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Building Semantic Descriptions of Linked Data

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Joint work with
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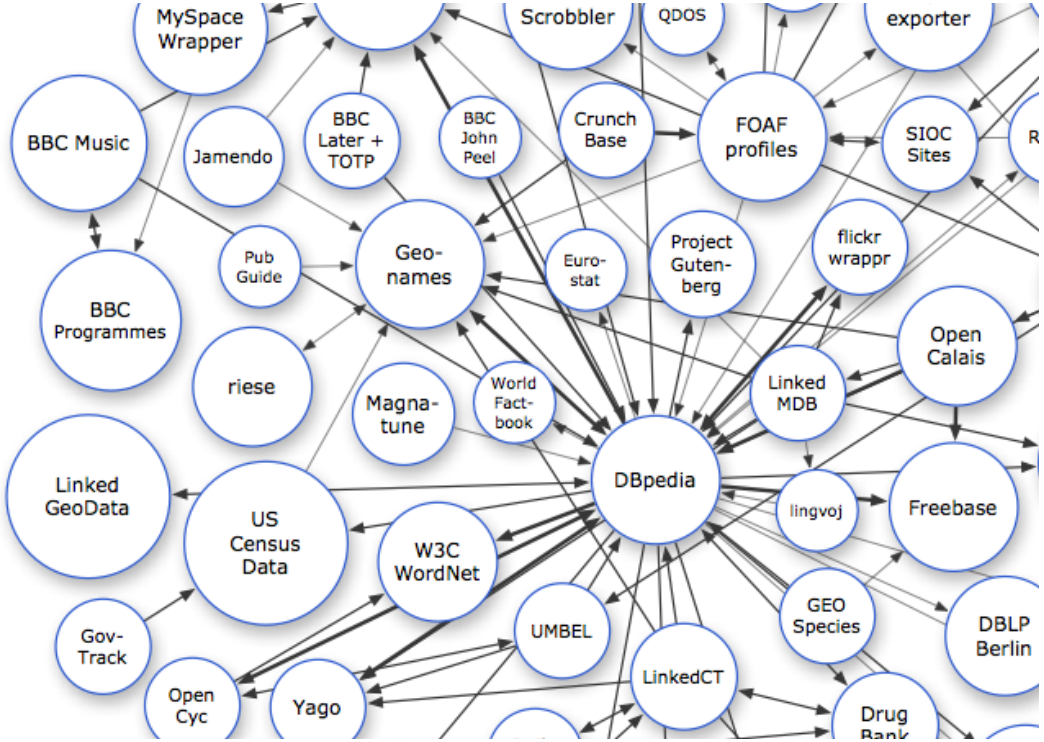
Linked Open Data and Services

- Vast collection of interlinked information
- Various sources and services with different schemas



Where do the Semantics Come From?

- Linked Open Data
  - Populated by manually linking or writing procedures that define the links across sources
  - But we don't know how the sources are related
  - In many cases there is no or very limited semantic descriptions of sources
- Linked Open Services
  - Manually constructed or built by wrapping existing Web services
  - Constructing the lifting and lowering rules that relate the services to existing ontologies is a difficult task
  - Even when done, it may only provide a partial description
    - e.g., descriptions of the inputs and outputs, but not the function of a service

Outline of the Talk

- Linked Open Data
  - Building and linking ontologies of linked data
- Linked Open Services
  - Building semantic web services from the Deep Web
- Discussion
  - Remaining challenges

