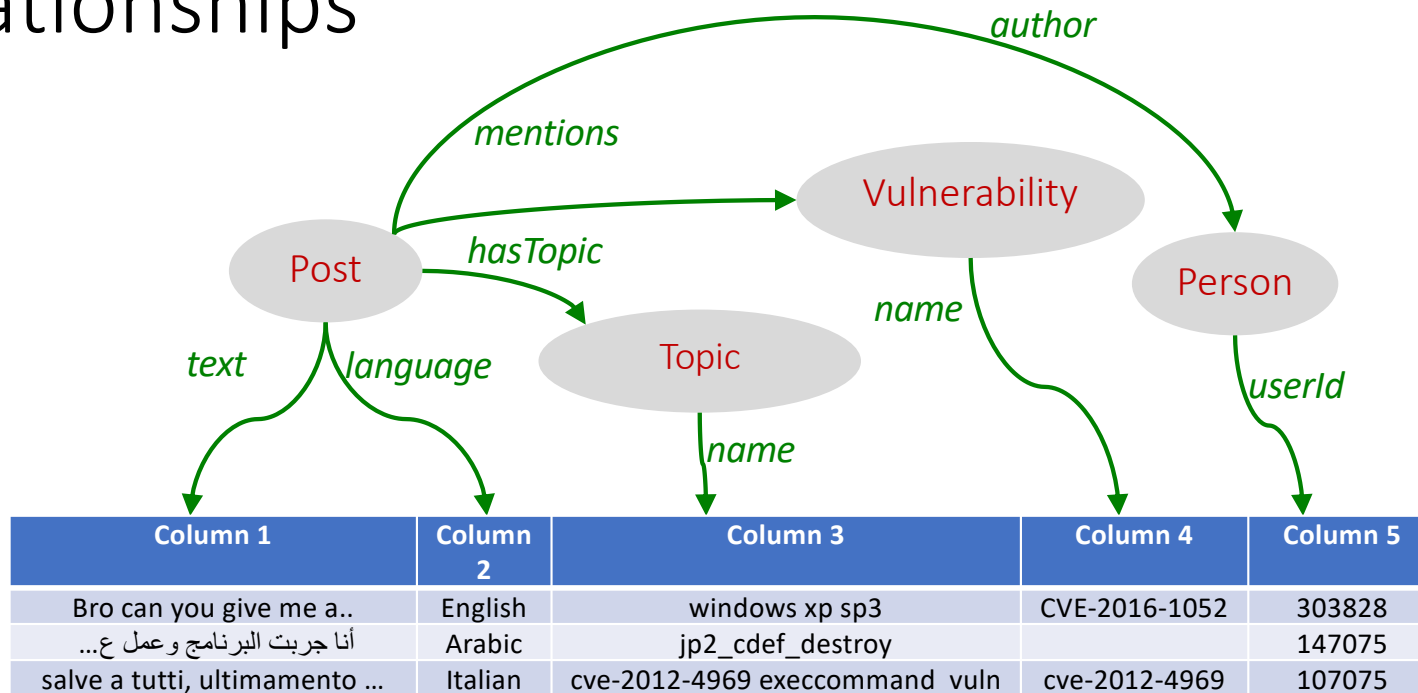


Column 1	Column 2	Column 3	Column 4	Column 5
Bro can you give me a..	English	windows xp sp3	CVE-2016-1052	303828
أنا جربت البرنامج وعمل ع...	Arabic	jp2_cdef_destroy		147075
salve a tutti, ultimamento ...	Italian	cve-2012-4969 execcommand vuln	cve-2012-4969	107075

