USC INFORMATION SCIENCES INSTITUTE

KARMA

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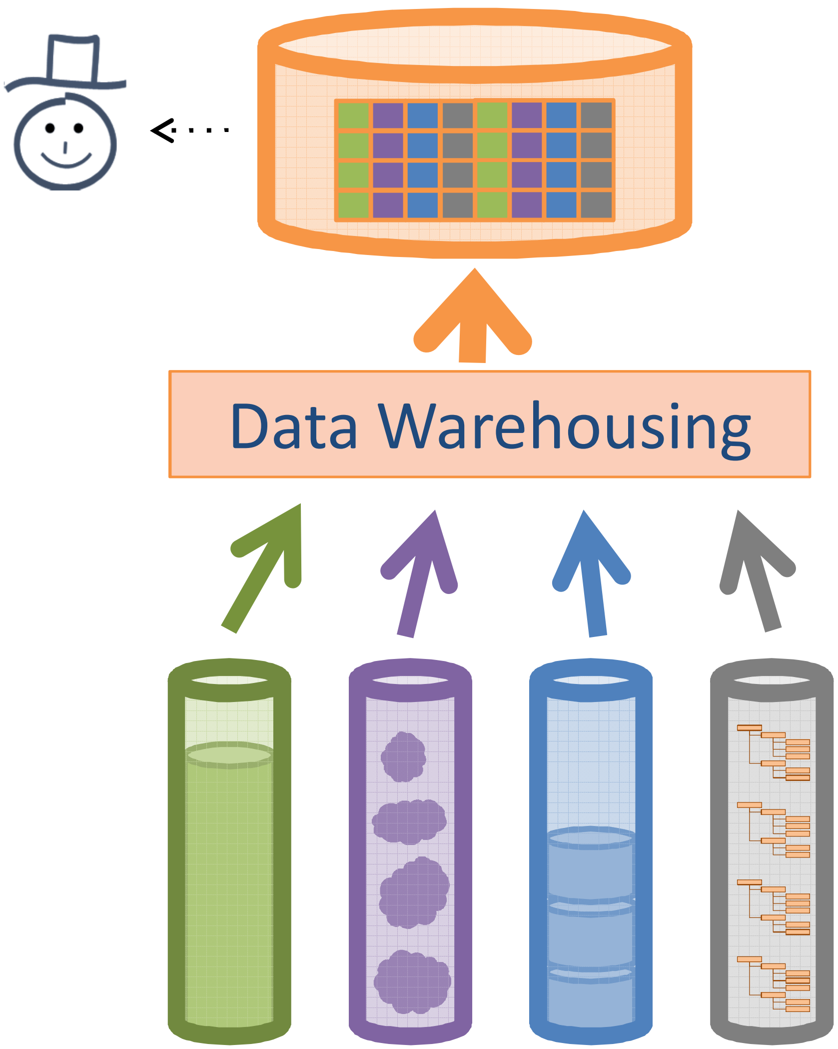
Work in collaboration with Mohsen Taheriyan, Jason Slepicka, Bo Wu, Dipsy Kapoor, Jose Luis Ambite, Yao-Yi Chiang, Aman Goel, Shubham Gupta, Maria Muslea, Kristina Lerman and many students.