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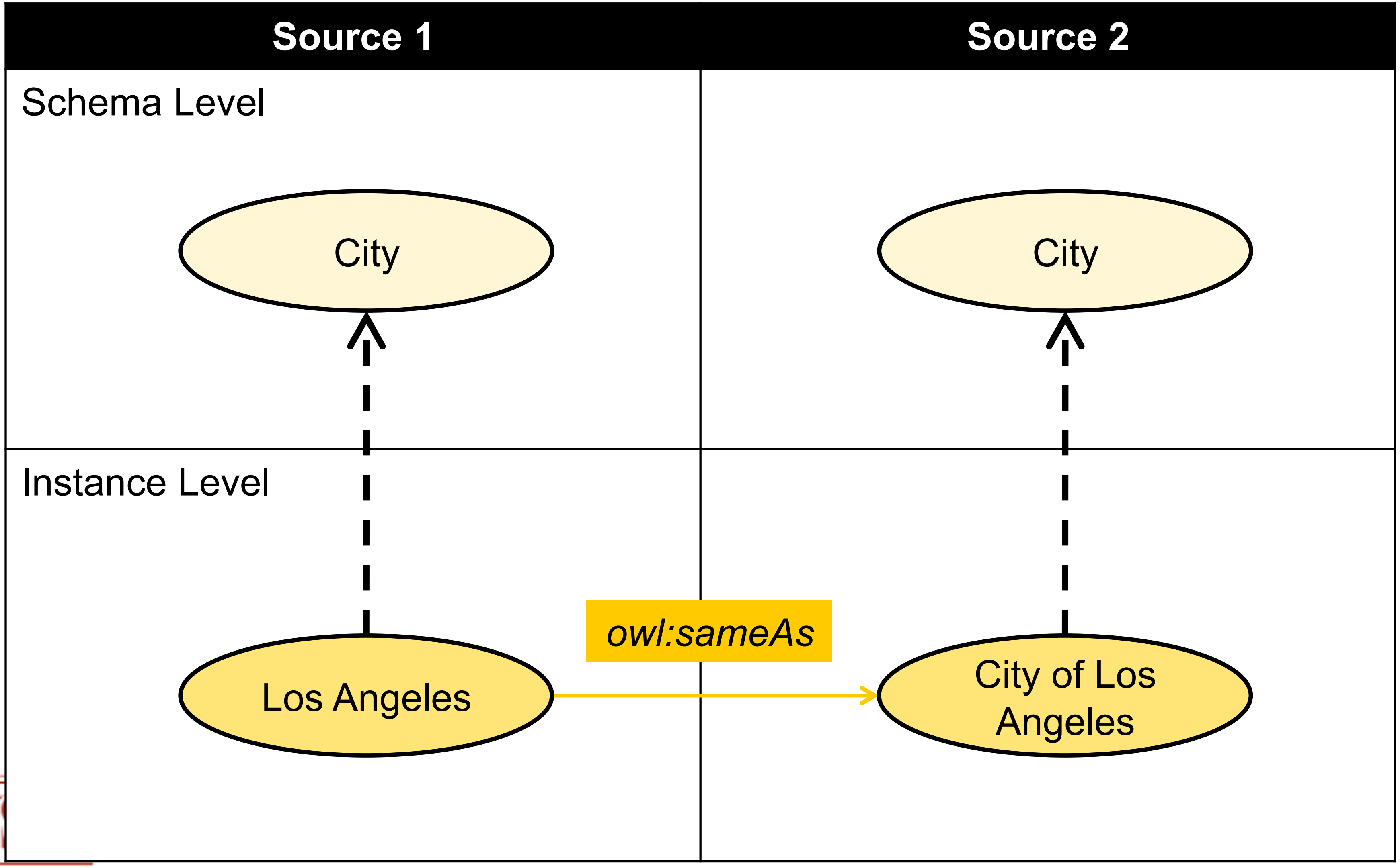
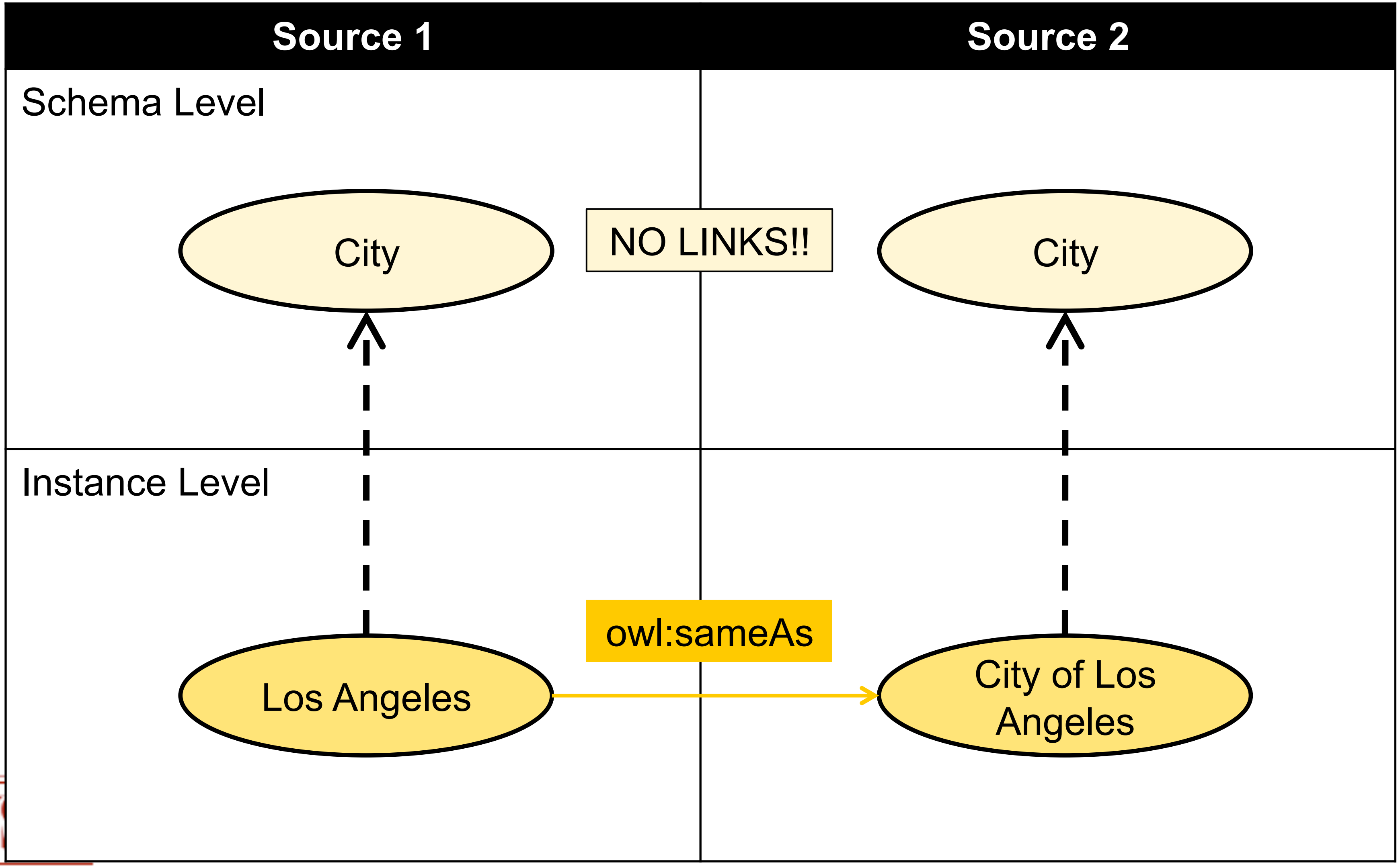
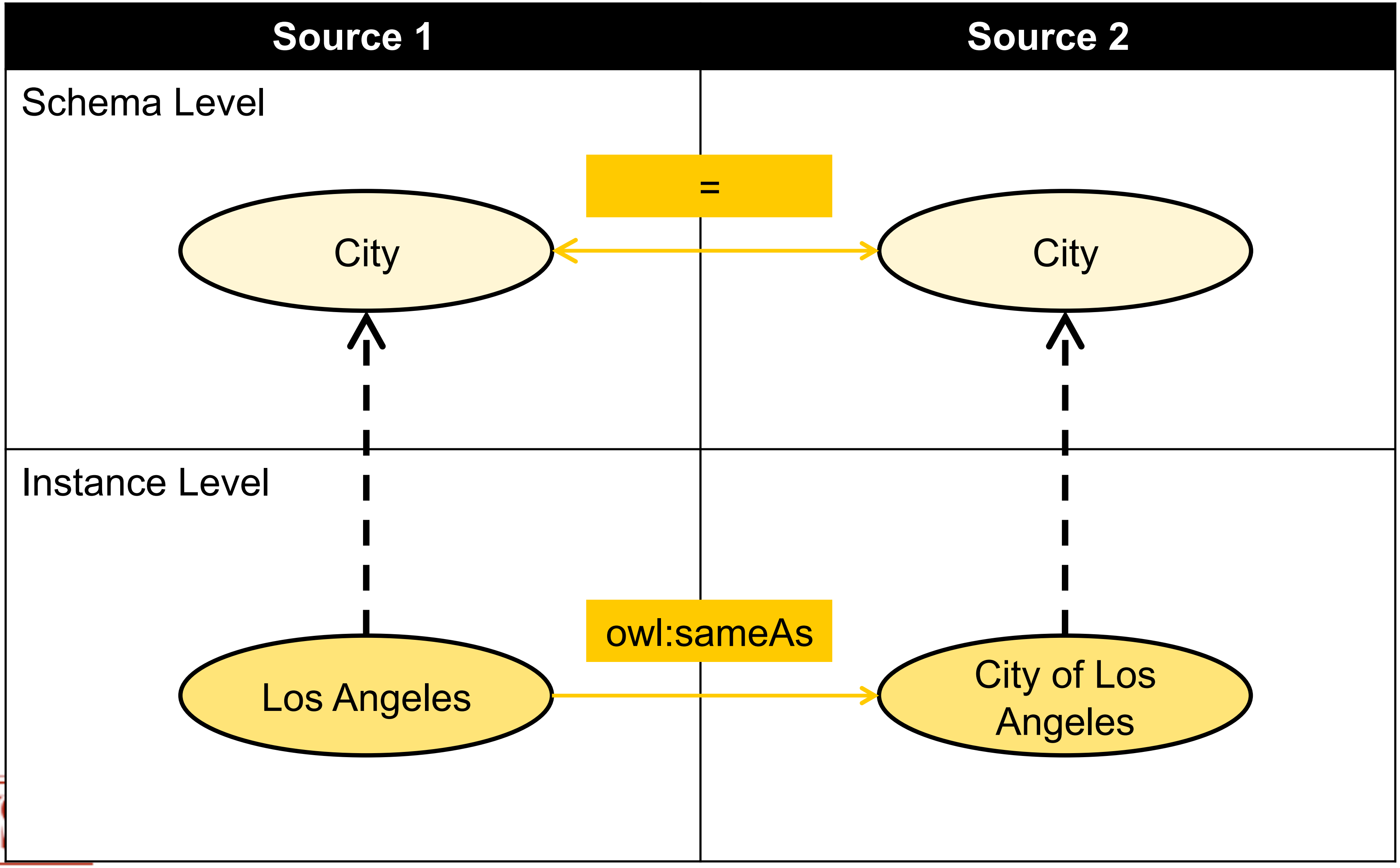
Building and linking ontologies of linked data [Parundekar et al., ISWC 2010]