Semantic Types

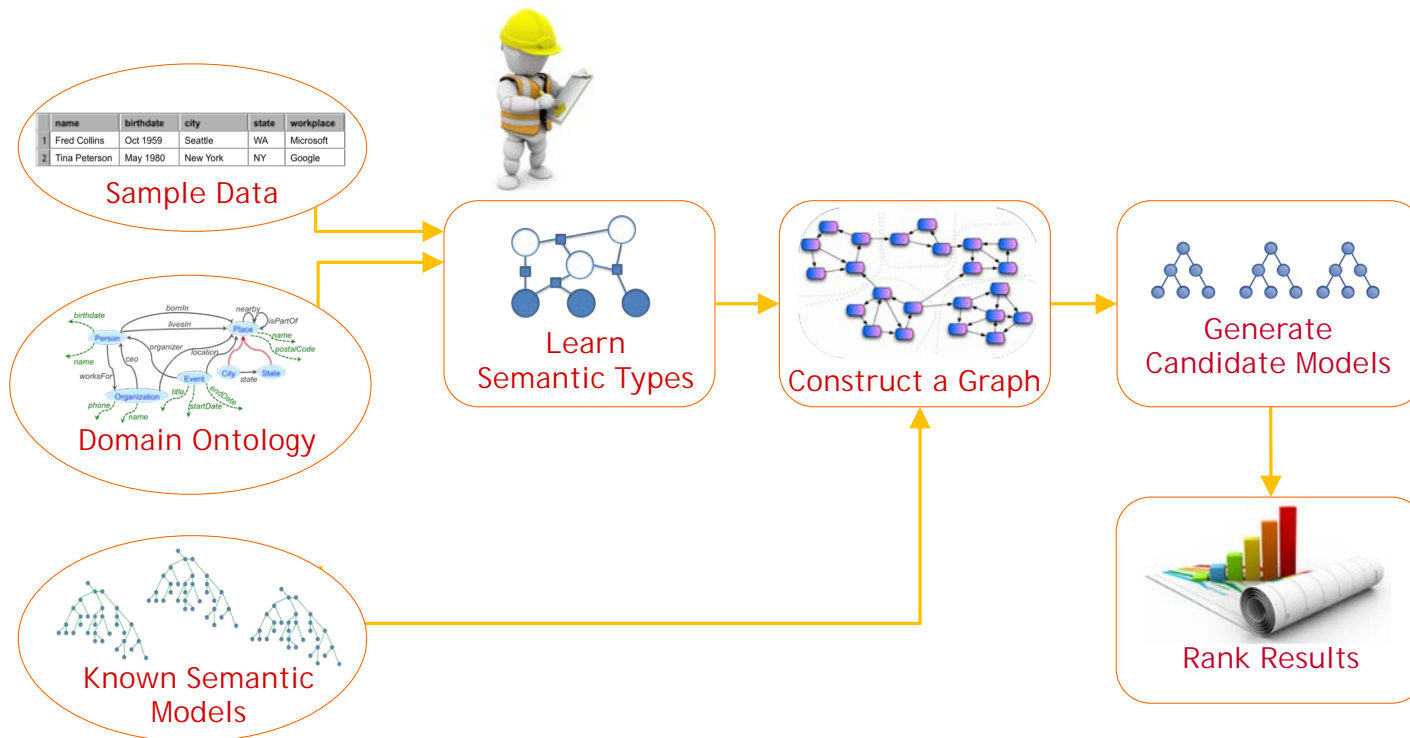


Relationships

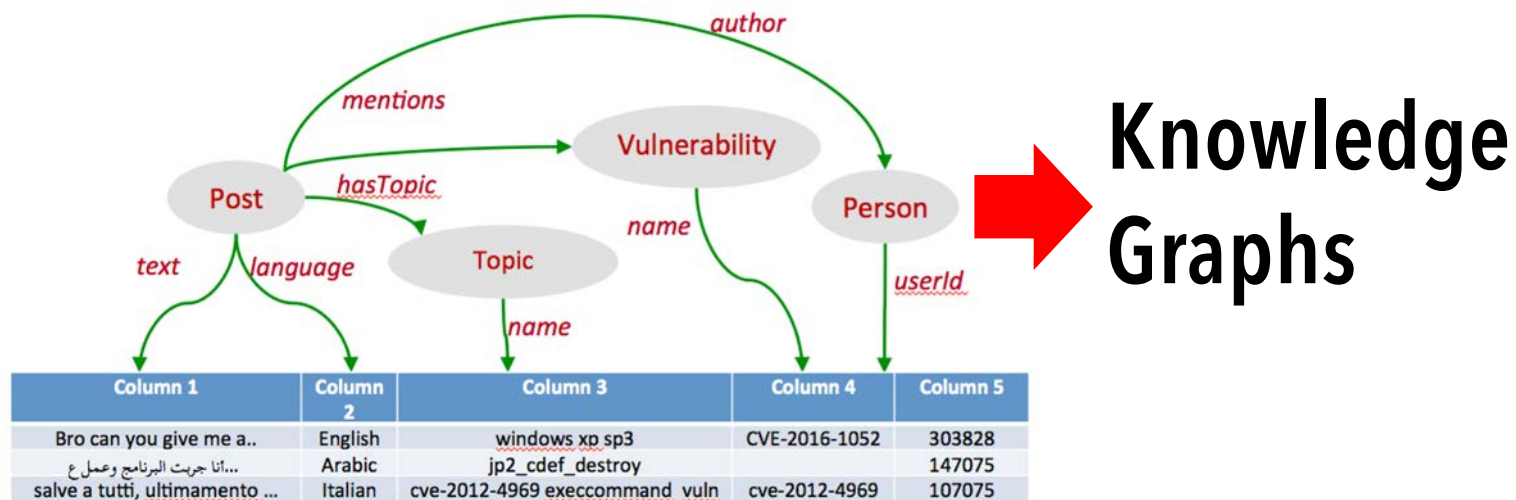


Karma Learns the Source Models

Taheriyan et al., ISWC 2013, ICSC 2014

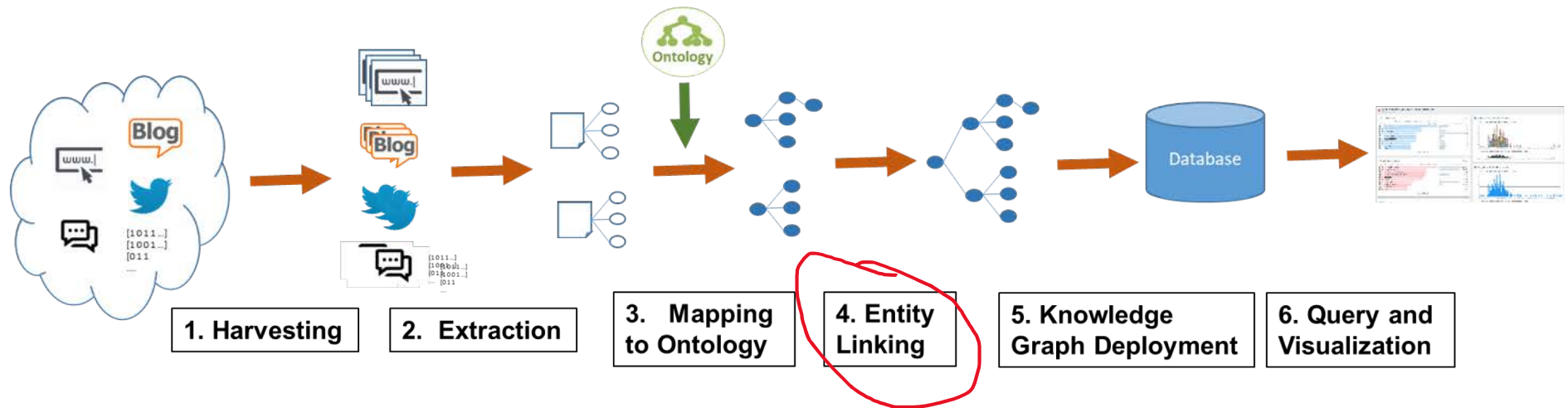


Karma **semi-automatically** builds semantic models

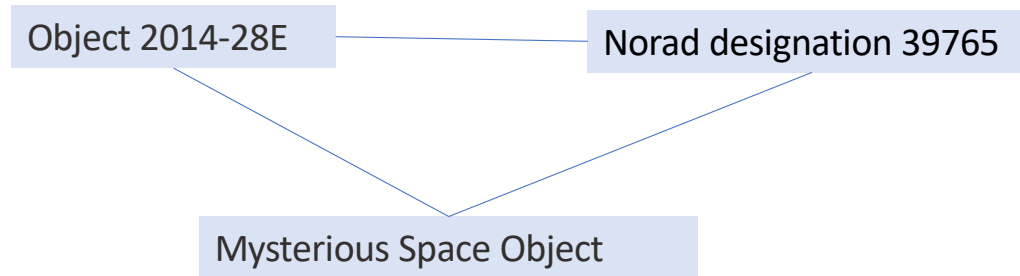


Karma uses **semantic models** to **create** knowledge graphs

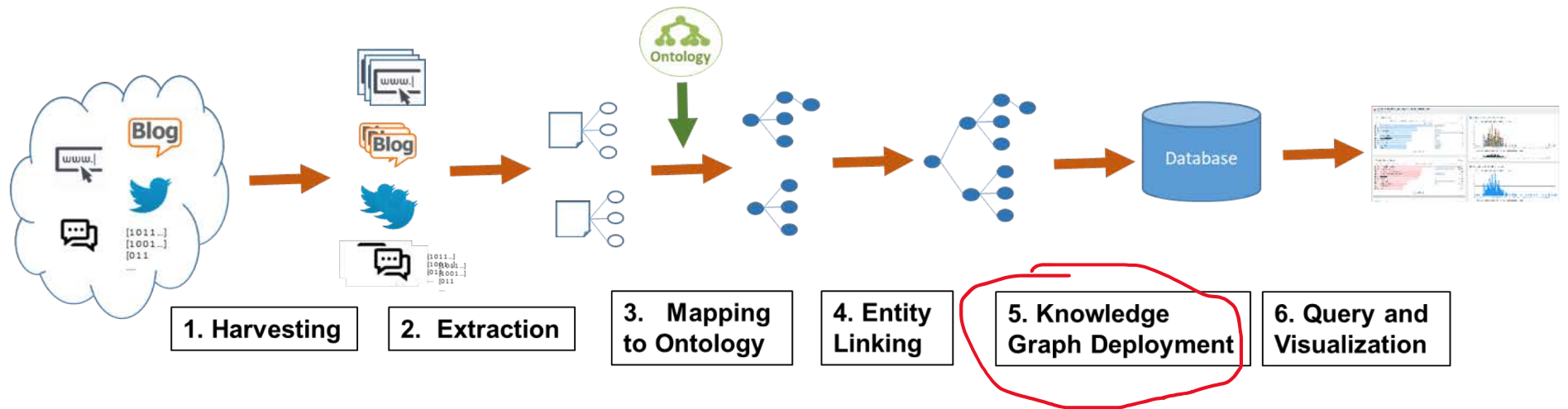
Steps To Build a KG



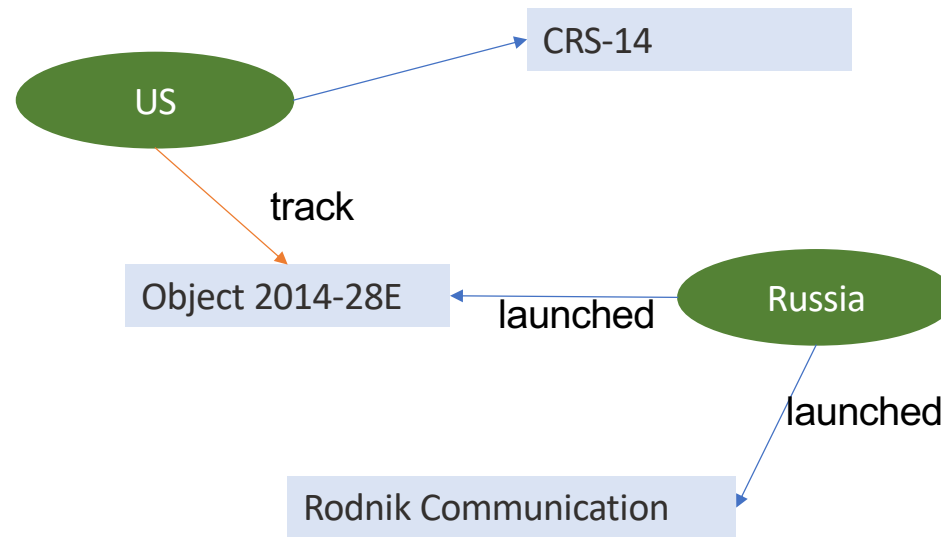
Entity Linking



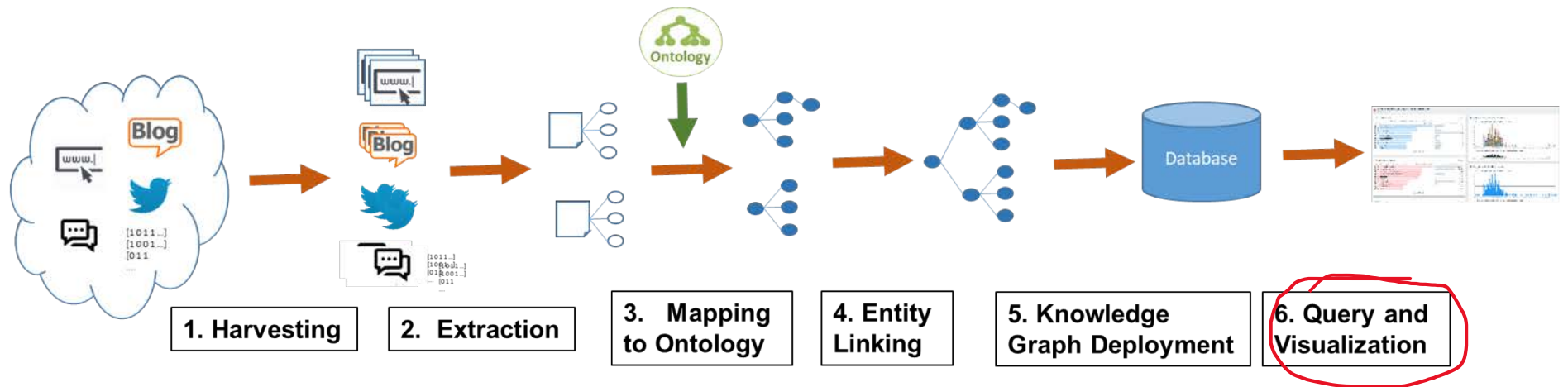
Steps To Build a KG



