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Web-Based Learning

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Joint work with
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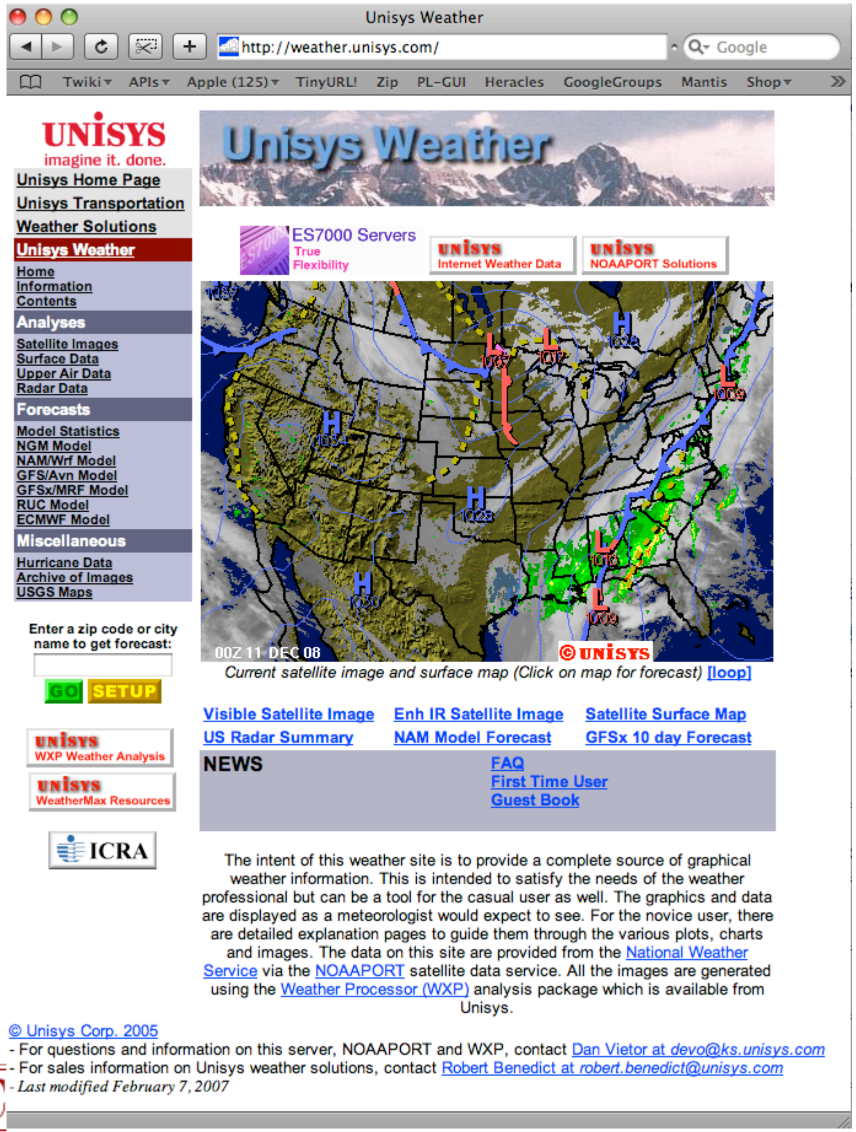
Introduction

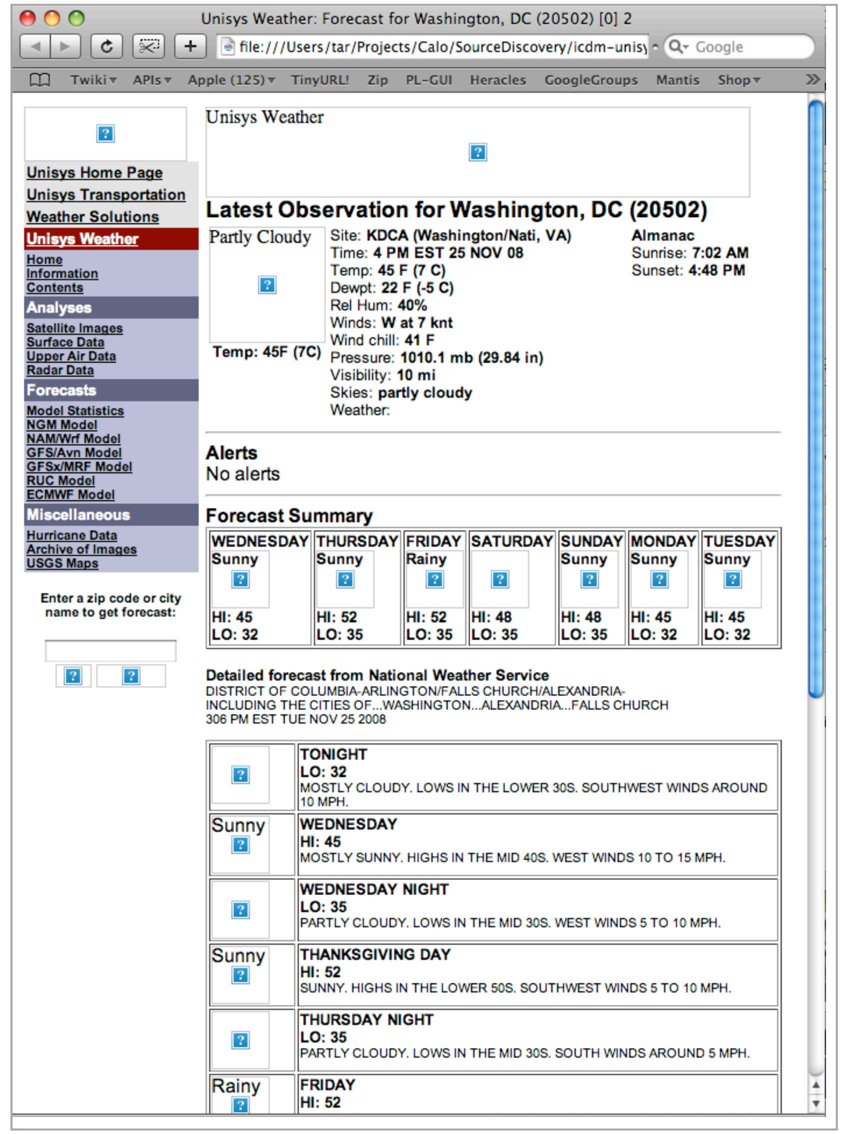
- Problem
  - Web sources and services are designed for people, not machines
  - Limited or no description of the information provided by these sources
  - This makes it hard, if not impossible to find, retrieve and integrate the vast amount of structured data available
    - *Weather sources, geocoders, stock information, currency converters, online stores, etc.*
- Approach
  - Start with an some initial knowledge of a domain
    - *Sources and semantic descriptions of those sources*
  - Automatically
    - *Discover related sources*
    - *Learn the syntactic structure of the sources*
    - *Build semantic models of the source*
    - *Validate the correctness of the results*