Disjoint Schemas



Objective 1: Find Schema Alignments

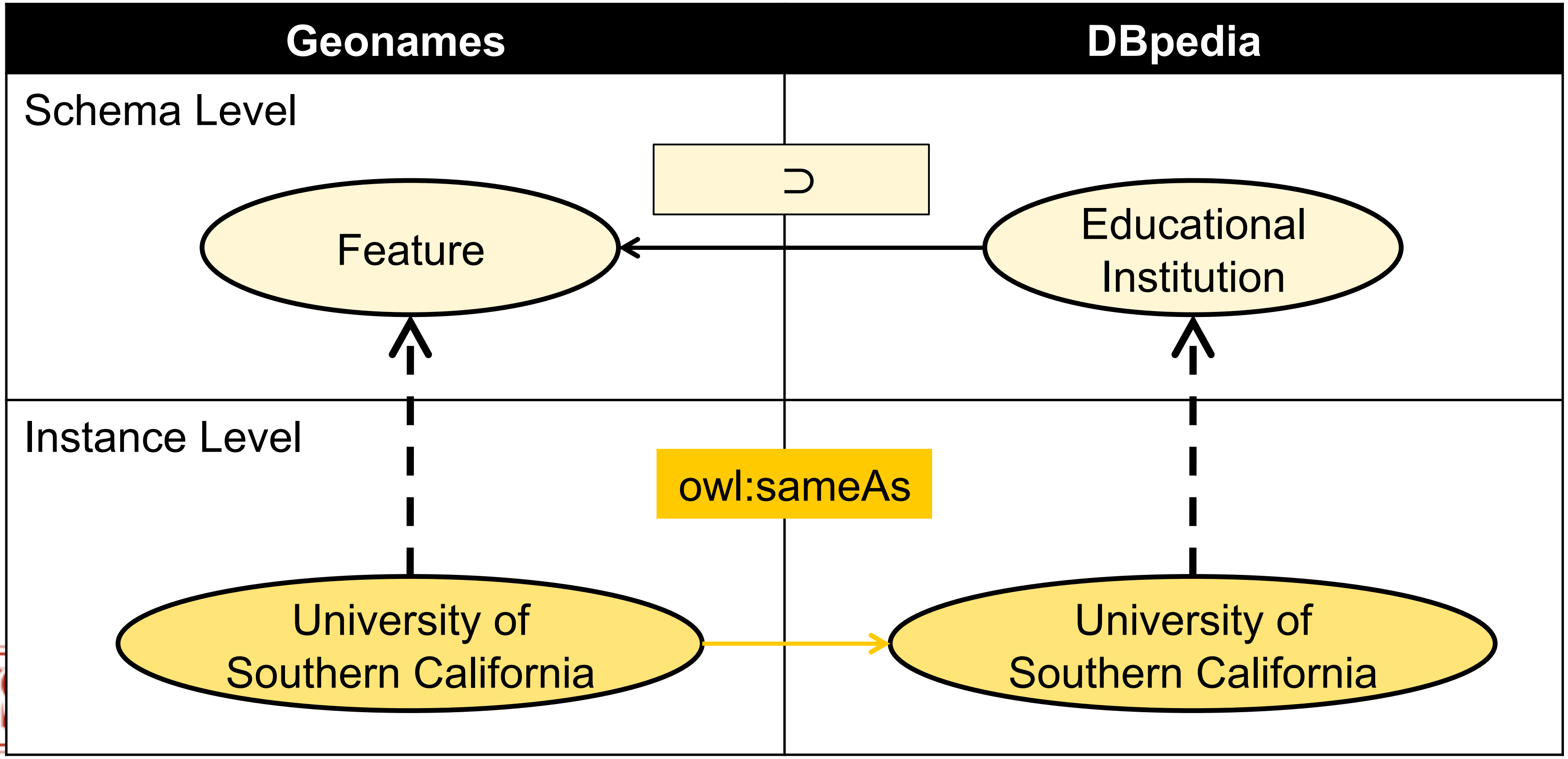


Ontologies of Linked Data

- Ontologies can be highly specialized
  - e.g. DBpedia has classes for *Educational Institutions, Bridges, Airports, etc.*
- Ontologies can be rudimentary
  - e.g. in Geonames all instances only belong to a single class – 'Feature'
  - Derived from RDBMS schemas from which Linked Data was generated
- There might not exist exact equivalences between classes in two sources

Traditional Alignments

- Only subset relations possible with difference in class specializations

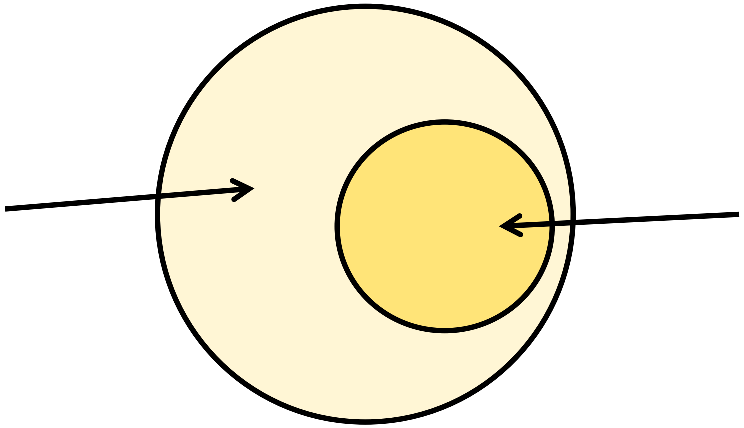


Restriction Classes

- A specialized class can be created by restricting the value of one or more properties

- The following Venn diagram explains a restriction class in Geonames with a restriction on the value of the *featureCode* property as 'S.SCH'

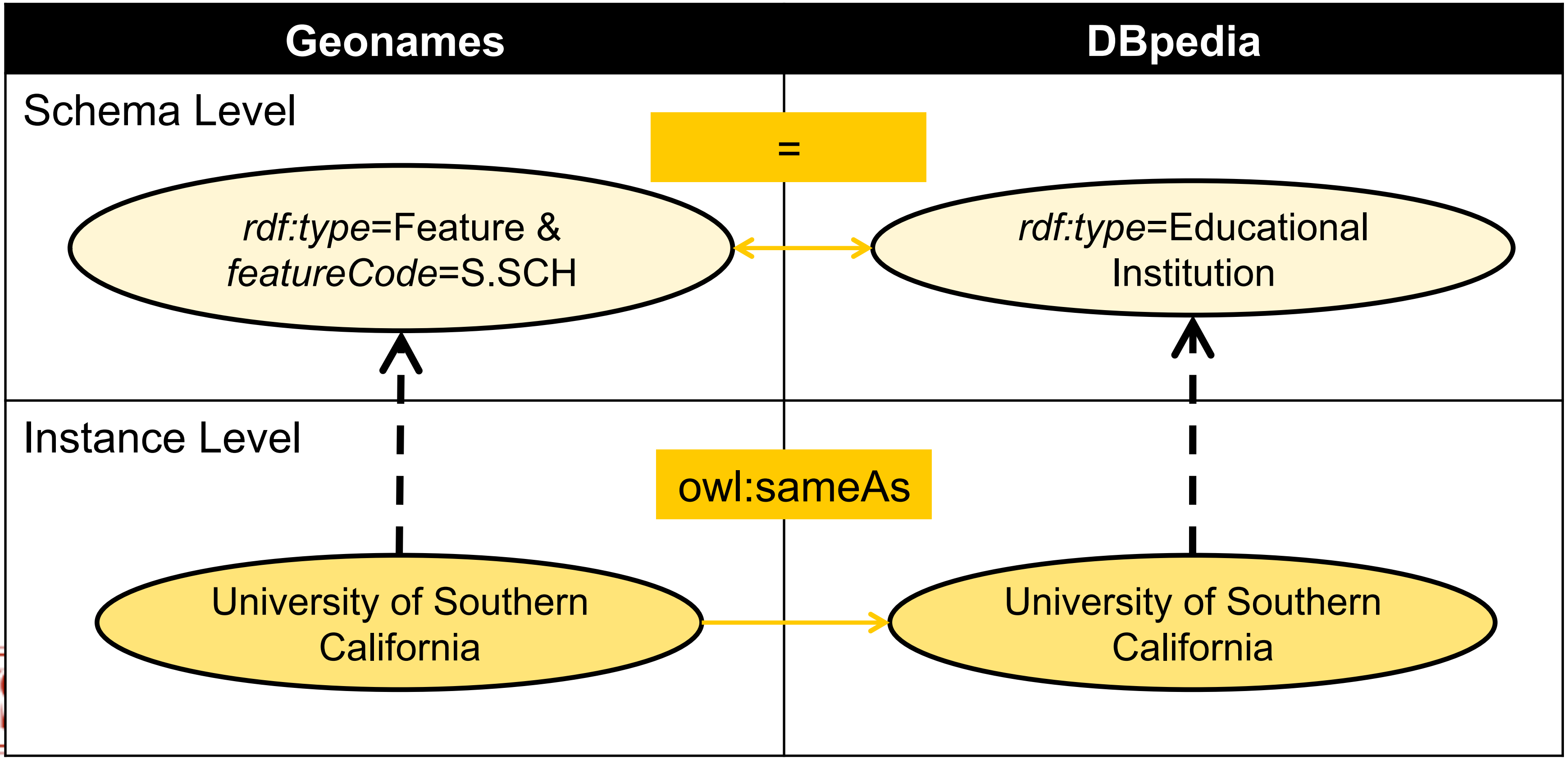
Set of all instances in Original Class - *rdf:type*=Feature



Set of all instances in Restricted Class - *rdf:type*=Feature & *featureCode*=S.SCH

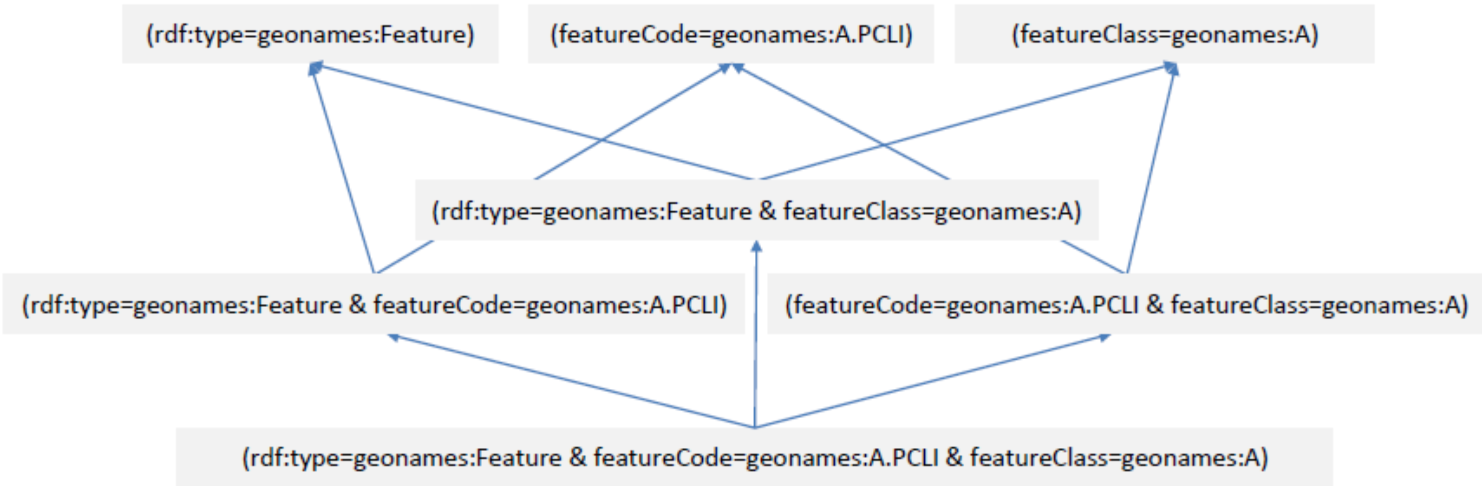
Objective 2: Find Alignments Between Restriction Classes