Knowledge Graph Construction



Steps To Build a KG



2018-090A

Not secure | spaceaware-crawler.ads.isi.edu:8000/casefiles/2018-090A

SpaceAware

ES'HAIL 2

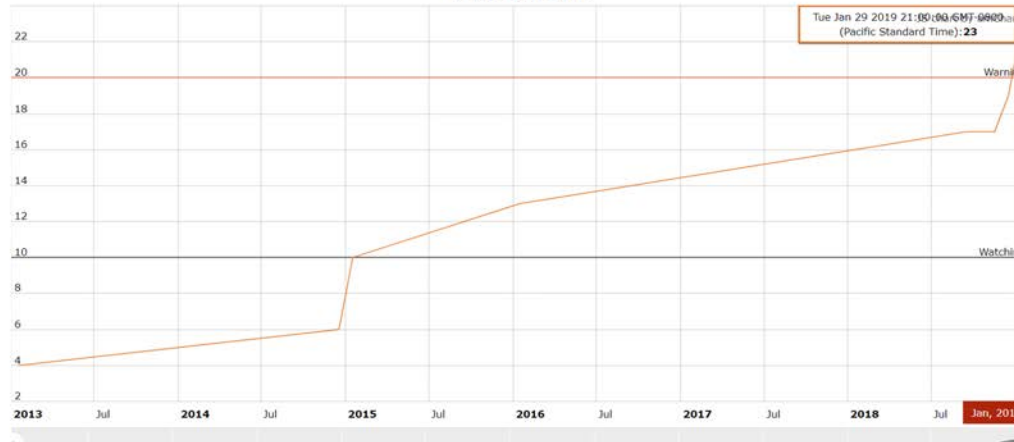
Fact Sheet

International Designator	• 2018-090A
Aliases	• ES'HAIL 2
NORAD ID	• 43700
Object Type	• PAYLOAD

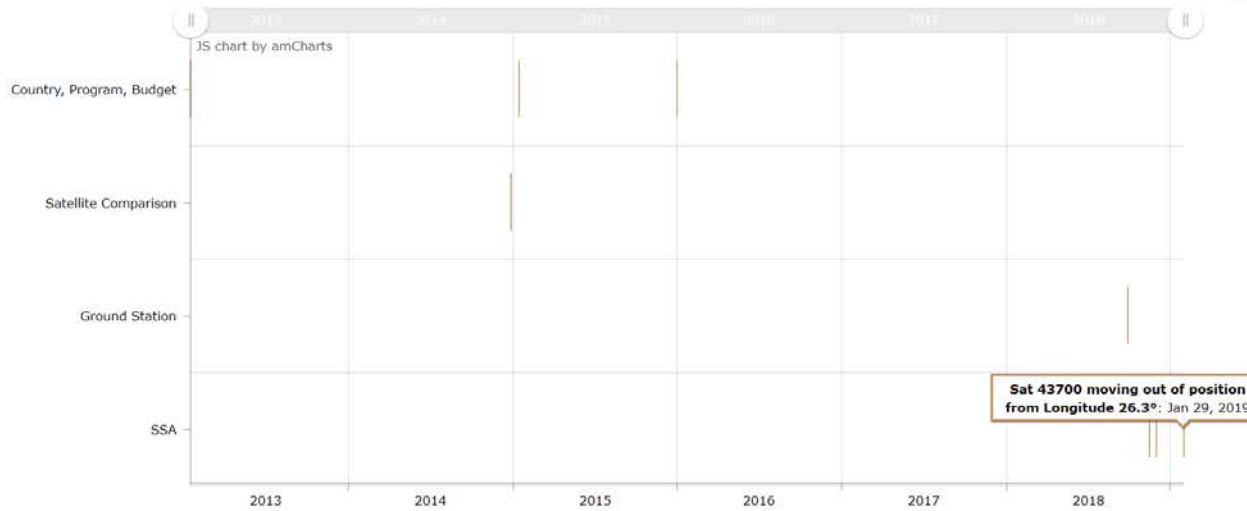
Latest TLEs

Epoch	Apogee (km)	Perigee (km)	Inclination (°)	AoP	Period	Eccentricity	RAAN
2018-12-16T04:19:42	35788.786	35782.975	0.0401	50.8408	1436.060	6.89e-05	254.1327
2018-12-15T22:25:03	35788.726	35783.110	0.0403	48.9294	1436.062	6.66e-05	254.6453