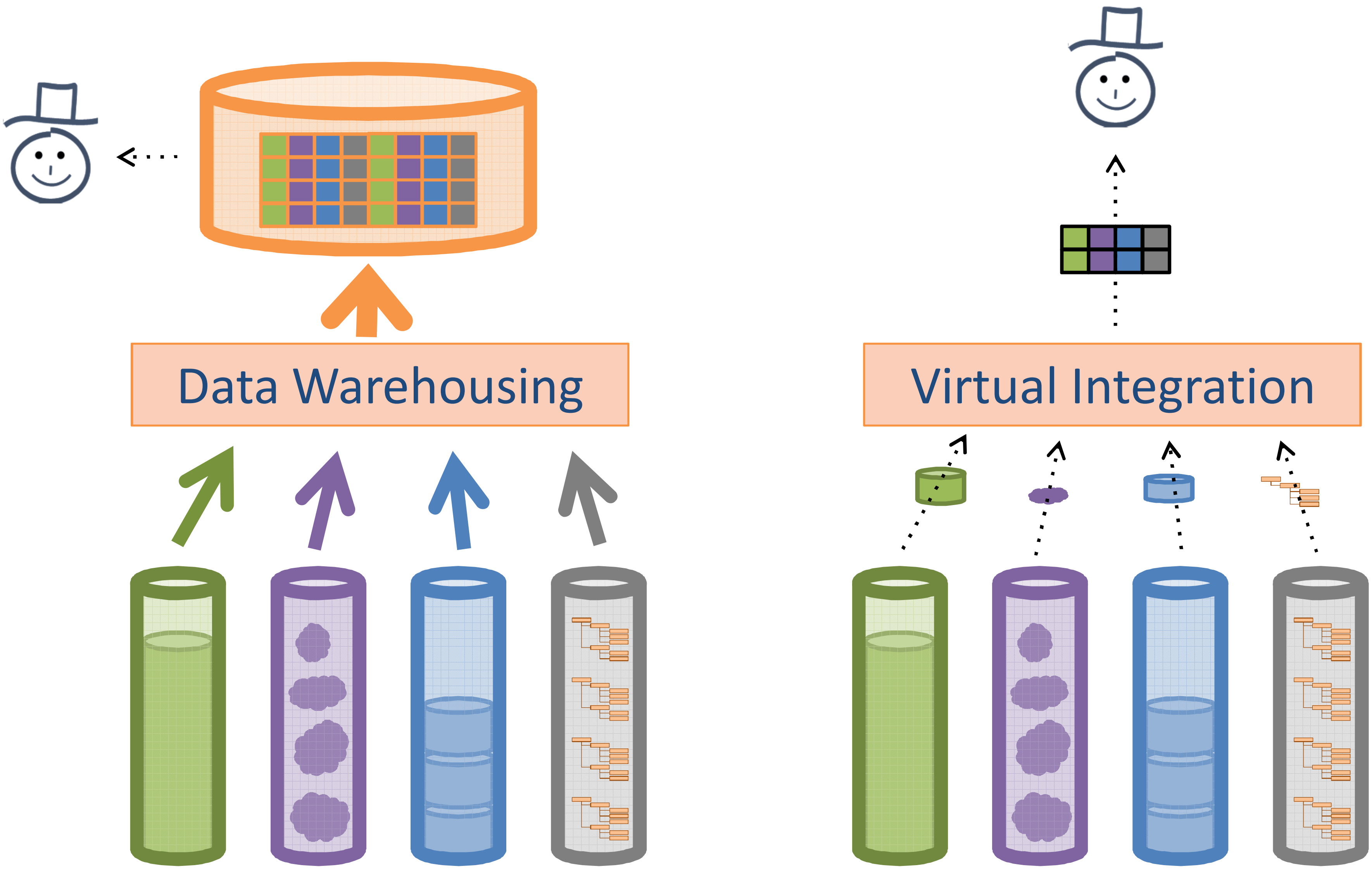
Outline

- Integrating data silos
- Our Karma tool
- Use cases

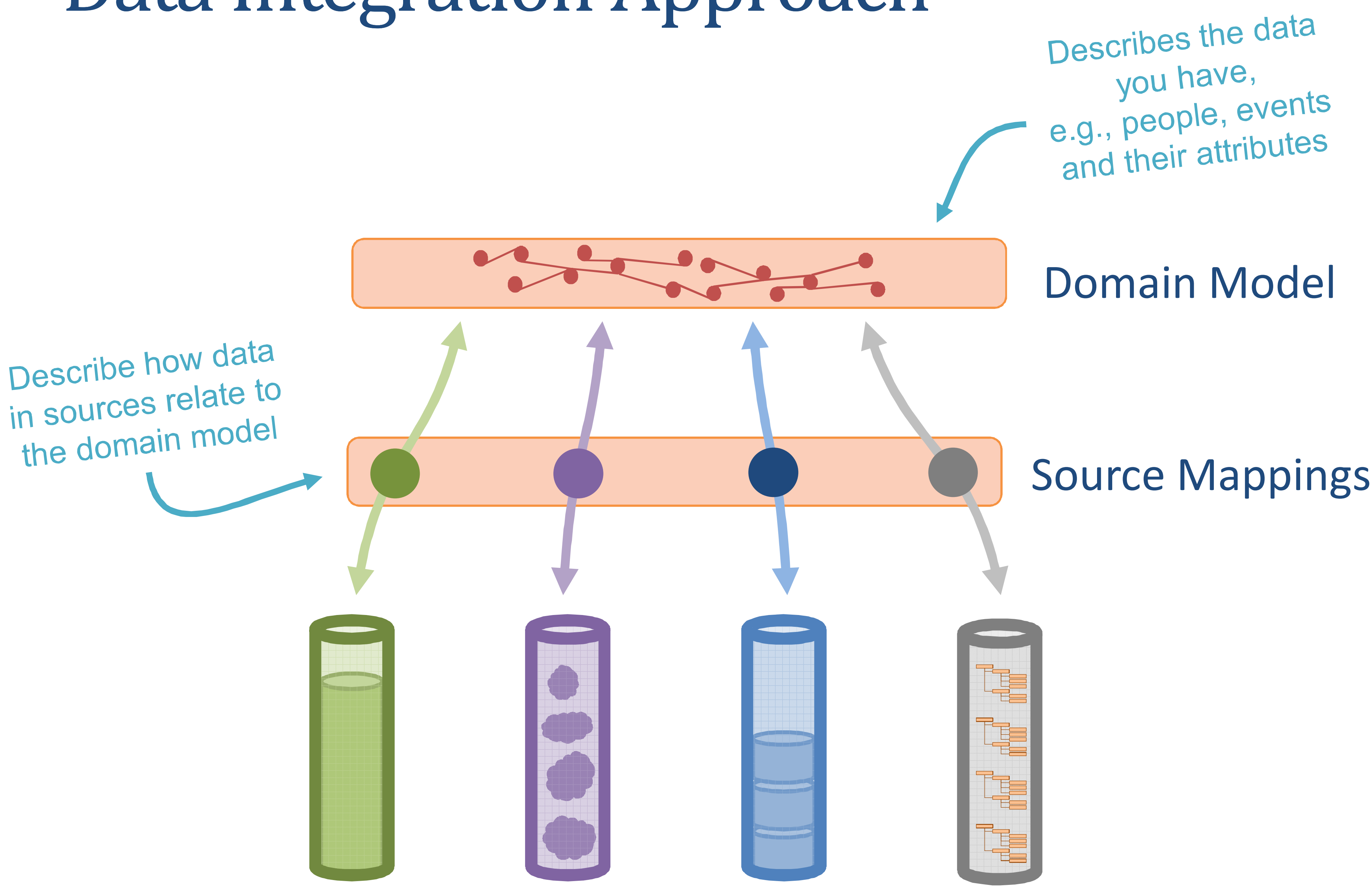
Data Integration Approaches