- Find and model specialized descriptions of classes



Nature of Restriction Classes

- Instances belonging to a restriction class also belong to parent restriction class
  - e.g. restrictions from Geonames below

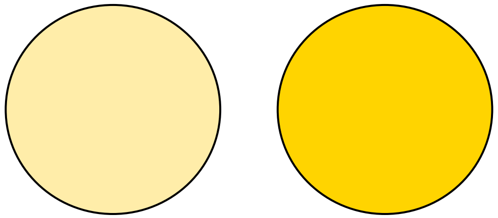
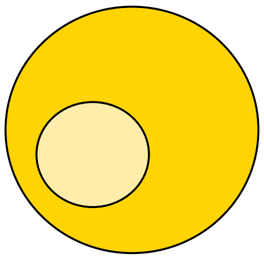
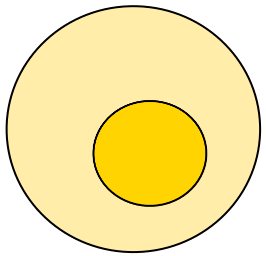


- This also results in a hierarchy in the alignments, which our algorithm exploits

Extensional Approach to Ontology Alignment

Represents set of instances belonging to ClassA

Represents set of instances belonging to ClassB

ClassA is disjoint from ClassB	ClassA is equivalent to ClassB
	
ClassA is subset of ClassB	ClassB is subset of ClassA
	

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Alignment Hypotheses

- An alignment hypothesis considers aligning
  - a restriction class from ontology O_1
  - another restriction class from ontology O_2
- Find relation between the two restriction classes
  - using extensional comparison on set of instances belonging to each restriction class
  - Use instance pair identifiers from pre-processing step (combination of URIs of linked instances)

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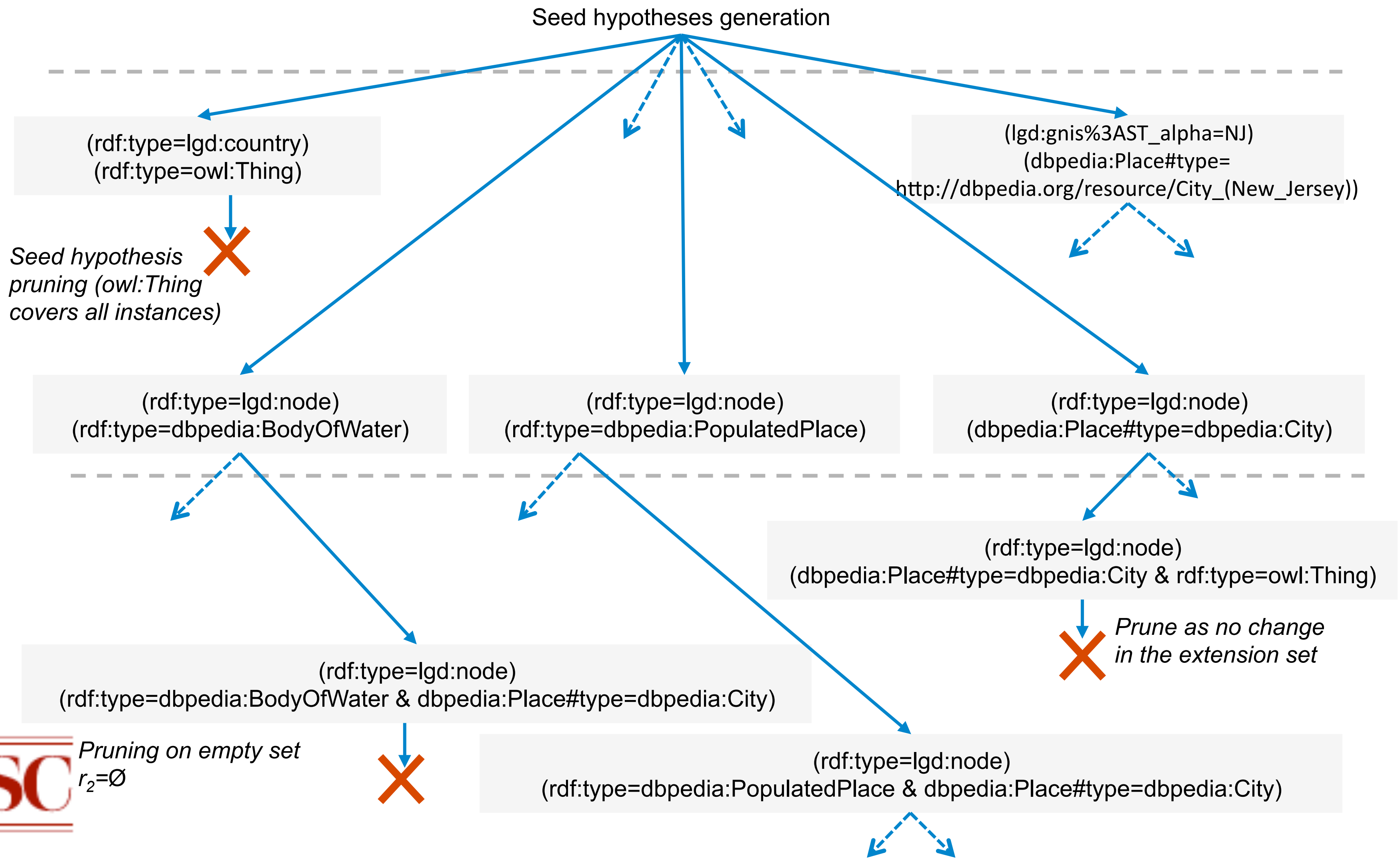
Exploration of Hypotheses Search Space



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Example Alignments from LinkedGeoData, Geonames, and DBpedia

#	LinkedGeoData *restriction*	DBpedia *restriction*	Relation
1	rdf:type=lgd:node	rdf:type=owl:Thing	$r_1 = r_2$
2	rdf:type=lgd:aerodrome	rdf:type=dbpedia:Airport	$r_1 = r_2$
3	rdf:type=lgd:island	rdf:type=dbpedia:Island	$r_1 = r_2$
4	lgd:gnis_%3AST_alpha=NJ	dbpedia:Place#type= http://dbpedia.org/resource/City_(New_Jersey)	$r_1 = r_2$
5	rdf:type=lgd:village	rdf:type=dbpedia:PopulatedPlace	$r_1 \subset r_2$
#	Geonames *restriction*	DBpedia *restriction*	Relation
6	geonames:featureClass=geonames:P	rdf:type=dbpedia:PopulatedPlace	$r_1 = r_2$
7	geonames:featureClass=geonames:H	rdf:type=dbpedia:BodyOfWater	$r_1 = r_2$
8	geonames:parentFeature=http://sws.geonames.org/3174618/	dbpedia:City_region=http://dbpedia.org/resource/Lombardy	$r_1 = r_2$
9	geonames:featureCode=geonames:S.SCH	rdf:type=dbpedia:EducationalInstitution	$r_1 = r_2$
10	geonames:featureCode=geonames:S.SCH & geonames:inCountry=geonames:US	rdf:type=dbpedia:EducationalInstitution	$r_1 = r_2$
11	geonames:featureCode=geonames:T.MT	rdf:type=dbpedia:Mountain	$r_1 \subset r_2$

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  - Building and linking ontologies of linked data
- Linked Open Services
  - Building semantic web services from the Deep Web
- Discussion
  - Remaining challenges