Flag Sparkline

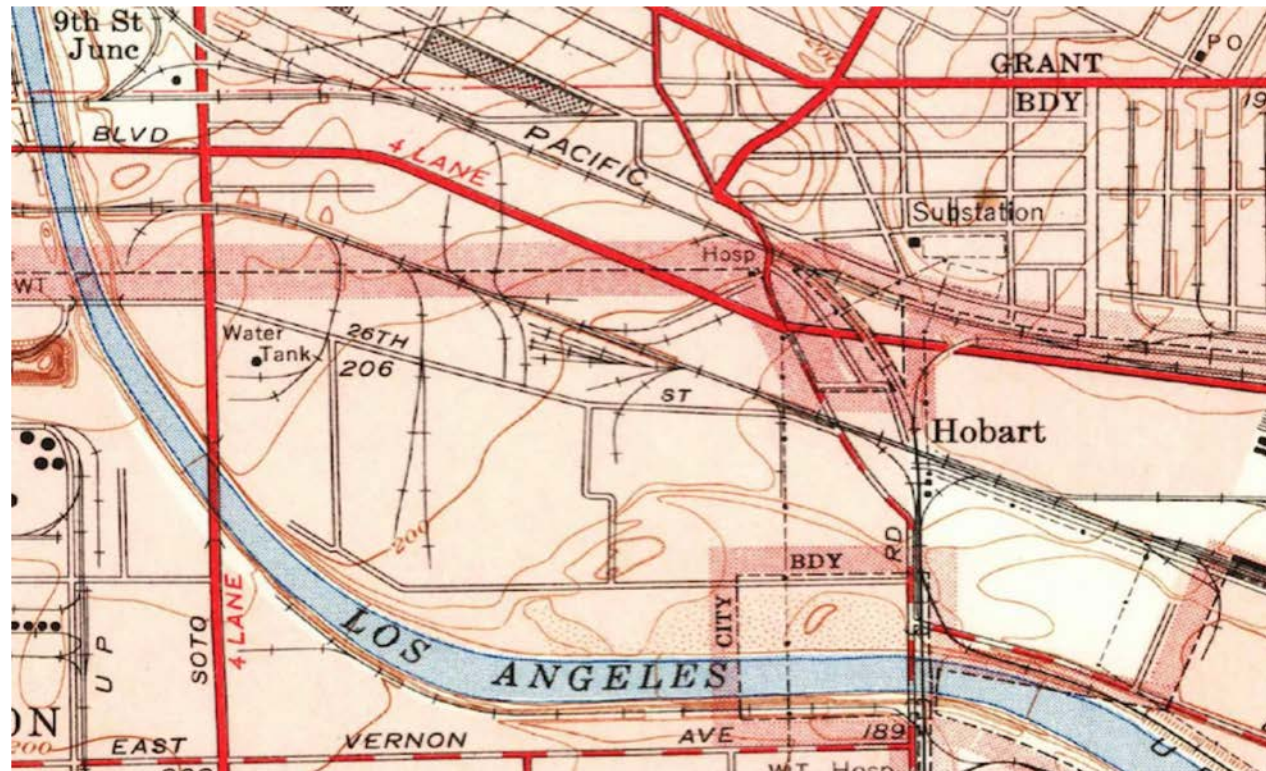


Event Information by Information Type

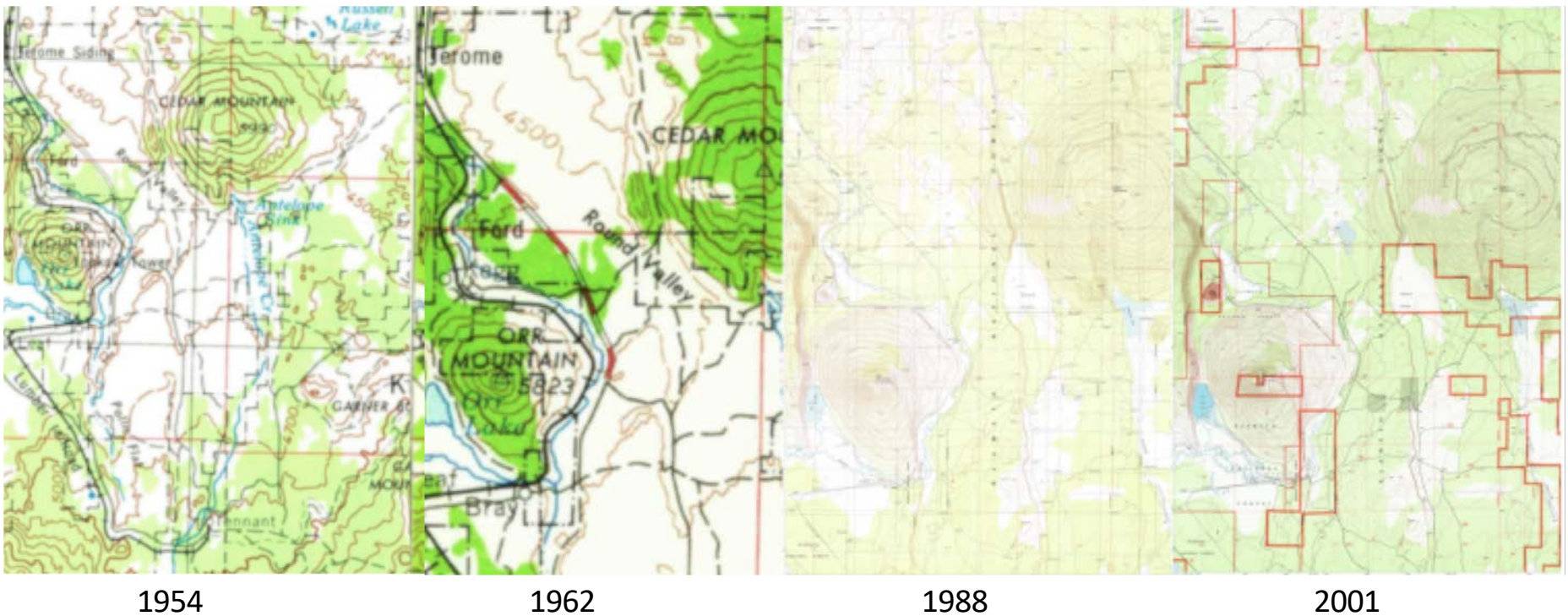


Building KGs from Maps

- Study changes in
 - Roads
 - Railroads
 - Wetlands
 - Built areas
 - Hydrography
 - ...