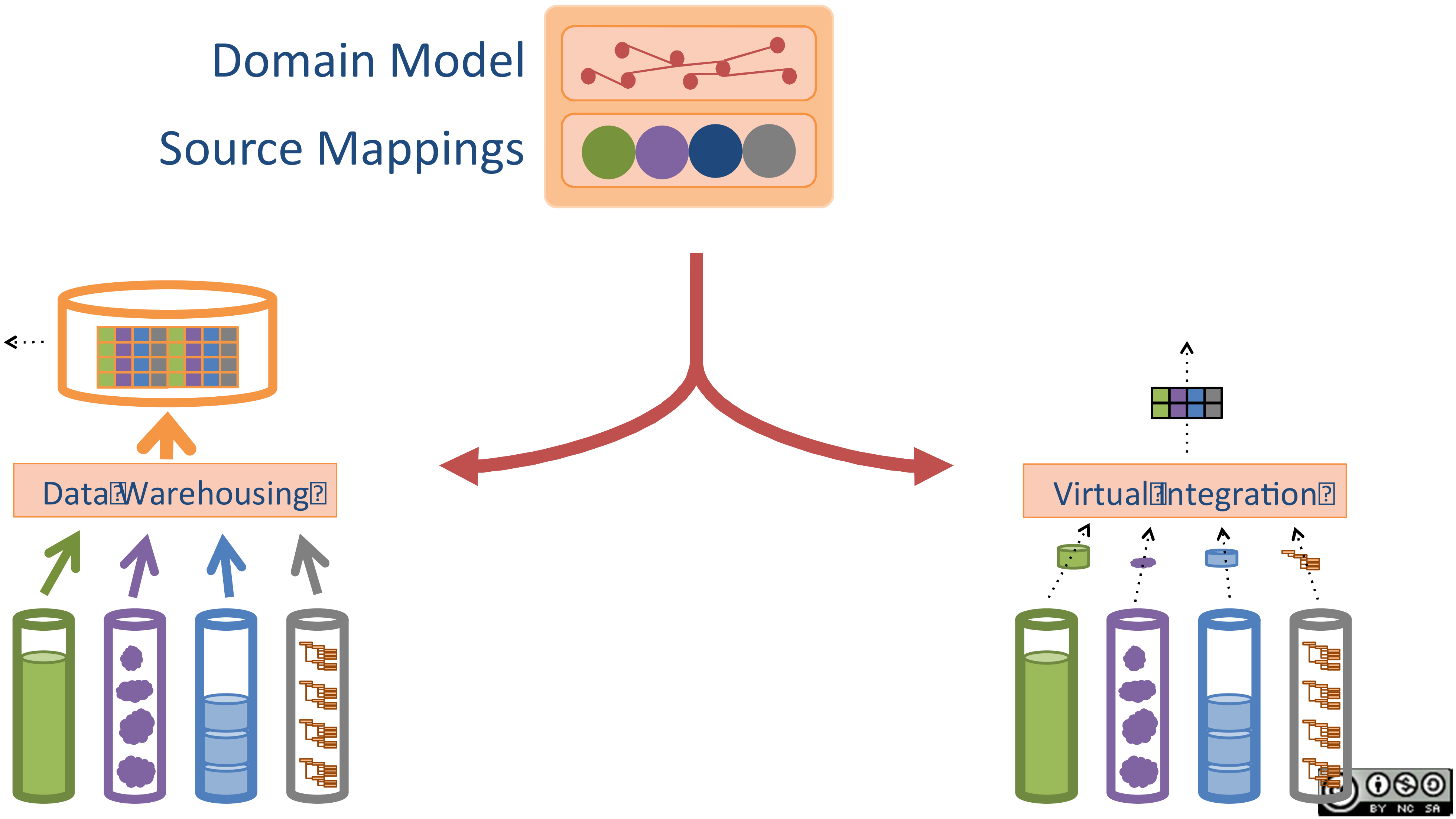
Data Integration Approaches



Data Integration Approach



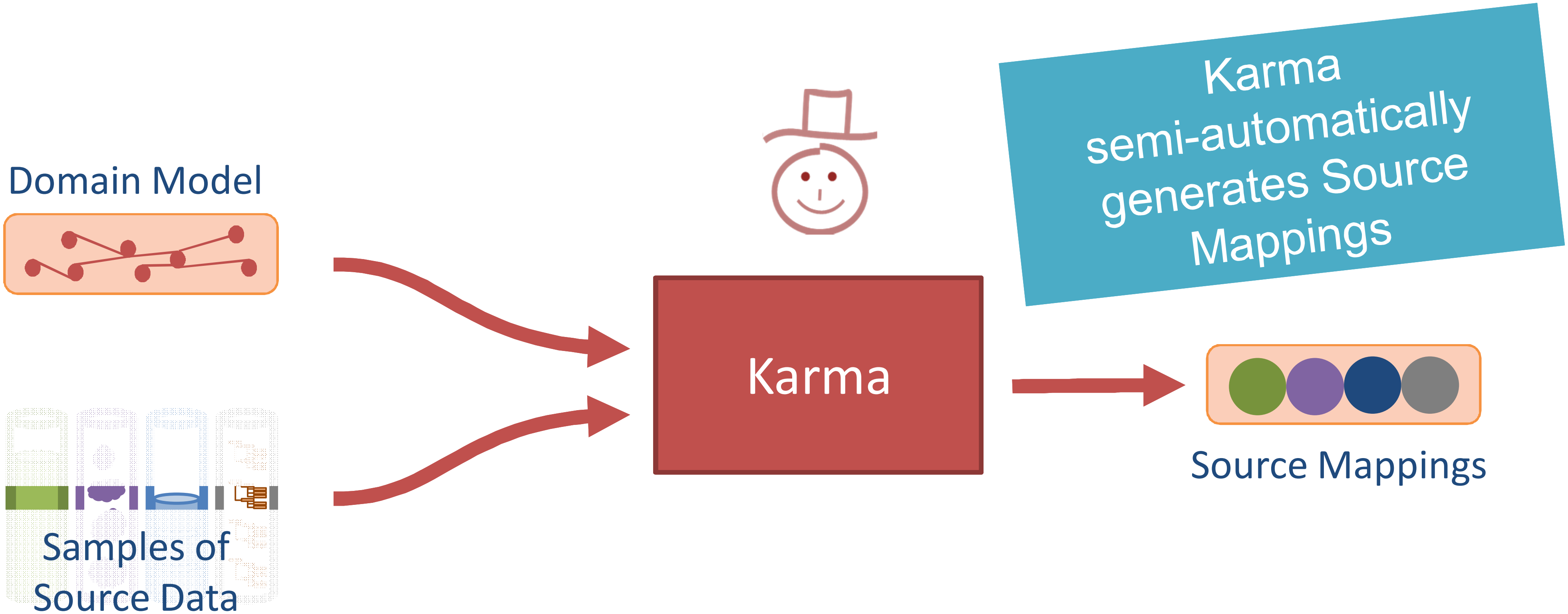
Information Integration Using Source Mappings