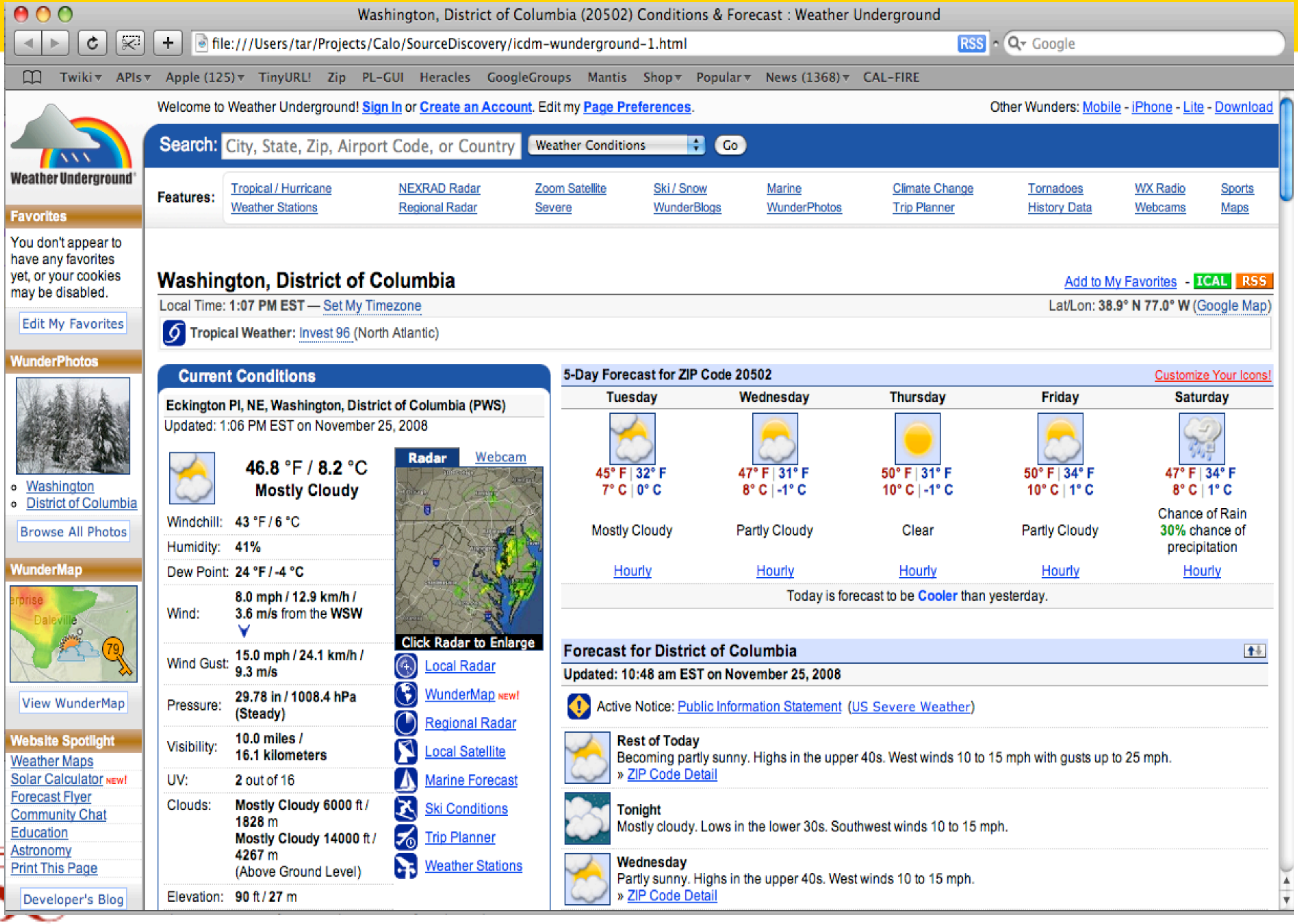
Building semantic web services from the Deep Web [Ambite et al., ISWC 2009]

- Automatically build semantic models for data and services available on the larger Web
- Construct models of these sources that are sufficiently rich to support querying and integration
  - Build models for the vast amount of structured and semi-structured data available
    - Not just web services, but also form-based interfaces
    - E.g., Weather forecasts, flight status, stock quotes, currency converters, online stores, etc.
  - Learn models for information-producing web sources and web services