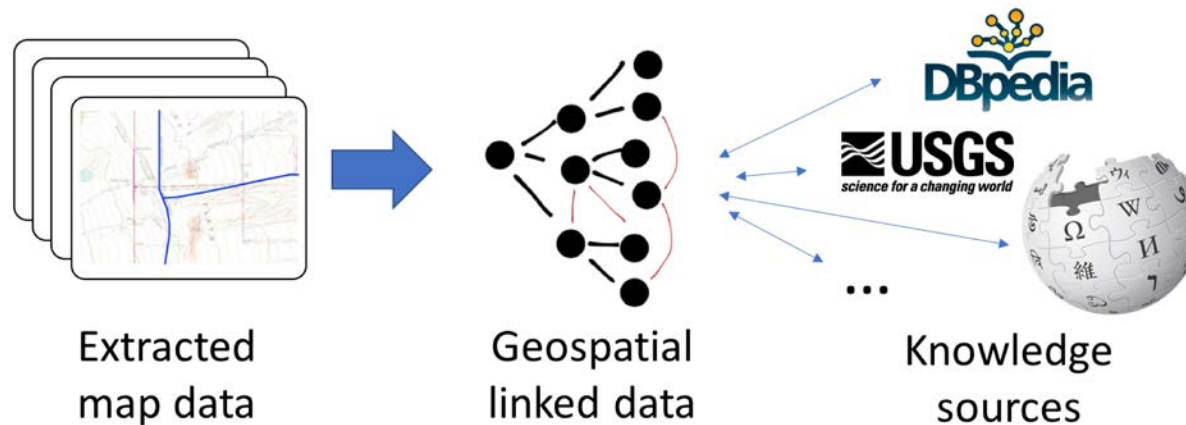


Maps of the Same Area Over Time and Scale



Goal of Building a KG for Maps

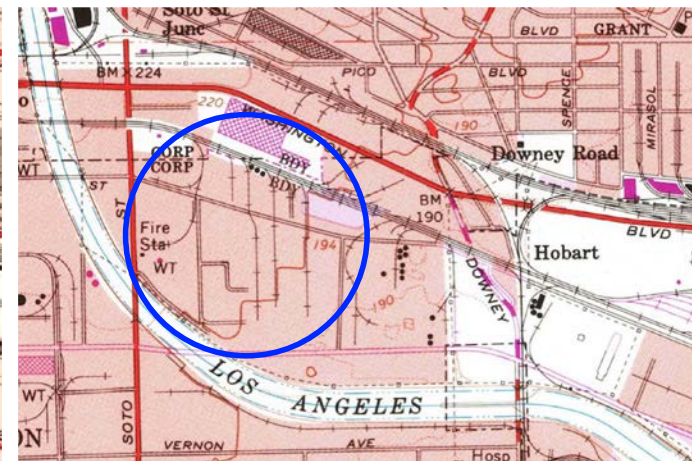
- Geospatial change analysis
- Utilize other knowledge sources
- Enable rich semantic queries