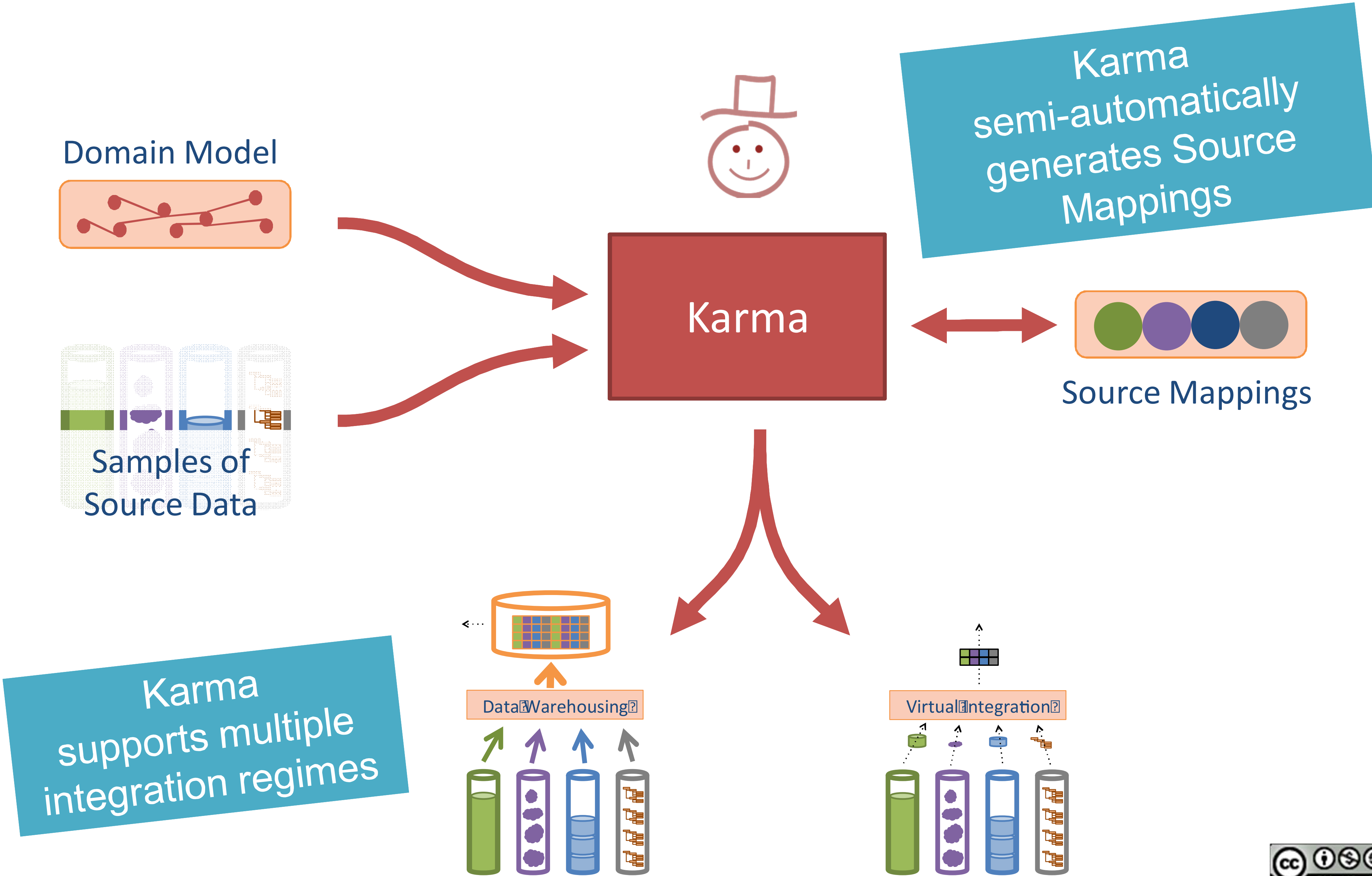
Karma:

Our Information Integration Toolkit

Information Integration Using Karma

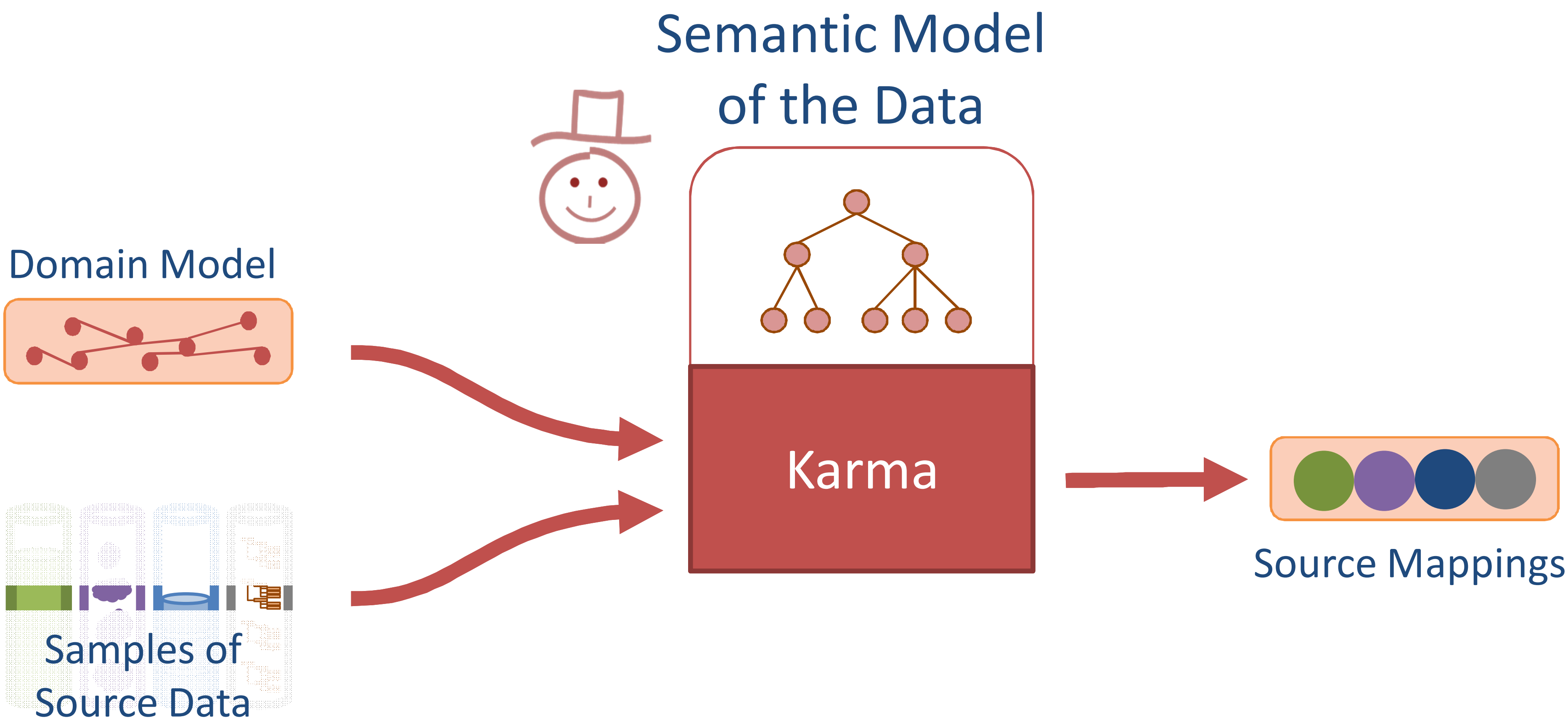


Information Integration Using Karma



Karma’s Secret Sauce

Karma Understands Your Data



Karma semi-automatically builds a semantic model of your data

Semantic Types: Meaning of Data in Columns

Semantic vs Syntactic Types

String	String	String	Date	String	String
Perpetrator Values	Nationality	Location	Time	Type	Description
Zian Akhtar Mehmood Afzal	...	...	...	Riot	Seen in demonstration o
Abdul Nomaz Faroq Nomaz	Somalia	Nairobi	12/24/2011 17:00Z	IED	...
...	...	Nairobi	...	...	...
Khair Shahed Riaz Afredi Zoha Afredi	...	...	12/24/2011 13:00Z	IED	...