Seed Source

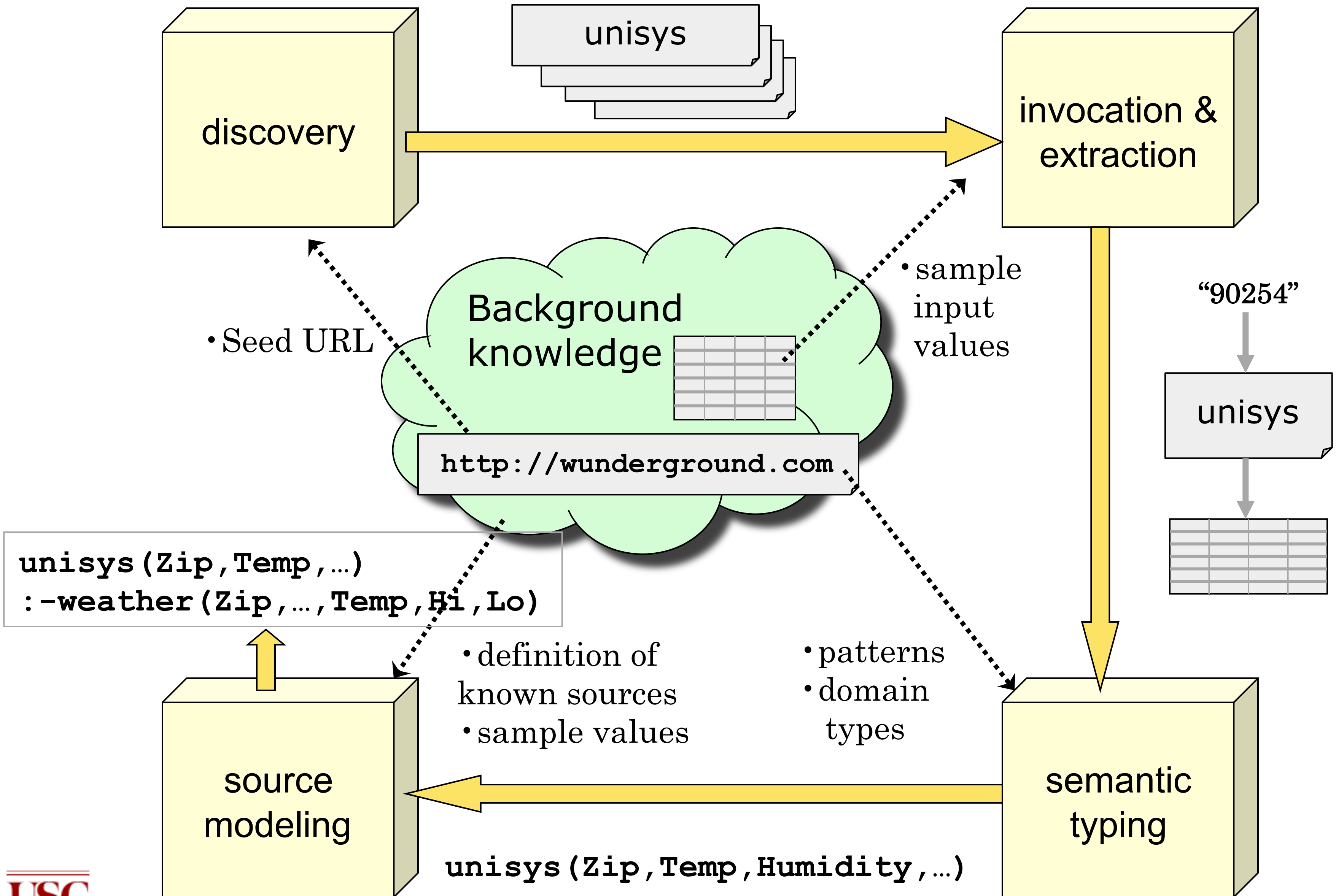
Washington, District of Columbia (20502) Conditions & Forecast : Weather Underground
file:///Users/tar/Projects/Calo/SourceDiscovery/icdm-wunderground-1.html
Welcome to Weather Underground! Sign In or Create an Account. Edit my Page Preferences.
Search: City, State, Zip, Airport Code, or Country
Weather Conditions
Washington, District of Columbia
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
5-Day Forecast for ZIP Code 20502
Tuesday 45° F | 32° F 7° C | 0° C Mostly Cloudy
Wednesday 47° F | 31° F 8° C | -1° C Partly Cloudy
Thursday 50° F | 31° F 10° C | -1° C Clear
Friday 50° F | 34° F 10° C | 1° C Partly Cloudy
Saturday 47° F | 34° F 8° C | 1° C Chance of Rain 30% chance of precipitation
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.
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.