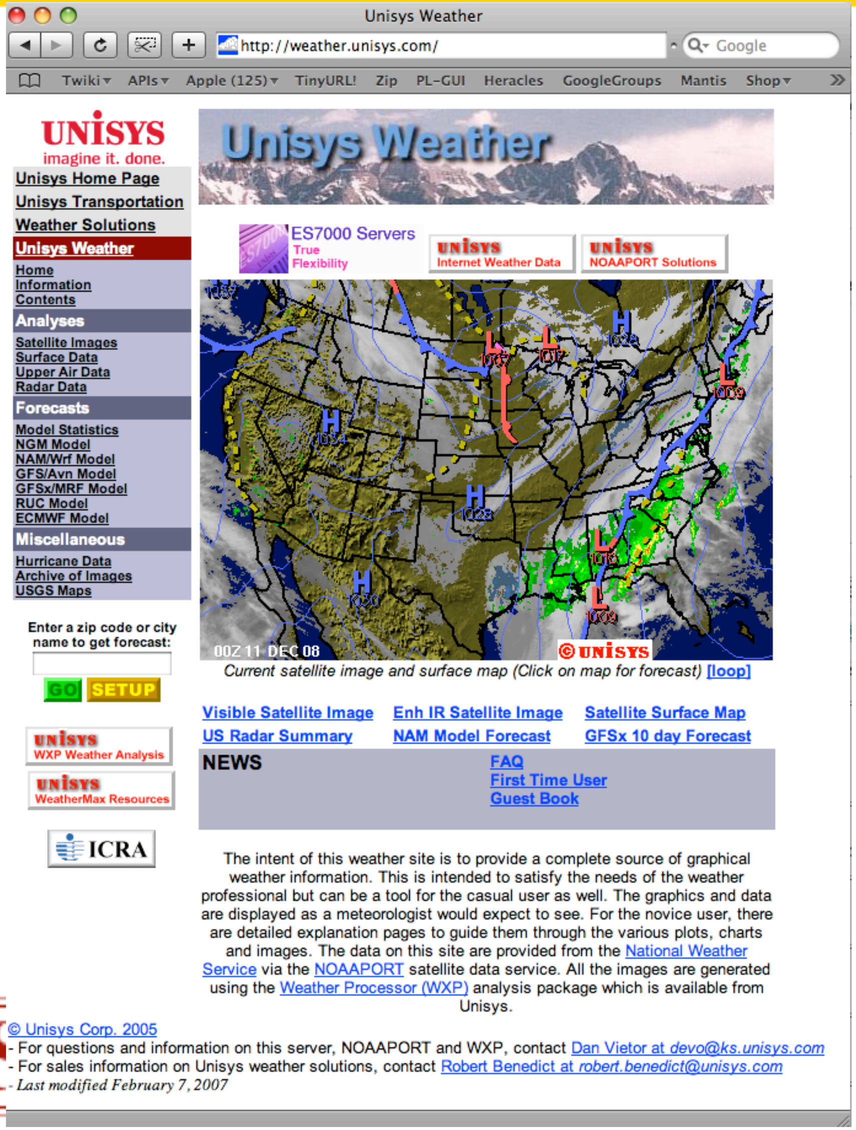
Approach

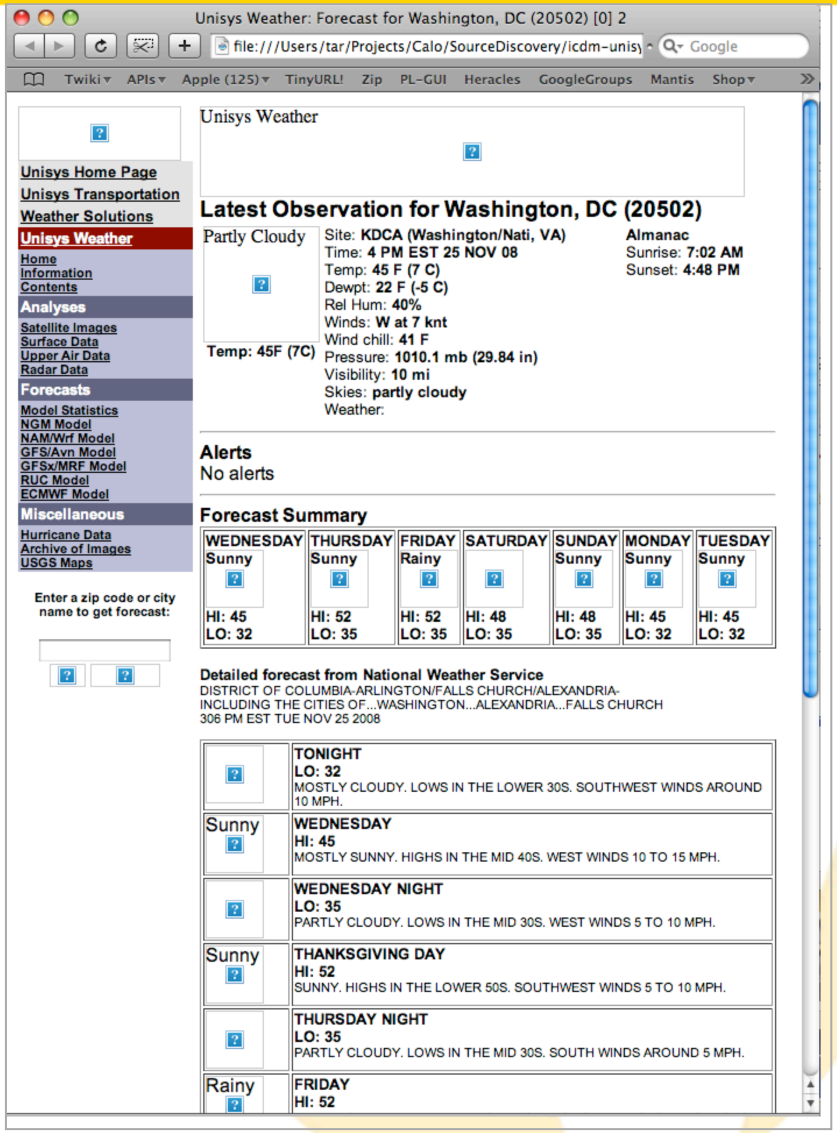
- Start with an some initial knowledge of a domain
  - Sources and semantic descriptions of those sources
- Automatically
  - Discover related sources
  - Determine how to invoke the sources
  - Learn the syntactic structure of the sources
  - Identify the semantic types of the data
  - Build semantic models of the source
  - Construct semantic web services

Seed Source

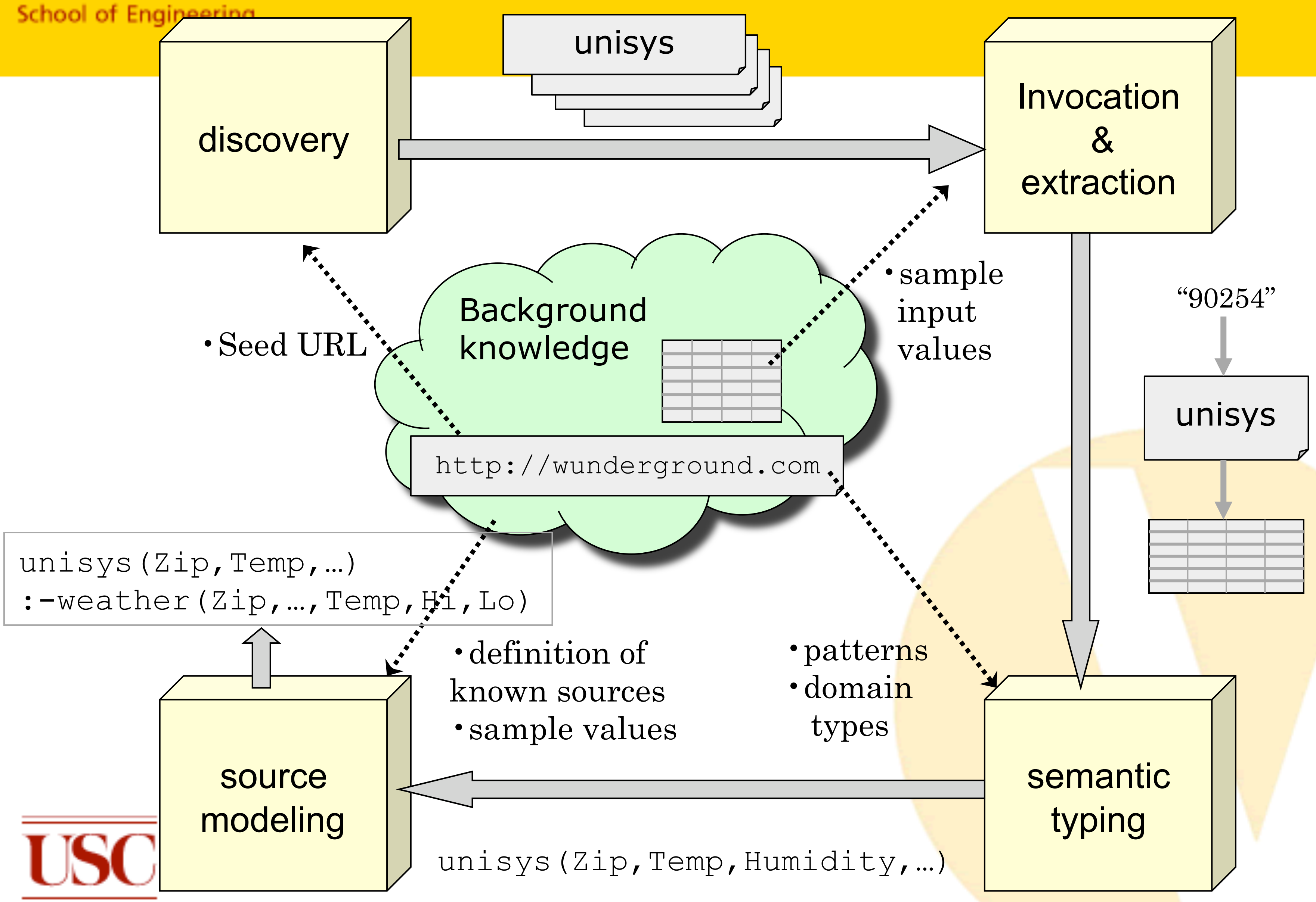

Washington, District of Columbia (20502) Conditions & Forecast : Weather Underground
file:///Users/tar/Projects/Calo/SourceDiscovery/icdm-wunderground-1.html
Twiki APIs Apple (125) TinyURL! Zip PL-GUI Heracles GoogleGroups Mantis Shop Popular News (1368) CAL-FIRE
Weather Underground
Welcome to Weather Underground! Sign In or Create an Account. Edit my Page Preferences.
Other Wunders: Mobile - iPhone - Lite - Download
Search: City, State, Zip, Airport Code, or Country
Weather Conditions
Go
Features:
Tropical / Hurricane
Weather Stations
NEXRAD Radar
Regional Radar
Zoom Satellite
Severe
Ski / Snow
WunderBlogs
Marine
WunderPhotos
Climate Change
Trip Planner
Tornadoes
History Data
WX Radio
Webcams
Sports
Maps
Favorites
You don't appear to have any favorites yet, or your cookies may be disabled.
Edit My Favorites
WunderPhotos
Washington
District of Columbia
Browse All Photos
WunderMap
View WunderMap
Website Spotlight
Weather Maps
Solar Calculator NEW!
Forecast Flyer
Community Chat
Education
Astronomy
Print This Page
Developer's Blog
Washington, District of Columbia
Add to My Favorites - ICAL RSS
Local Time: 1:07 PM EST — Set My Timezone
Lat/Lon: 38.9° N 77.0° W (Google Map)
Tropical Weather: Invest 96 (North Atlantic)
Current Conditions
Eckington Pl, NE, Washington, District of Columbia (PWS)
Updated: 1:06 PM EST on November 25, 2008
46.8 °F / 8.2 °C
Mostly Cloudy
Windchill: 43 °F / 6 °C
Humidity: 41%
Dew Point: 24 °F / -4 °C
Wind: 8.0 mph / 12.9 km/h / 3.6 m/s from the WSW
Wind Gust: 15.0 mph / 24.1 km/h / 9.3 m/s
Pressure: 29.78 in / 1008.4 hPa (Steady)
Visibility: 10.0 miles / 16.1 kilometers
UV: 2 out of 16
Clouds: Mostly Cloudy 6000 ft / 1828 m
Mostly Cloudy 14000 ft / 4267 m
(Above Ground Level)
Elevation: 90 ft / 27 m
Radar
Webcam
Click Radar to Enlarge
Local Radar
WunderMap NEW!
Regional Radar
Local Satellite
Marine Forecast
Ski Conditions
Trip Planner
Weather Stations
5-Day Forecast for ZIP Code 20502
Customize Your Icons!
Tuesday
45° F | 32° F
7° C | 0° C
Mostly Cloudy
Hourly
Wednesday
47° F | 31° F
8° C | -1° C
Partly Cloudy
Hourly
Thursday
50° F | 31° F
10° C | -1° C
Clear
Hourly
Friday
50° F | 34° F
10° C | 1° C
Partly Cloudy
Hourly
Saturday
47° F | 34° F
8° C | 1° C
Chance of Rain
30% chance of precipitation
Hourly
Today is forecast to be Cooler than yesterday.
Forecast for District of Columbia
Updated: 10:48 am EST on November 25, 2008
Active Notice: Public Information Statement (US Severe Weather)
Rest of Today
Becoming partly sunny. Highs in the upper 40s. West winds 10 to 15 mph with gusts up to 25 mph.
» ZIP Code Detail
Tonight
Mostly cloudy. Lows in the lower 30s. Southwest winds 10 to 15 mph.
Wednesday
Partly sunny. Highs in the upper 40s. West winds 10 to 15 mph.
» ZIP Code Detail