Not useful for information integration

Semantic Types Capture the Meaning of Data in Columns

Semantic vs Syntactic Types

Name of Person	Nationality of Entity	Location of Event	Date of Event	Type of Event	Description of Event
Perpetrator **Values**	**Nationality**	**Location**	**Time**	**Type**	**Description**
Zian Akhtar Mehmood Afzal	…	…	…	Riot	Seen in demonstration o
Abdul Nomaz Faroq Nomaz	Somalia	Nairobi	12/24/2011 17:00Z	IED	…
…	…	Nairobi	…	…	…
Khair Shahed Riaz Afredi Zoha Afredi	…	…	12/24/2011 13:00Z	IED	…

Semantic Types Defined Using an Ontology

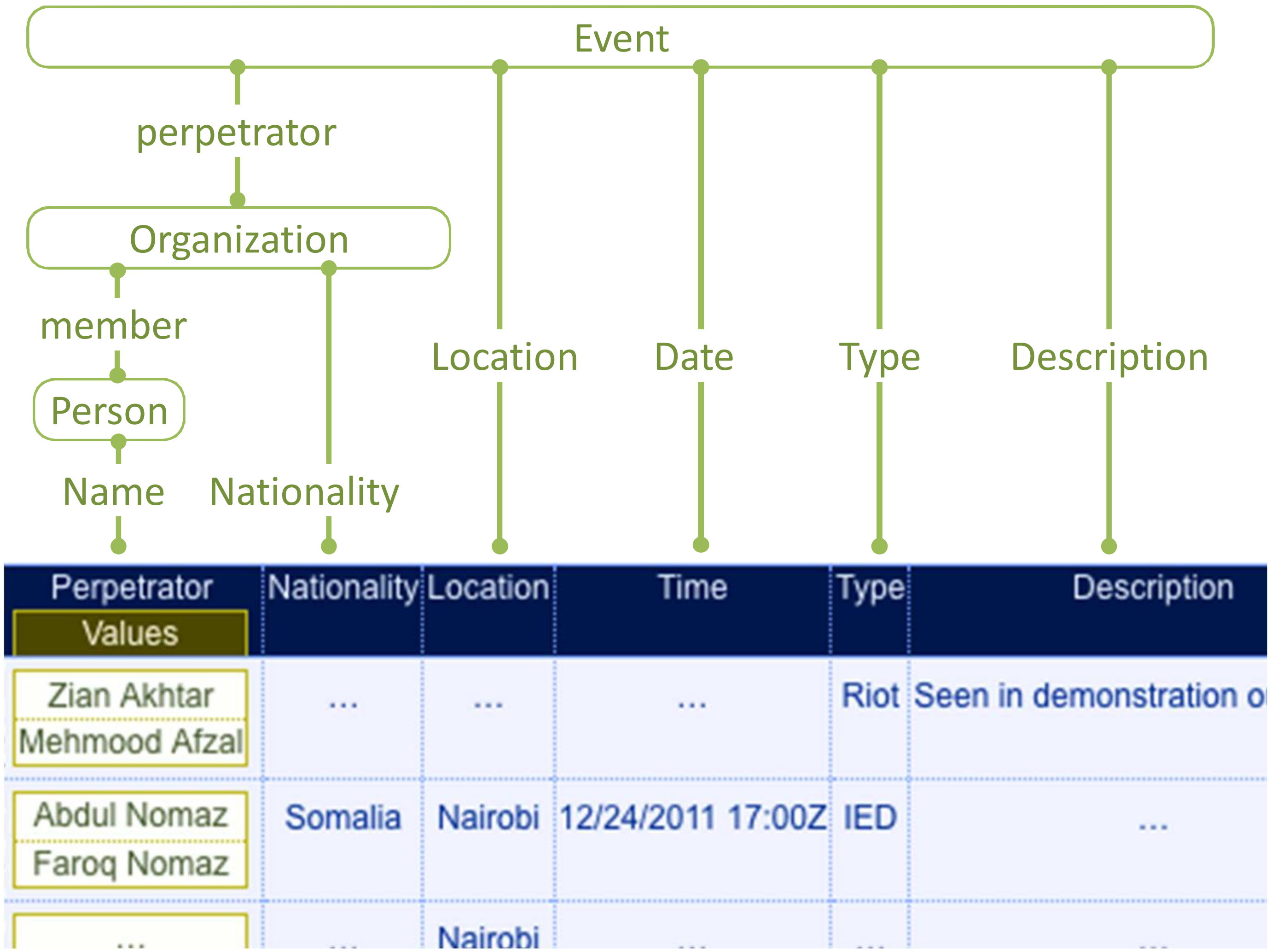
Perpetrator Values	Nationality	Location	Time	Type	Description
Zian Akhtar Mehmood Afzal	...	...	...	Riot	Seen in demonstration o
Abdul Nomaz Faroq Nomaz	Somalia	Nairobi	12/24/2011 17:00Z	IED	...
...	...	Nairobi	...	...	...

Karma Learns the Semantic Types

1. User specifies them once
2. Karma learns features to recognize them
3. Next time Karma sees similar data it automatically proposes semantic types