Analyzing Changes Across Maps



1953

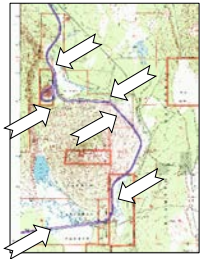


1966

Railroads change in Los Angeles, California

Pipeline

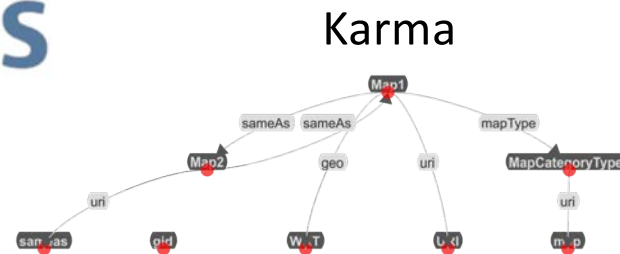
Extraction



Linking



Mapping to the
Ontology



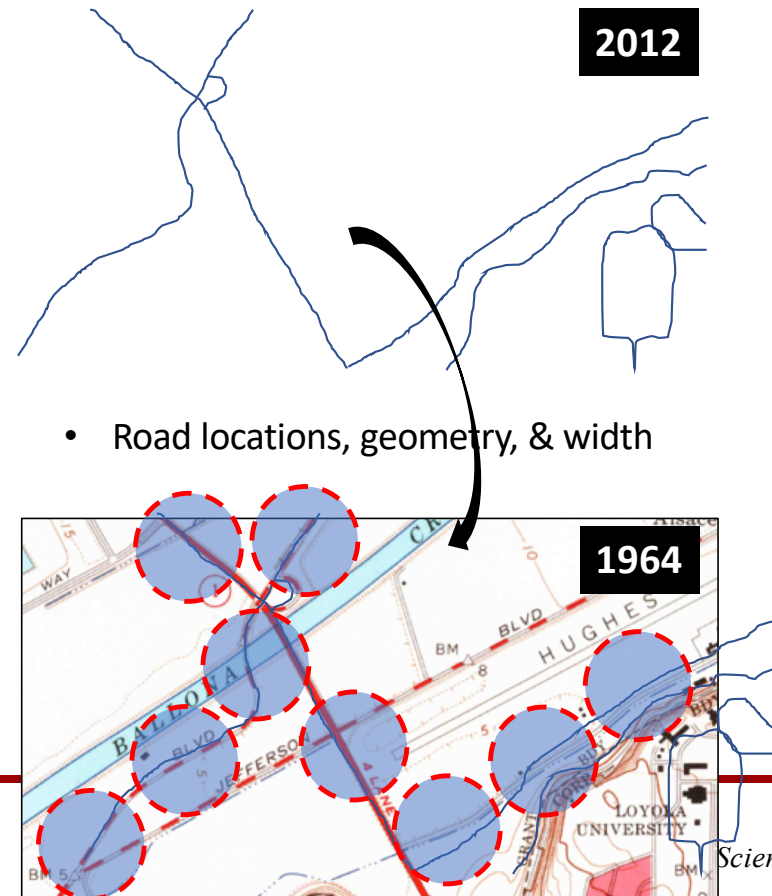
Querying



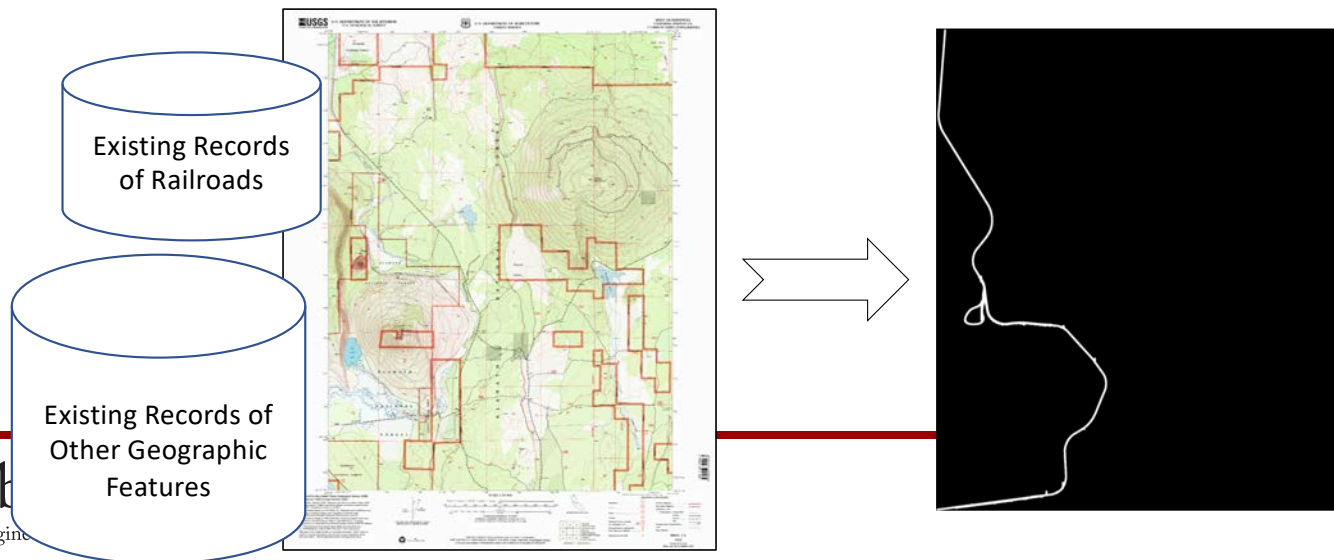
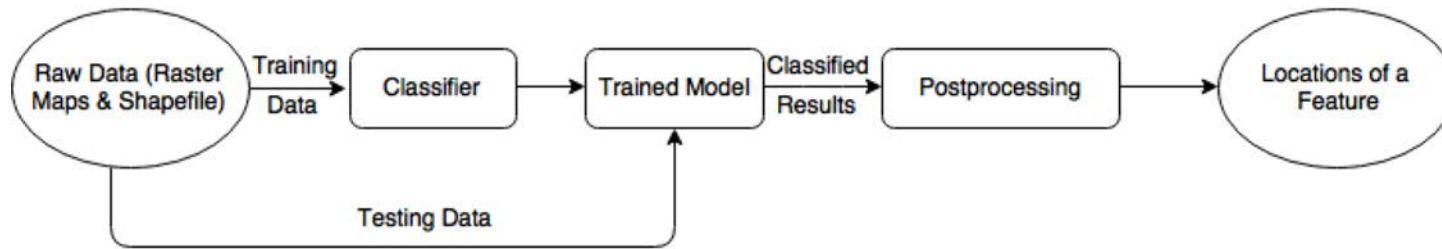
Feature Extraction from Historical Maps

- **Problem:** Train a robust model for feature recognition requires **lots of training samples**
- **Solution:** Adaptive graphics sampling using existing data
 - Collect **spatially constrained** graphics examples automatically
- Train Convolutional Neural Networks with the automatically collected samples

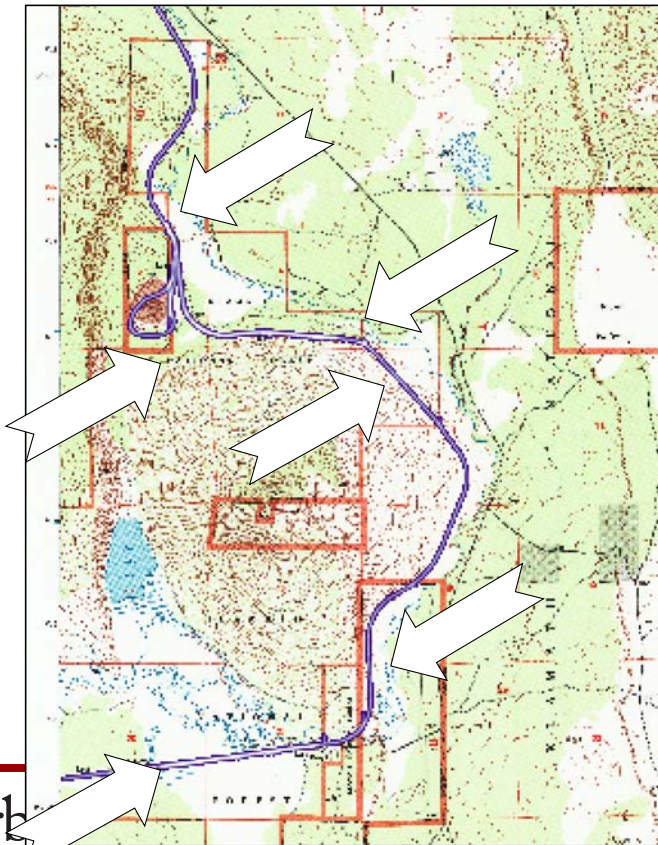
Duan et al., GeoAI 2017; Uhl et al., ICPRS 2017 (Best Paper Award)



Railroad Extraction Example

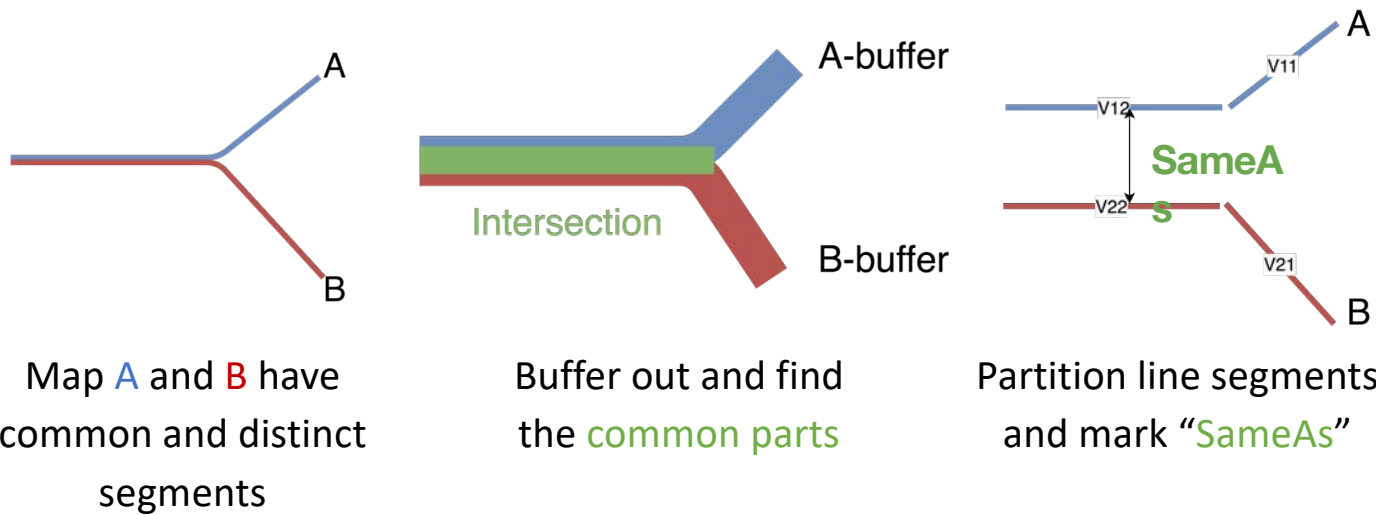


Railroad Extraction Example

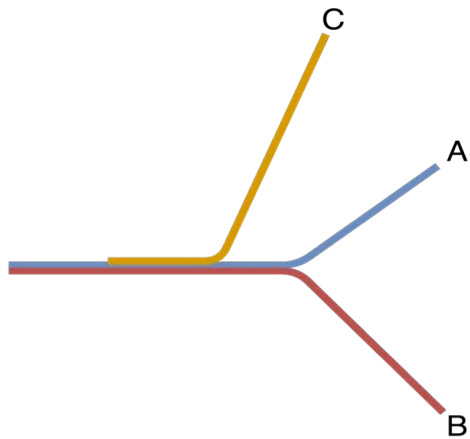


- **Fully Automatic!**
- Trained a 4-layer model of Convolutional Neural Networks for recognizing railroads from USGS maps
 - Precision: 71.8% Recall: 92.1%