Automatically Discover and Model a Source in the Same Domain





Approach



discovery
unisys
invocation & extraction
Background knowledge
http://wunderground.com
• Seed URL
• sample input values
“90254”
unisys
unisys(Zip,Temp,…)
:-weather(Zip,…,Temp,Hi,Lo)
• definition of known sources
• sample values
• patterns
• domain types
source modeling
semantic typing
unisys(Zip,Temp,Humidity,…)

Outline

- Discovering sources using social annotations
- Discovering the structure of sources
- Learning semantic types of the source data
- Learning semantic models of the sources
- Experimental Results
- Discussion

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Learning Concepts from Social Annotation (Tags)

By sparky2000

By A lion Rohrs

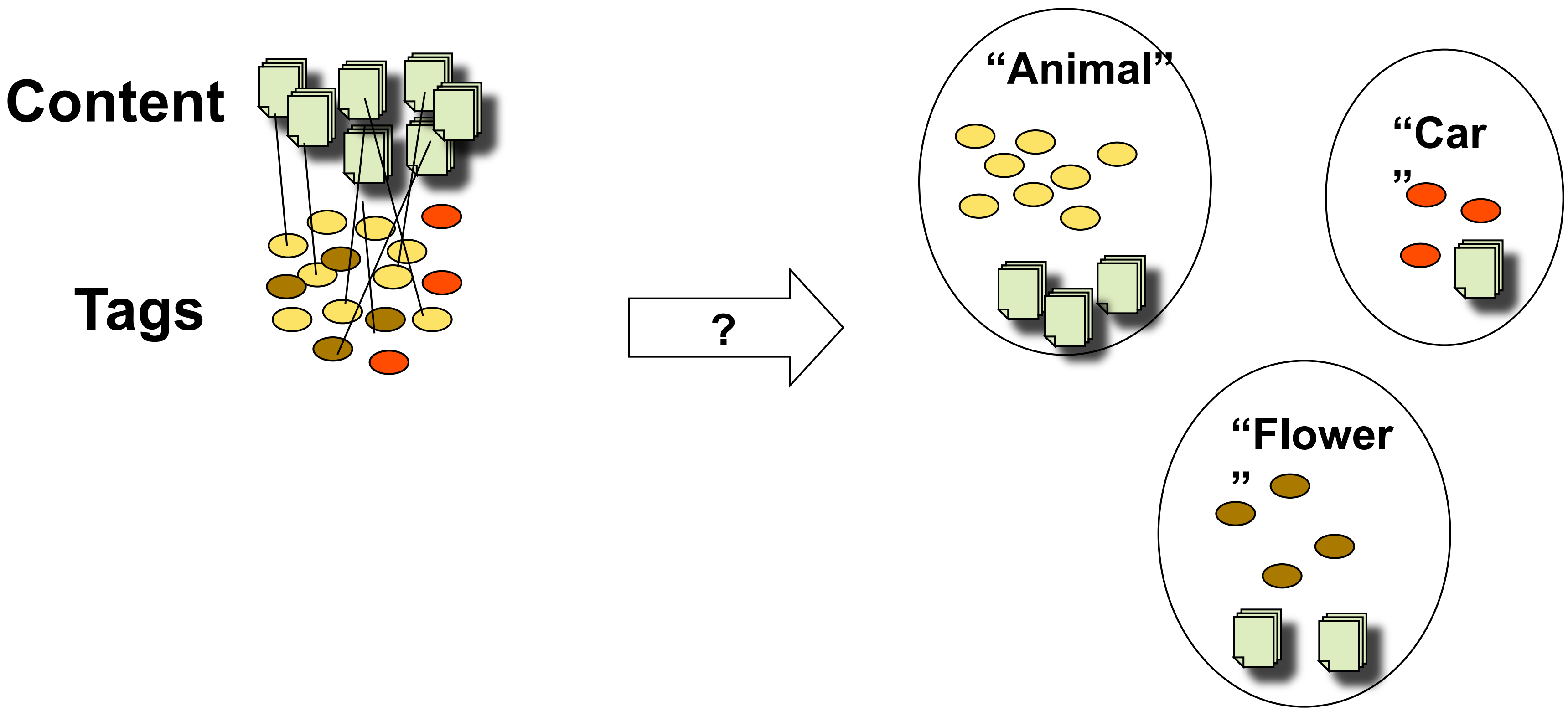
“Black” + “Jaguar”

= ?