Automatically Discover and Build Semantic Web Services for Related Sources



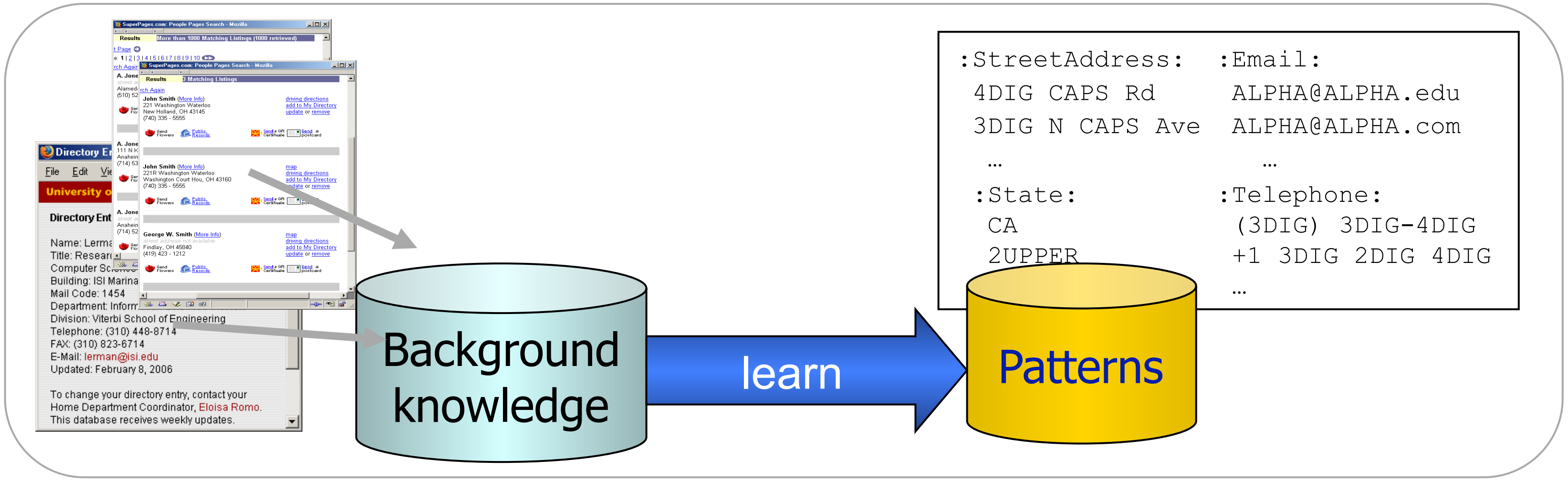


Integrated Approach



Semantic Typing [Lerman, Plangprasopchok, & Knoblock]

✓Idea: Learn a model of the content of data and use it to recognize new examples

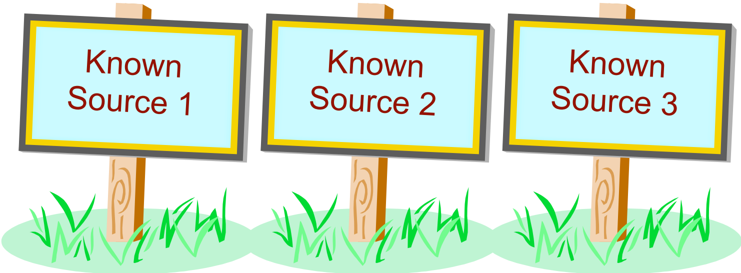


Person	Address	Work
E Lewis	3518 Hilltop Rd	(419) 531 - 0504
Andrew Lewis	3543 Larchmont Pkwy	(518) 474 - [illegible]
C. S. Lewis	555 Willow Run Dr	(612) 578 [illegible]
Carmen Jones	355 Morgan Ave N	(612) 522 [illegible]
John Jones	3574 Brookside Rd	(555) 531 - 9566
Location	**State_prov**	**Postal_code**
Toledo	OH	64325-3000
Toledo	OH	64356
Seattle	WA	8422
Seattle	WA	8435
Omaha	NE	52456-6444

label

:FullName:	:StreetAddress:	:Telephone:
E Lewis	3518 Hilltop Rd	(419) 531 - 0504
[illegible]drew Lewis	3543 Larchmont Pkwy	(518) 474 - 4799
[illegible] Lewis	555 Willow Run Dr	(612) 578 - 5555
[illegible]rmen Jones	355 Morgan Ave N	(612) 522 - 5555
John Jones	3574 Brookside Rd	(555) 531 - 9566
:City:	**:State:**	**:Zipcode:**
Toledo	OH	64325-3000
Toledo	OH	64356
Seattle	WA	8422
Seattle	WA	8435
Omaha	NE	52456-6444

Inducing Source Definitions

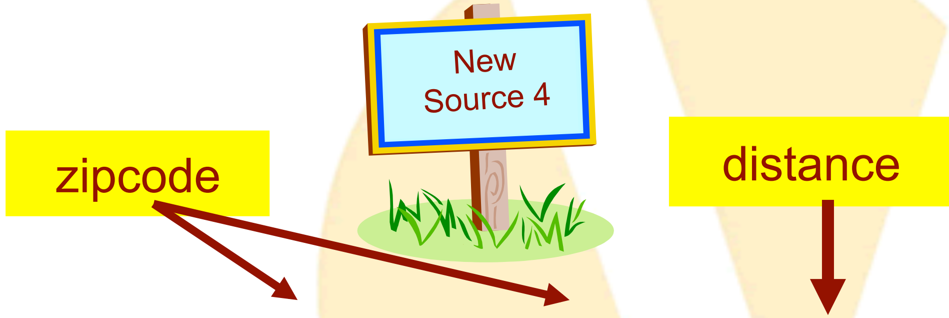


source1($zip, lat, long) :-
  centroid(zip, lat, long).

source2($lat1, $long1, $lat2, $long2, dist) :-
  greatCircleDist(lat1, long1, lat2, long2, dist).

source3($dist1, dist2) :-
  convertKm2Mi(dist1, dist2).

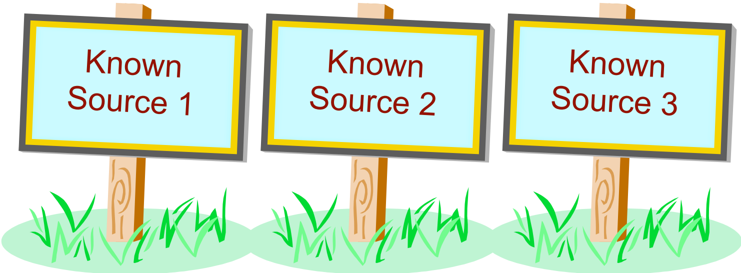
- Step 1: classify input & output semantic types



source4($startZip, $endZip, separation)

Generating Plausible Definition

[Carman & Knoblock, 2007]



source1($zip, lat, long) :-
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- Step 1: classify input & output semantic types
- Step 2: generate plausible definitions

```
source4($zip1, $zip2, dist):-
   source1(zip1, lat1, long1),
   source1(zip2, lat2, long2),
   source2(lat1, long1, lat2, long2, dist2),
   source3(dist2, dist).
```

```
source4($zip1, $zip2, dist):-
   centroid(zip1, lat1, long1),
   centroid(zip2, lat2, long2),
   greatCircleDist(lat1, long1, lat2, long2, dist2),
   convertKm2Mi(dist1, dist2).
```

Invoke and Compare the Definition

- Step 1: classify input & output semantic types
- Step 2: generate plausible definitions
- Step 3: invoke service & compare output

```
source4($zip1, $zip2, dist):-
    source1(zip1, lat1, long1),
    source1(zip2, lat2, long2),
    source2(lat1, long1, lat2, long2, dist2),
    source3(dist2, dist).
```

```
source4($zip1, $zip2, dist):-
   centroid(zip1, lat1, long1),
   centroid(zip2, lat2, long2),
   greatCircleDist(lat1, long1, lat2, long2,dist2),
   convertKm2Mi(dist1, dist2).
```

match

$zip1	$zip2	dist *(actual)*	dist *(predicted)*
80210	90266	842.37	843.65
60601	15201	410.31	410.83
10005	35555	899.50	899.21