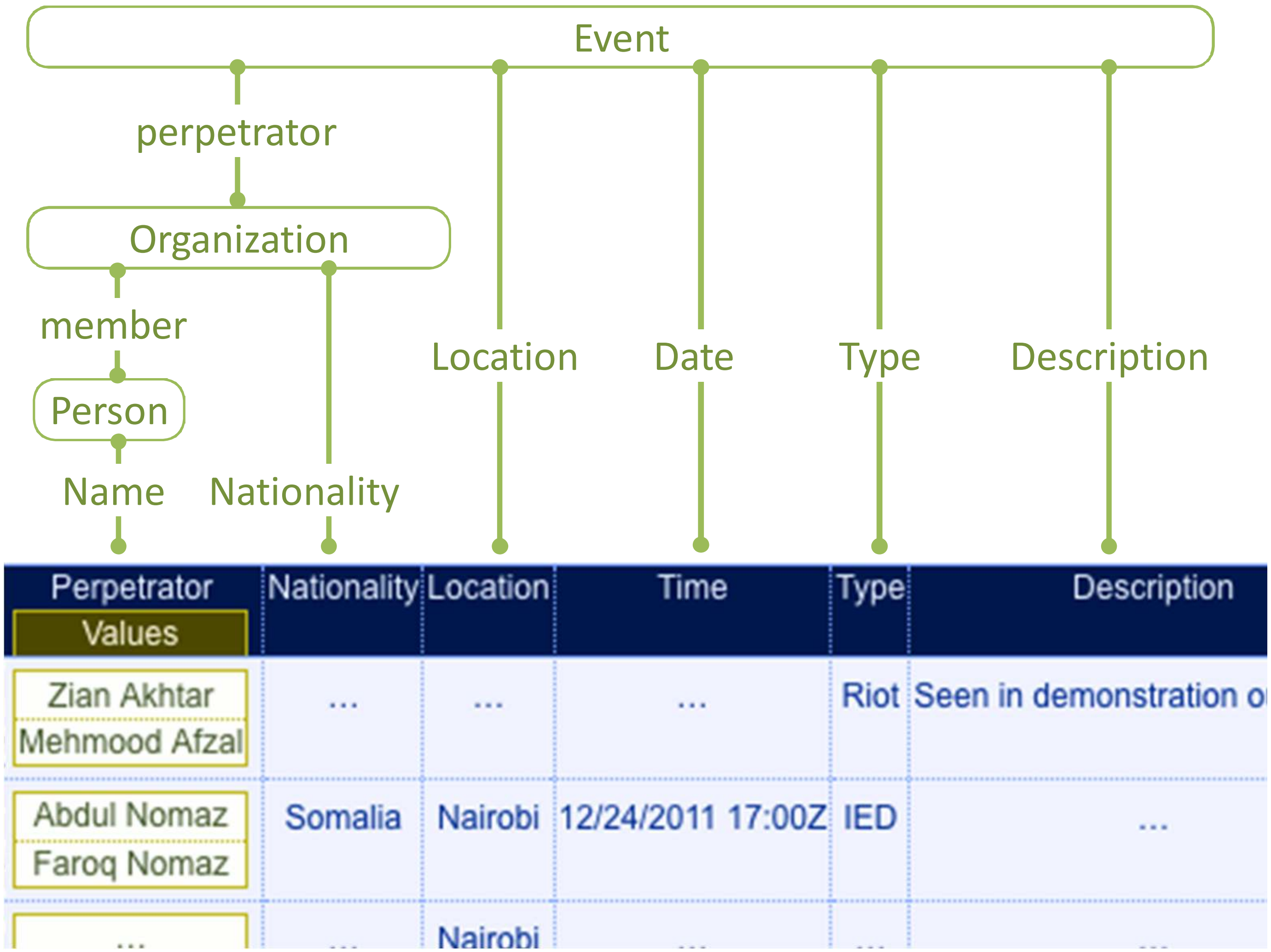
Relationships Among Columns

Relationships Among Specified in Terms of Classes and Properties



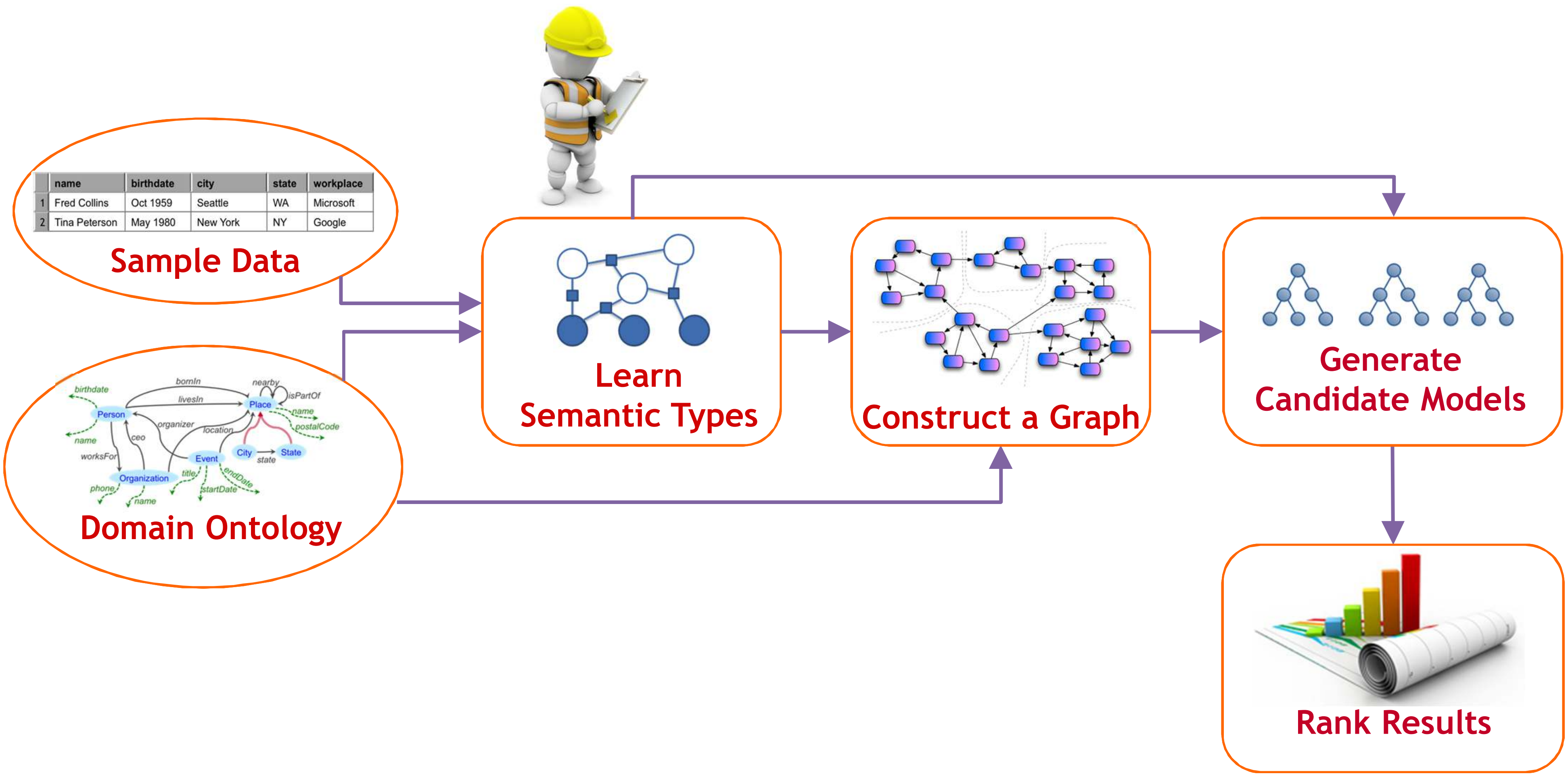
Perpetrator Values	Nationality	Location	Time	Type	Description
Zian Akhtar Mehmood Afzal	...	...	...	Riot	Seen in demonstration o
Abdul Nomaz Faroq Nomaz	Somalia	Nairobi	12/24/2011 17:00Z	IED	...
...	...	Nairobi	...	...	...