Animal

Car

Goal

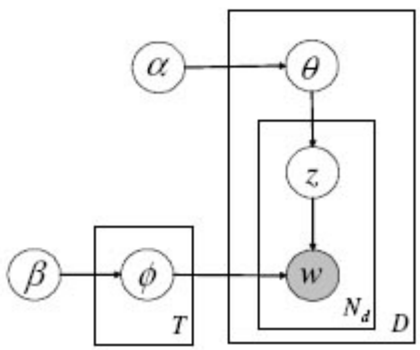


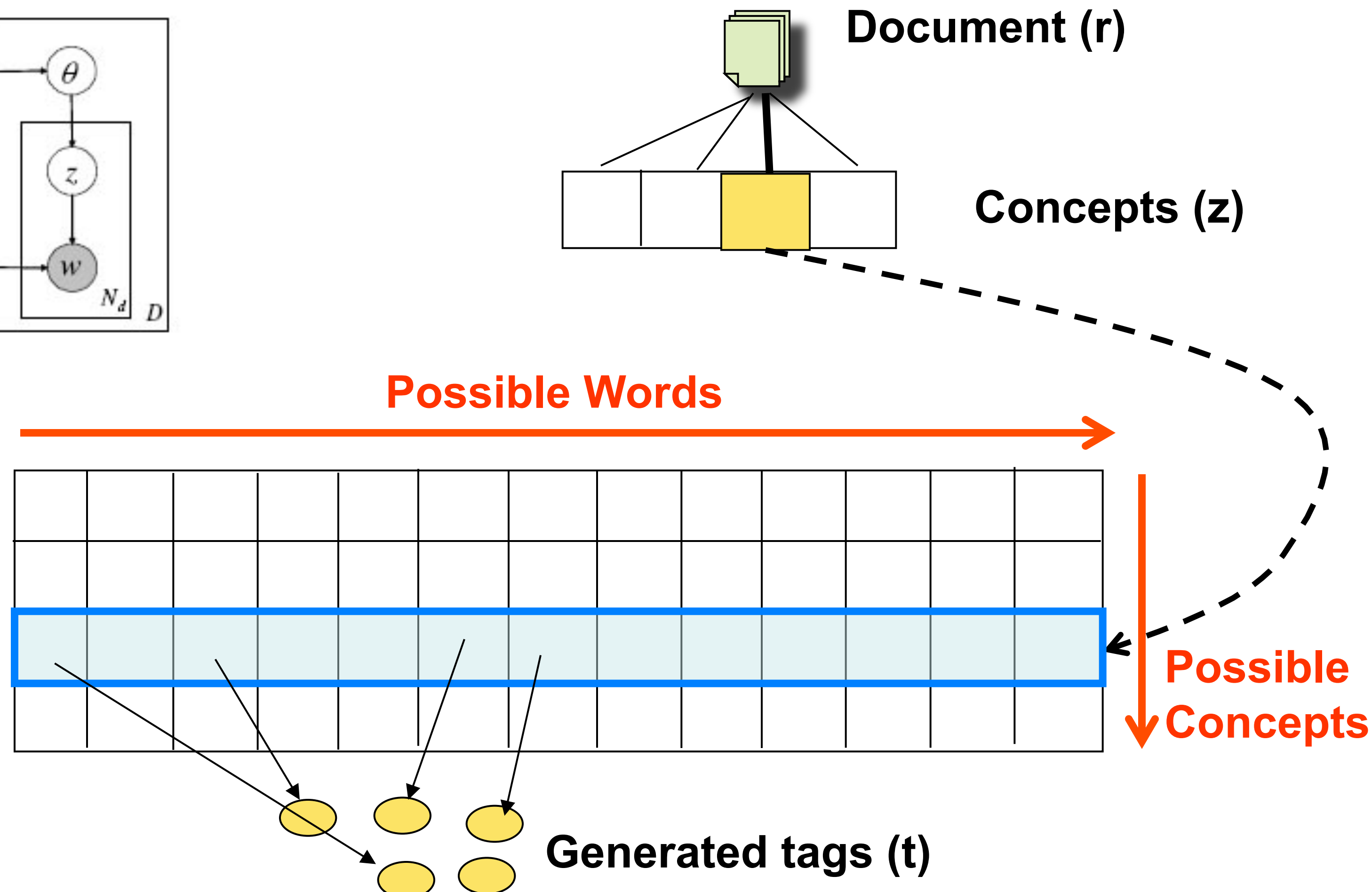
Grouping semantically related tags and content

A group ~ A concept

A stochastic process of tag generation

PLSA (Hofmann99);
LDA (Blei03+)

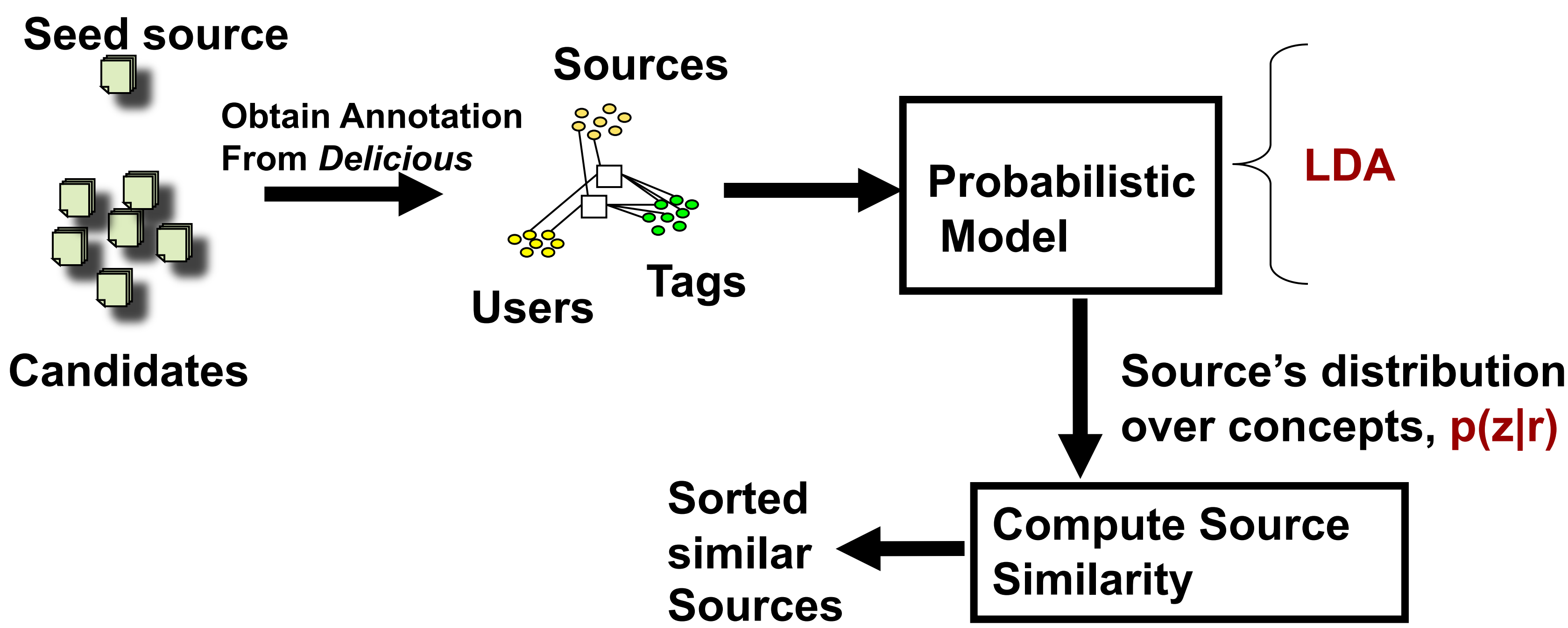




A data point (tuple) <r,t,z>

Exploiting Social Annotations for Resource Discovery

- Simplified resource discovery task : "*given a seed source, find other most similar sources*"