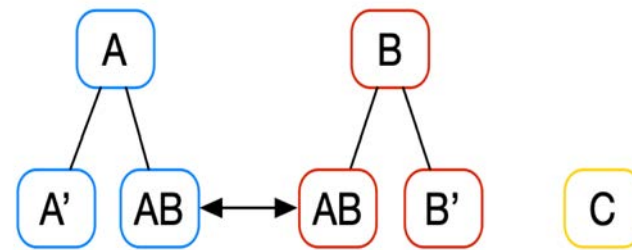
Linking: Line Segmentation



Linking: “Contains” Relation

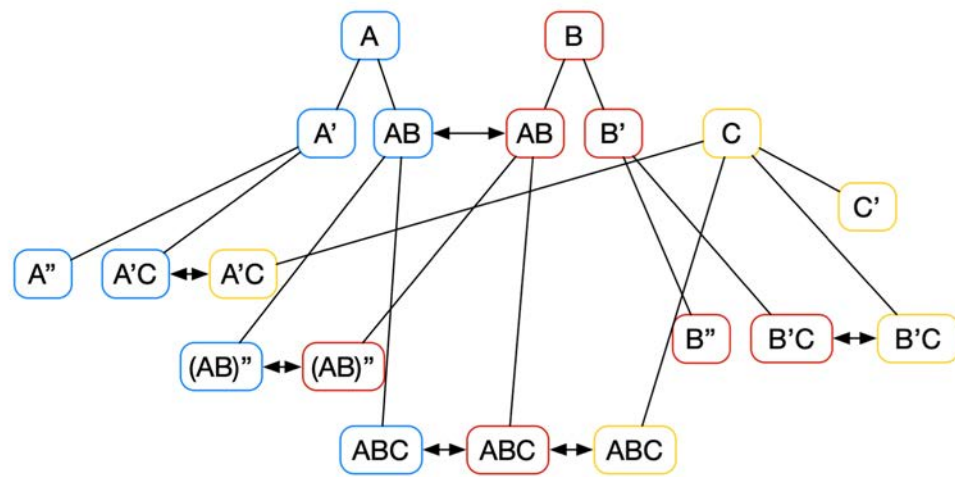
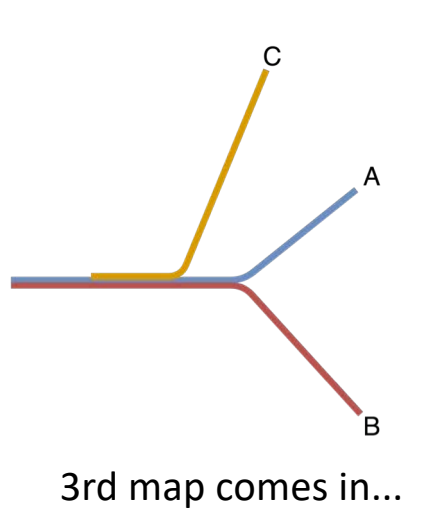


3rd map comes in...



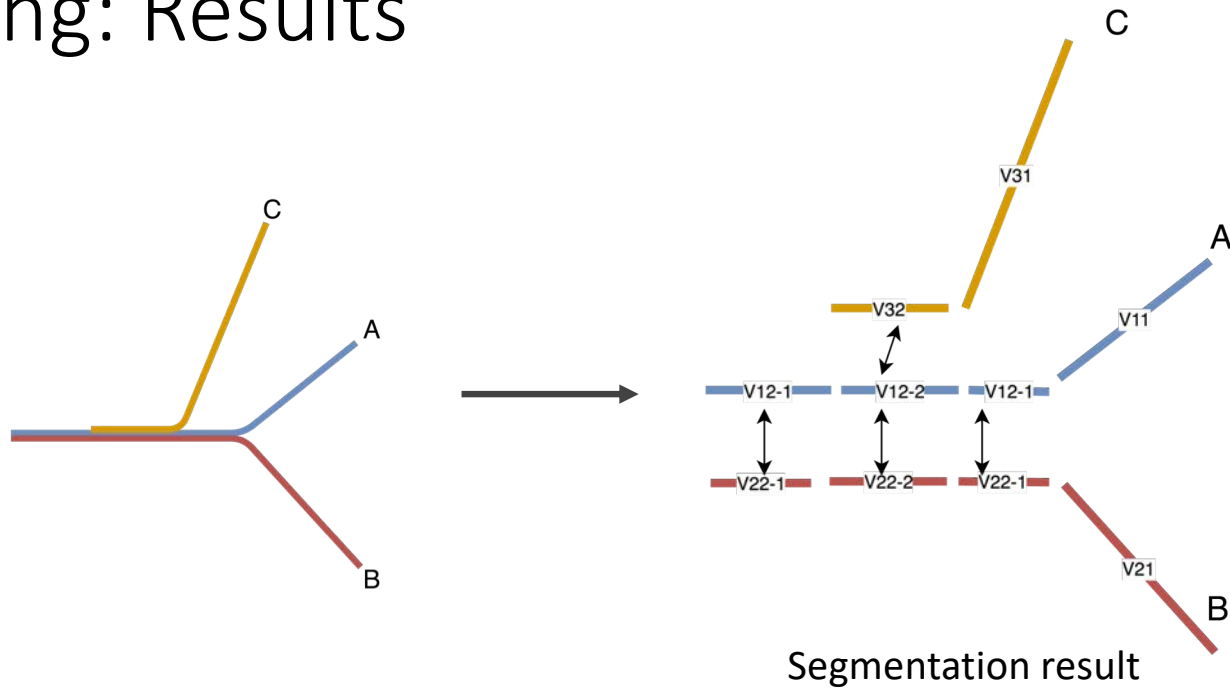
“Contains” relationship tree

Linking: "Contains" Relation



"Contains" relationship tree

Linking: Results



Creating the Linked Data: Preparation

WKT

WKB
0105000020AD1000005102000 001020000000E000000DD1FA6 140F8A5DC0080000000000414 048D576....



WKT
MULTILINESTRING((-118.157170450431 34.0000000000001,-118.15711628537 34.0001117586834,-118.157055418703 34.0002624753498,-118.15701194162 34.0004160920163,.....))

URI

WKT	MULTILINESTRING((-118.157170450431 34.0000000000001,-118.15711628537 34.0001117586834,.....))
Map Source	USGS vector data for Los Angeles, CA



"45bf12bd"

Linking Results in Tables

Map vectors

URI	WKT	Map
V12-2	LineString...	A
V22-2	LineString...	B
V32	LineString...	C
...

"SameAs"

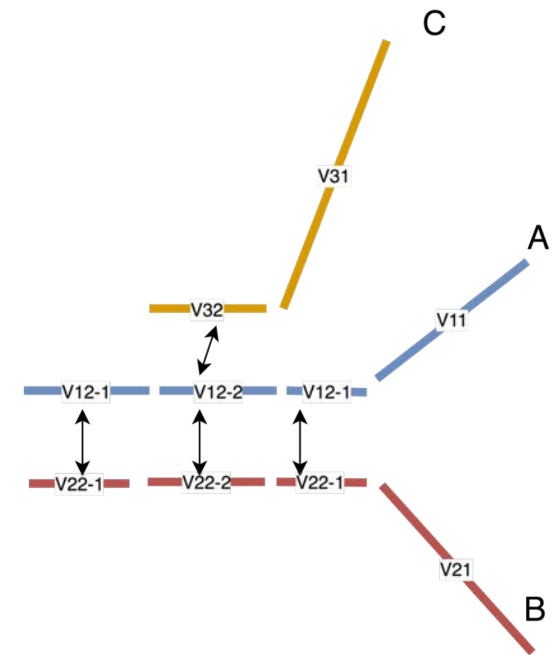
URI	SameAs
V12-2	V22-2
V22-2	V12-2
V32	V12-2

"Contains"

URI	Contains
A	V12
B	V22
V12	V12-1
...	...