Karma Automatically Infers Relationships



1. Karma automatically finds relationships using the ontology
2. When proposed relationships are incorrect, the user adjusts them

Approach

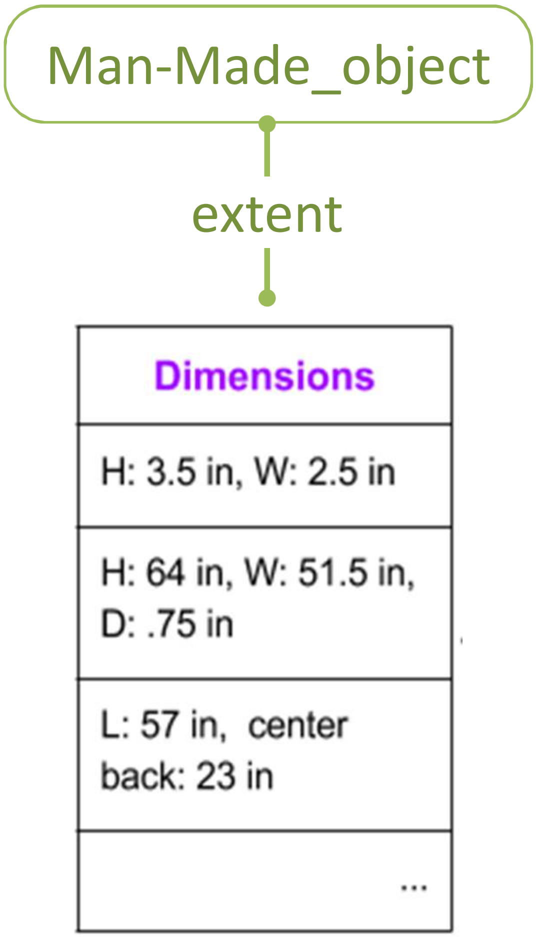


name | birthdate | city | state | workplace
1 | Fred Collins | Oct 1959 | Seattle | WA | Microsoft
2 | Tina Peterson | May 1980 | New York | NY | Google
Sample Data
Domain Ontology
Learn Semantic Types
Construct a Graph
Generate Candidate Models
Rank Results

Learning Semantic Types

Dimensions
H: 3.5 in, W: 2.5 in
H: 64 in, W: 51.5 in, D: .75 in
L: 57 in, center back: 23 in
...

Learning Semantic Types



1. User specifies
2. System learns

Learning Semantic Types

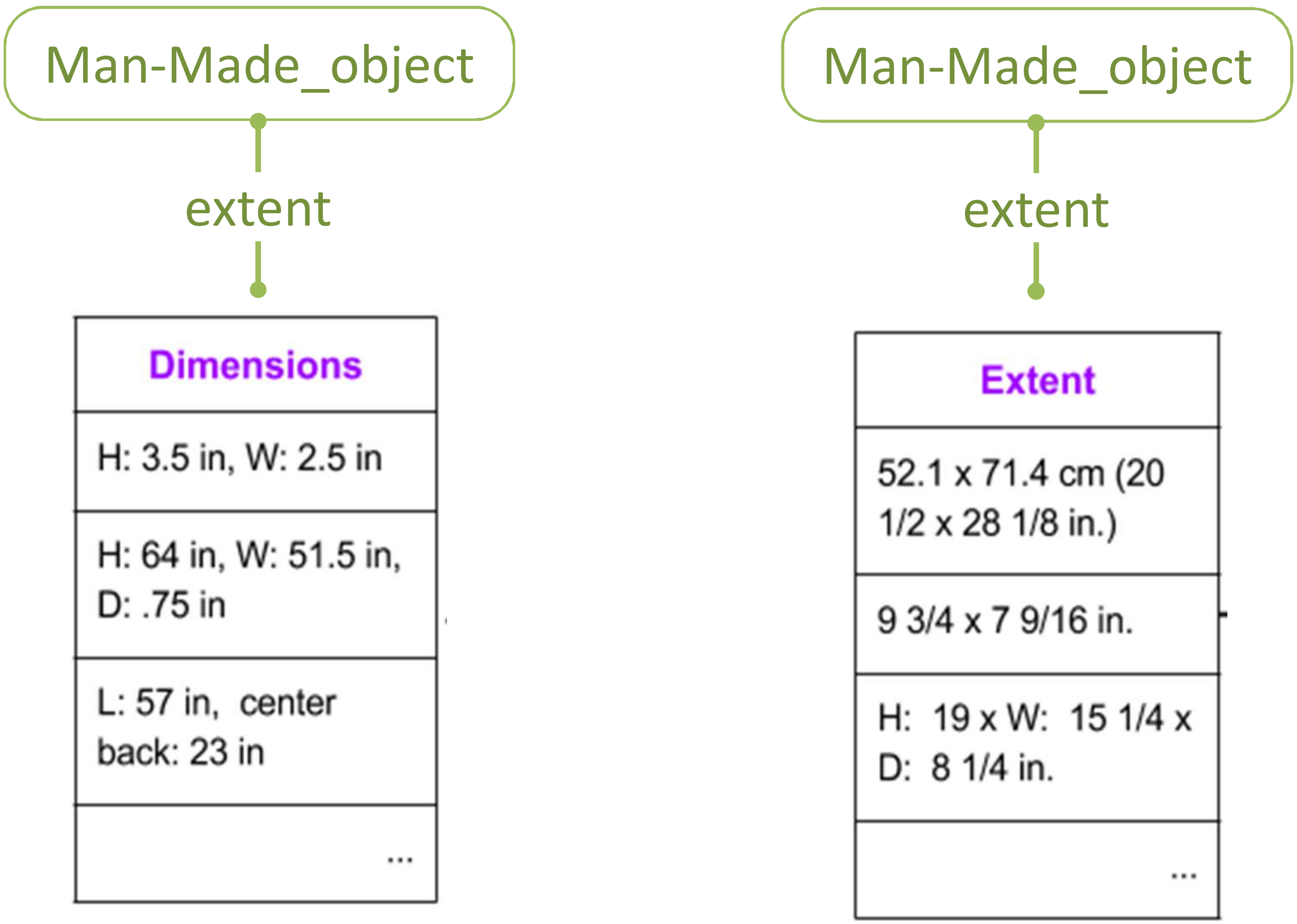
Man-Made_object

extent

Dimensions
H: 3.5 in, W: 2.5 in
H: 64 in, W: 51.5 in, D: .75 in
L: 57 in, center back: 23 in
...