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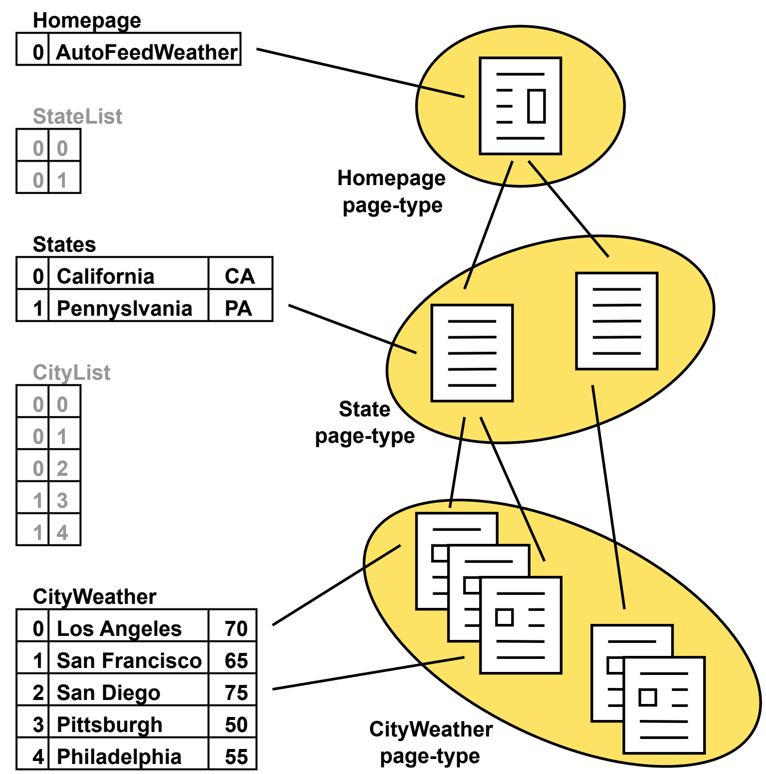
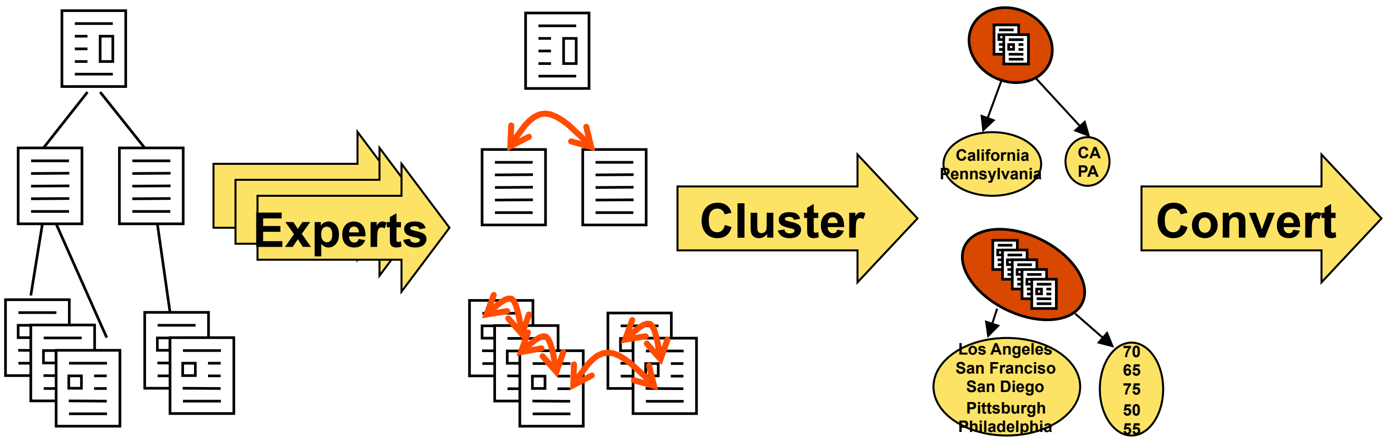
Discovering Web Structure

- Goal:
  - Model Web sources that generate pages dynamically in response to a query
    - Find the relational data underlying a semi-structured web site
  - *Generate a page template that can be used to extract data on new pages*
- Approach
  - *Site extraction*
    - Exploit the common structure within a web site
  - Take advantage of multiple structures
    - HTML structure, page layout, links, data formats, etc.