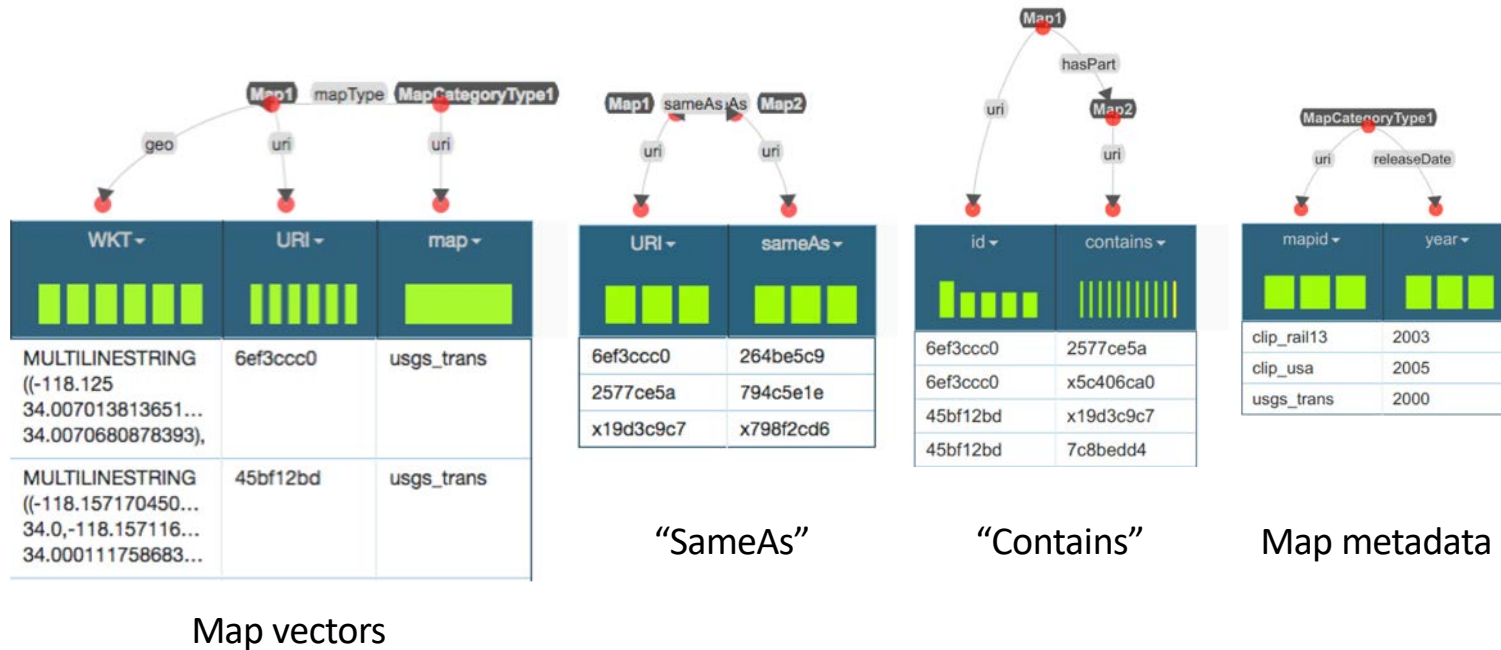
Map metadata

Map	Year
A	2000
B	2003
C	2005



Segmentation result

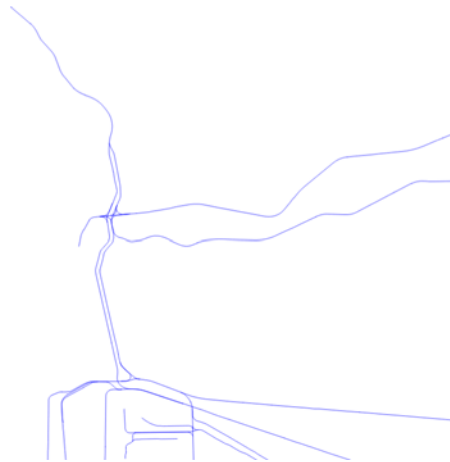
Mapping the Data to the Ontology



Test Case: Railroad Maps for Los Angeles



USGS vector data for Los Angeles, California
(373 KB)



California Rail Network
(183 KB)

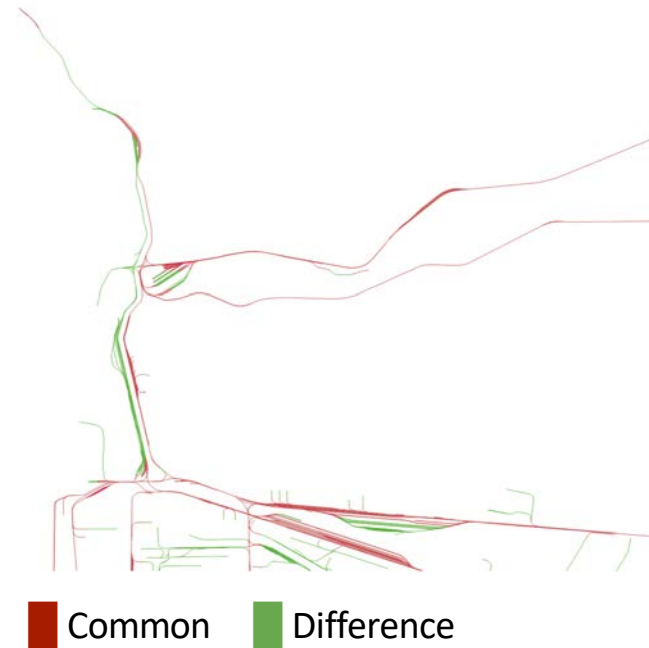


National Atlas of the United States
(45 KB)

Querying the Knowledge Graph

What railroads existed in 2000 but not in 2005?

```
PREFIX schema: <http://schema.org/>
select distinct ?a ?mapa
where {?a schema:geo ?geo.
      ?a schema:mapType ?mapa.
      ?mapa schema:releaseDate "2000".
      filter not exists{
        ?a schema:sameAs ?b.
        ?b schema:mapType ?mapb.
        ?mapb schema:releaseDate
"2005" .}
      minus{?a schema:contains ?x}}
```



Related Work

- Linking process
 - Map vector data conflation [Ruiz et al. 2011]
 - Feature matching between maps
 - No segmentation on feature vectors
 - Similarity measures of vector data [Sherif et al. 2015]
 - Detailed measurement for “SameAs” with point set
 - Trade-off: computationally expensive
- Creating the Linked Data
 - Integrating geospatial information using Linked Data [Usery et al. 2012, Sehgal et al. 2006, Yu et al. 2018]
 - Focuses on points of interest data, not vector

Discussion:

What's Special About Spatial for KGs

- Extraction of spatial data
 - Turning raster maps into vector data
- Linking of spatial data
 - Segmenting and linking vectors across maps
 - Analyzing relationships between orbits of satellites
- Aligning of spatial data
 - Ontologies that describe the spatial content
- Visualization
 - Visualization of the spatial data

Questions?