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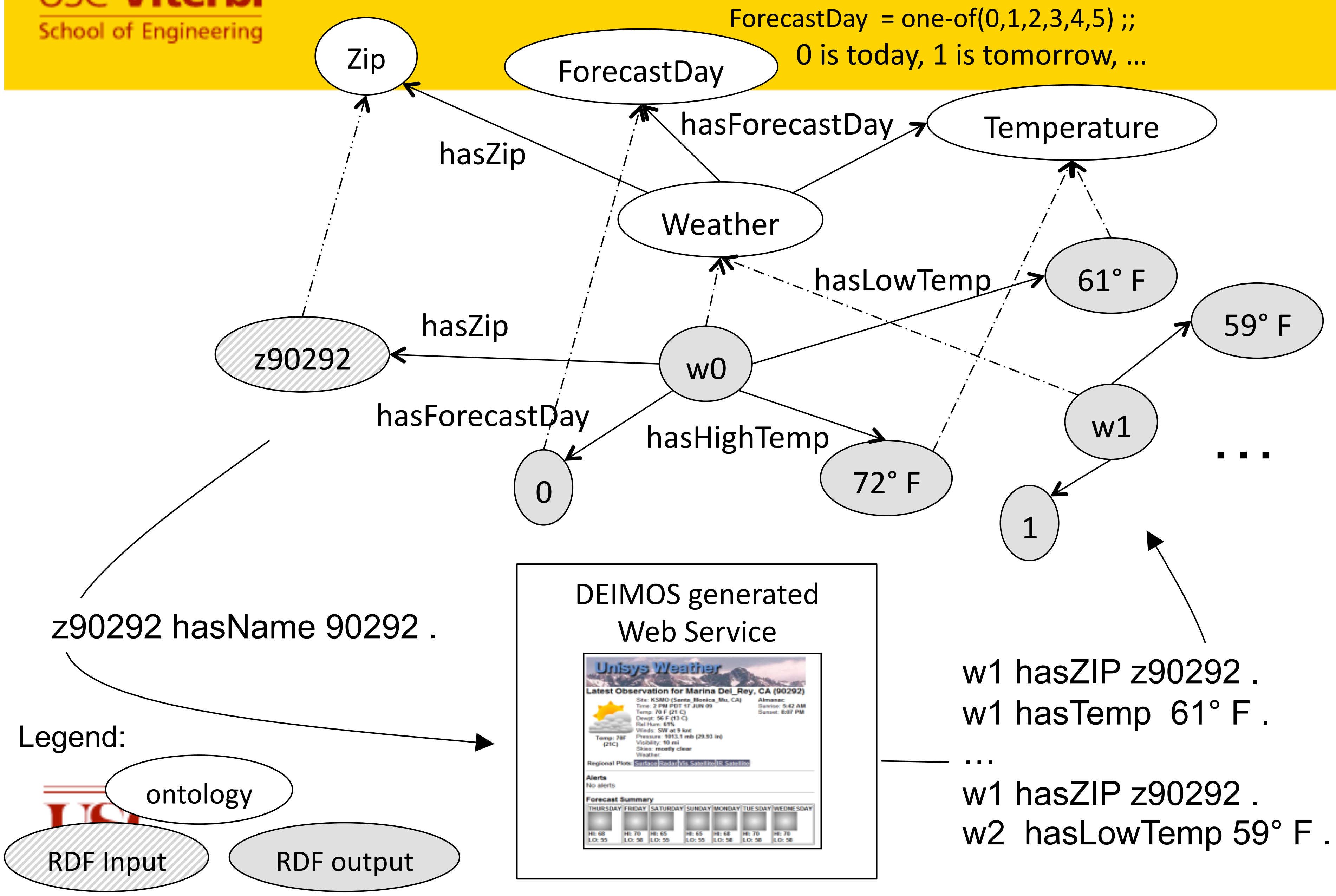
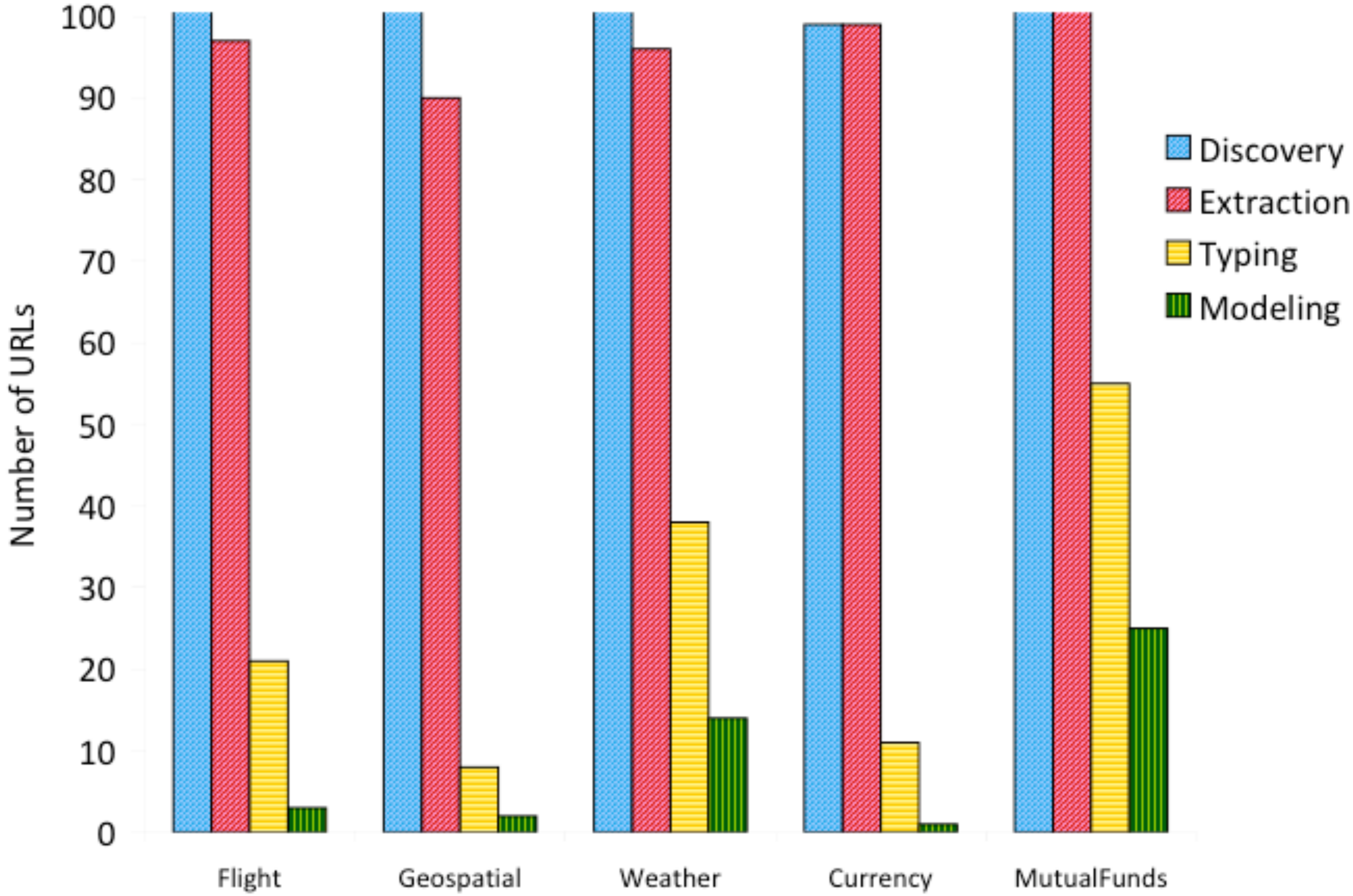
Constructing Semantic Web Services



Evaluation on Multiple Domains



Accuracy of the Models

domain	Precision	Recall	F_1-measure
weather	0.64	0.29	0.39
geospatial	1.00	0.86	0.92
flights	0.69	0.35	0.46
currency	1.00	1.00	1.00
mutualfund	0.72	0.30	0.42

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Discussion

- Initial work described here just scratches the surface of the problem
  - Goal is to both populate the Web of linked data and have rich semantic models of the data
  - Building semantic descriptions of linked open data will allow us to better understand the available sources and use the sources in a broad range of applications
  - Methods for automatically constructing linked open services will improve the coverage and quality of the sources available

Some Challenges

- Linked Open Data
  - How do we build build an overall class hierarchy for a source
  - How do the relations map across sources
  - What do we do about missing and extraneous links
- Linked Open Services
  - How do we improve the accuracy of the learned semantic descriptions
  - How can we learn semantic descriptions that go beyond the current sources
  - How do we learn mappings between enumerated types (e.g., “Arrived” vs. “Landed”)