Overview



Homepage

0	AutoFeedWeather

States

0	California	CA
1	Pennysvlania	PA

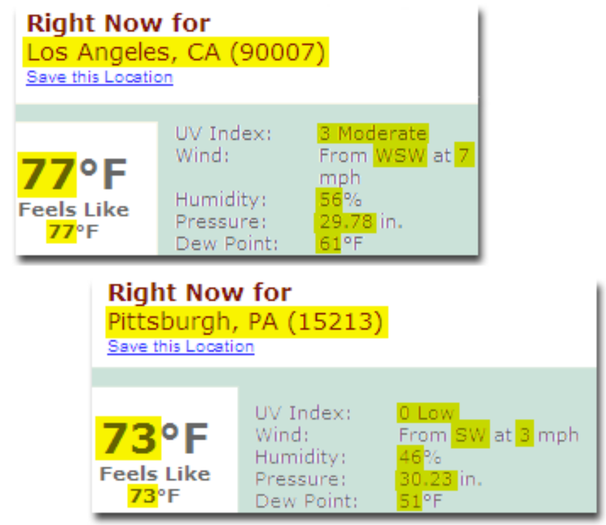
CityWeather

0	Los Angeles	70
1	San Francisco	65
2	San Diego	75
3	Pittsburgh	50
4	Philadelphia	55

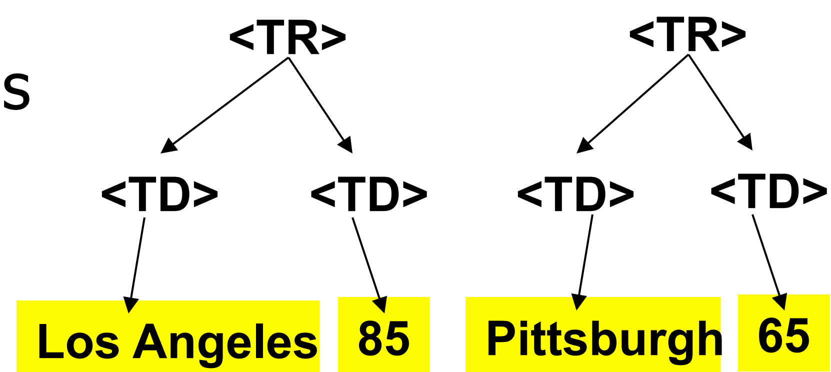
Web Site — **Page & Data Hypotheses** — **Page & Data Clusters** — **Site and Page Structure**

Sample Experts

- Page Templates
  - Similar pages contain common sequences of substrings



- HTML Structure
  - List rows are represented as repeating HTML structures



Extracting Data

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Pages

```
<td valign="top" width="14%">
```

```
<td valign="top" width="14%">
 <font face="Arial, Helvetica, sans-serif">
  <small><b>FRIDAY<br>
  <img src="images/Sun-s.png" alt="Sunny"><br>
  HI: 65<br>LO: 52<br></b></small></font></td>
<td valign="top" width="14%">
 <font face="Arial, Helvetica, sans-serif">
 <small><b>SATURDAY<br>
 <img src="images/Rain-s.png" alt="Rainy"><br>
 HI: 60<br>LO: 48<br></b></small></font></td>
```

Hypotheses

- **group_member (FRIDAY, SATURDAY)**
- **group_member (Sunny, Rainy)**
- **same_html_context (65, 60)**
- **vertically_aligned (Sun, Rain)**
- **two_digit_number (65, 52, 60, 48)**
- …

Clusters

FRIDAY SATURDAY

65 52 60 48

Rainy

Extracted Data

FRIDAY	Sun	Sunny	65	52
SATURDAY	Rain	Rainy	60	48

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Fetch TECHNOLOGIES

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Learning Patterns to Recognize Semantic Types

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- Domain-independent token-level language to represent the structure of data as patterns
  - Token is a string or a general type
    - *90202 is a specific token*
    - *5DIGIT number is a general type*
  - Pattern is a sequence of tokens
    - *E.g., Phone numbers*

Sample values	Patterns
`310 448-8714`	
`310 448-8775`	[310 448 – 4DIGIT]
`212 555-1212`	[3DIGIT 3DIGIT – 4DIGIT]

- Efficiently learn patterns from examples of semantic types
- Score the match between a type (patterns) and data

Weather Data Types

Sample values

- PR-TempF
  88 F
  57°F
  82 F ...

- PR-Visibility
  8.0 miles
  10.0 miles
  4.0 miles
  7.00 mi
  10.00 mi

- PR-Zip
  07036
  97459
  02102

Patterns

- PR-TempF
  [88, F]
  [2DIGIT, F]
  [2DIGIT, °, F]

- PR-Visibility
  [10, ., 0, miles]
  [10, ., 00, mi]
  [10, ., 00, mi, .]
  [1DIGIT, ., 00, mi]
  [1DIGIT, ., 0, miles]

- PR-Zip
  [5DIGIT]

Labeled Columns of Target Source Unisys

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Column	4	18	25	15	87
Type	**PR-Zip**	**PR-TempF**	**PR-Humidity**	**PR-Sky**	**PR-Sky**
Score	0.333	0.68	1.0	0.325	0.375
Values	20502	45F	40%	Partly Cloudy	Sunny
	32399	63F	23%	Sunny	Partly Cloudy
	33040	73F	73%	Sunny	Rainy
	90292	66F	59%	Partly Cloudy	Sunny
	36130	62F	24%	Sunny	Partly Cloudy

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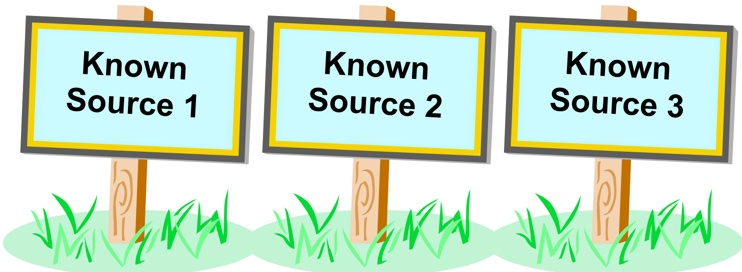
Inducing Source Definitions

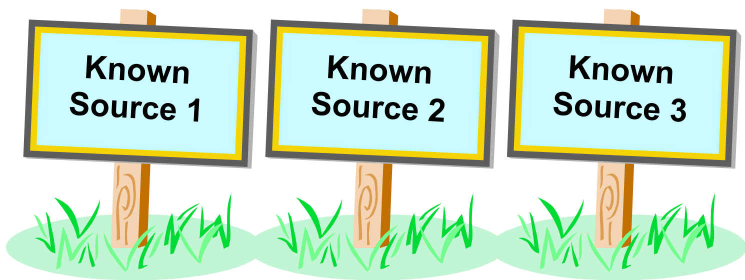


source1($zip, lat, long) :-
  centroid(zip, lat, long).

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

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

Inducing Source Definitions



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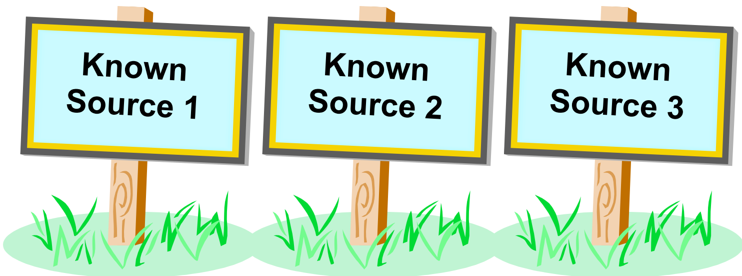
source4($startZip, $endZip, separation)

Inducing Source Definitions



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centroid(zip, lat, long).

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

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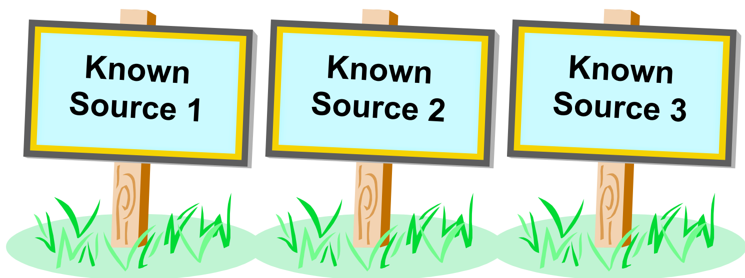
- Step 1: classify input & output semantic types

source4($startZip, $endZip, separation)

Inducing Source Definitions



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

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

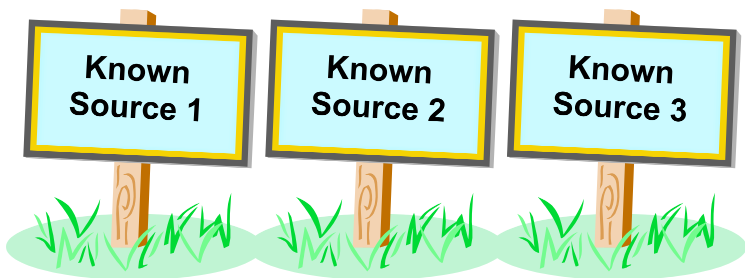
source3($dist1, dist2) :-
  convertKm2Mi(dist1, dist2).

- Step 1: classify input & output semantic types

zipcode

source4($startZip, $endZip, separation)

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).

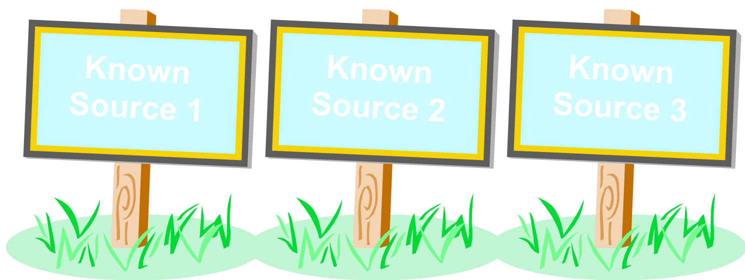
- Step 1: classify input & output semantic types

zipcode

distance

source4($startZip, $endZip, separation)

Generating Plausible Definition



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

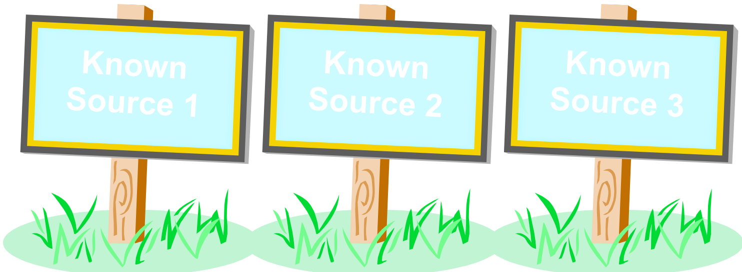
source2($lat1, $long1, $lat2, $long2, dist) :-
greatCircleDist(lat1, long1, lat2, long2, dist).

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

- Step 1: classify input & output semantic types
- Step 2: generate plausible definitions

source4($zip1, $zip2, dist)

Generating Plausible Definition



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

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

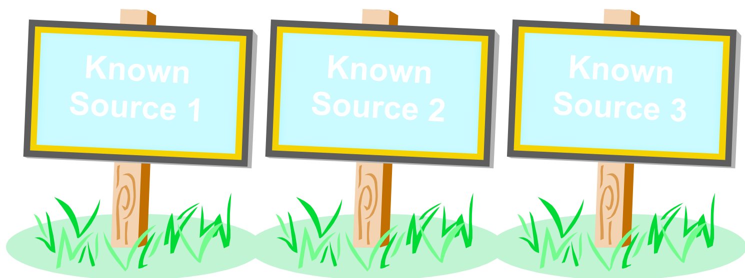
source3($dist1, dist2) :-
  convertKm2Mi(dist1, dist2).

- Step 1: classify input & output semantic types
- 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)

Generating Plausible Definition



source1($zip, lat, long) :-
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source2($lat1, $long1, $lat2, $long2, dist) :-
  greatCircleDist(lat1, long1, lat2, long2, dist).

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

- Step 1: classify input & output semantic types
- 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

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- 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

Source Modeling for Weather

- Given a set of known sources and their descriptions
  - wunderground($Z,CS,T,F0,S0,Hu0,WS0,WD0,P0,V0) :- weather(0,Z,CS,D,T,F0,_,_,S0,Hu0,P0,WS0,WD0,V0)
  - convertC2F(C,F) :- centigrade2farenheit(C,F)
- Learn a description of a new source in terms of the known sources
  - unisys($Z,CS,T,F0,C0,S0,Hu0,WS0,WD0,P0,V0) :- wunderground(Z,CS,T,F0,S0,Hu0,WS0,WD0,P0,V0), convertC2F(C0,F0)

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Experimental Evaluation

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- Experiments in 3 domains
  - Geospatial
    - *Geocoder that maps street addresses into lat/long coordinates*
  - Weather
    - *Produces current and forecasted weather*
  - Flight Status
    - *Current status for a given airline and flight*
- Evaluation:
  - 1) Can we correctly learn a model for those sources that perform the same task
  - 2) What is the precision and recall of the attributes in the model

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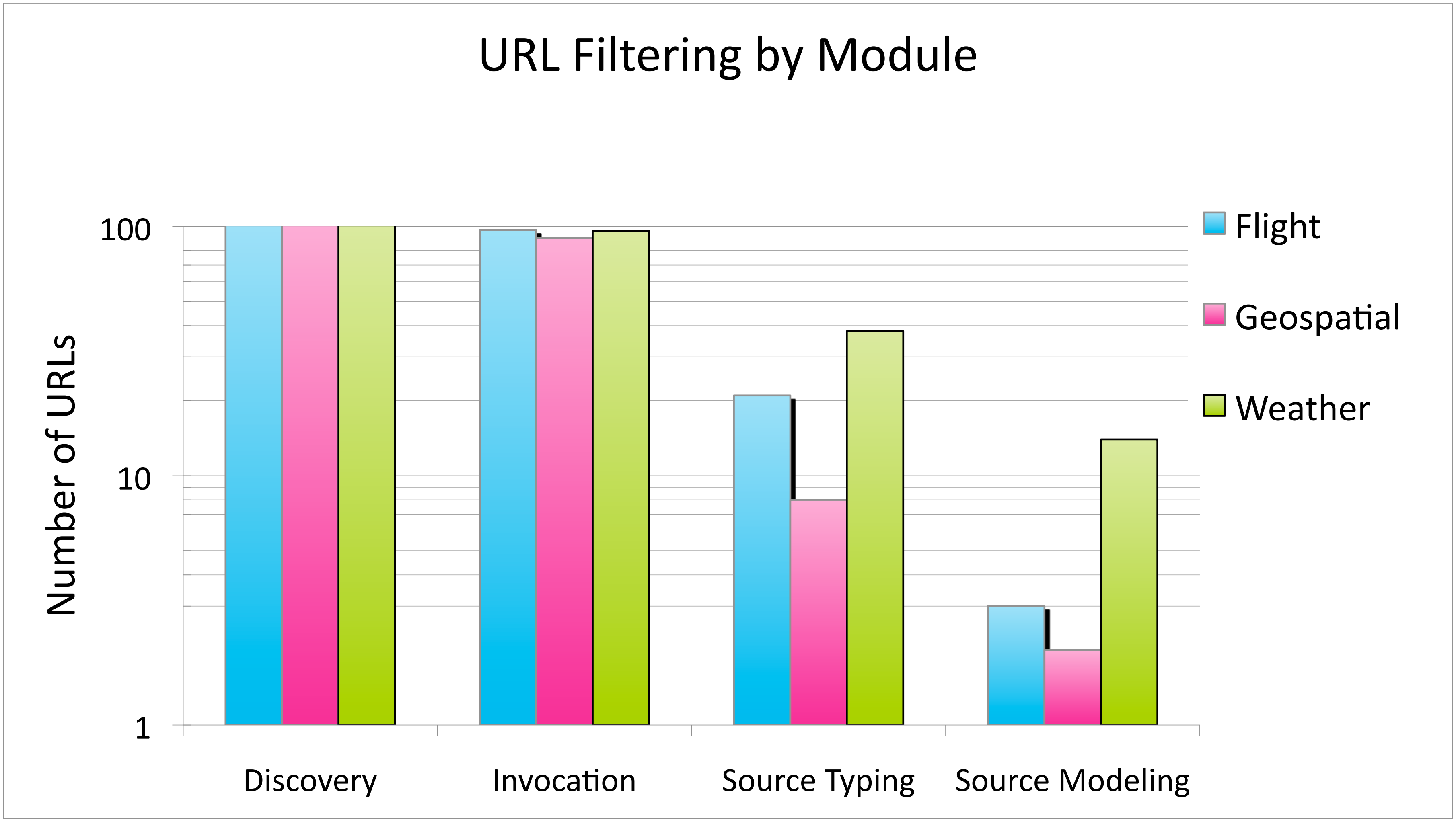
Candidate Sources after Each Step



Evaluation of the Models

	Recall	Precision	F-measure
geospatial	86	100	92
weather	29	64	39
flight	35	69	46

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Related Work

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- ILA & Category Translation (Perkowitz & Etzioni 1995)
  - Learn functions describing operations on internet
- iMAP (Dhamanka et. al. 2004)
  - Discovers complex (many-to-1) mappings between DB schemas
- Metadata-based classification of data types used by Web services and HTML forms (Hess & Kushmerick, 2003)
  - Naïve Bayes classifier
- Woogle: Metadata-based clustering of data and operations used by Web services (Dong et al, 2004)
  - Groups similar types together: Zipcode, City, State

Discussion

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- Integrated a diverse set of learning and reasoning techniques
  - *Discover new sources*
  - *Discover the template for a source*
  - *Find the semantic types of source data*
  - *Learn a definition of what a source does*
- Provides an end-to-end completely automatic approach to discover and build models of sources