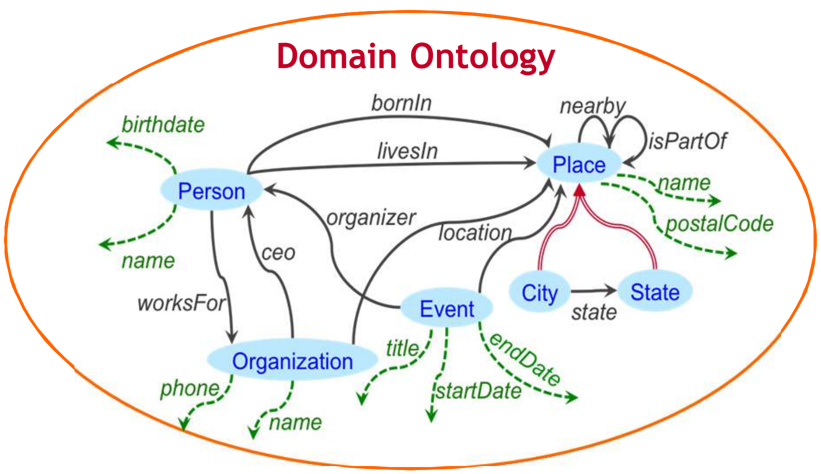
Extent
52.1 x 71.4 cm (20 1/2 x 28 1/8 in.)
9 3/4 x 7 9/16 in.
H: 19 x W: 15 1/4 x D: 8 1/4 in.
...

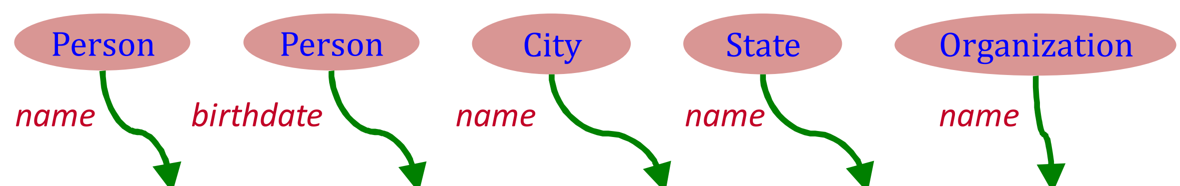
System Suggests Semantic Types



Learning Semantic Types

- Requirements:
  - Learn from a small number of examples
  - Distinguish both string and numeric values
  - Can be learned quickly and is highly scalable to large numbers of semantic types





	name	date	city	state	workplace
1	Fred Collins	Oct 1959	Seattle	WA	Microsoft
2	Tina Peterson	May 1980	New York	NY	Google

Approach for Textual Data

Dimensions
H: 3.5 in, W: 2.5 in
H: 64 in, W: 51.5 in, D: .75 in
L: 57 in, center back: 23 in
...

Each semantic label has a characteristic set of tokens

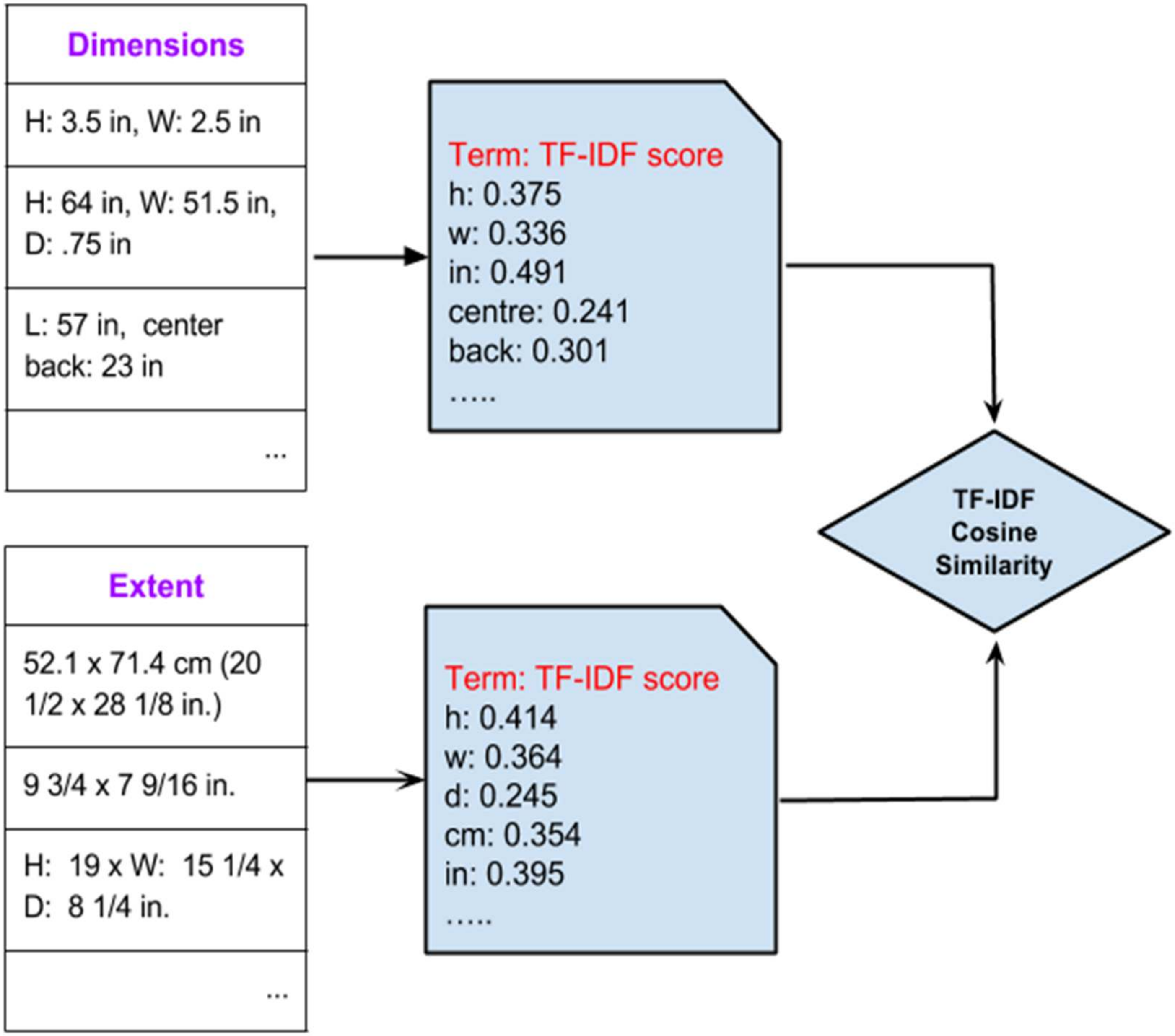
Each column of data is a document

Use information retrieval techniques to compare documents

Labeled data is indexed using Apache Lucene

Compare documents using TF-IDF cosine similarity

Semantic Types for Text Data



$$tf(t,d) = frequency^{1/2}$$

$$idf(t) = 1 + log(\frac{numDocs}{docFreq + 1})$$

$$sim(q,d) = \frac{V(q).V(d)}{|V(q)|.|V(d)|}$$

Approach for Numeric Data

Total Population
107875
47823
60704
81034
.....

Number of people
11070
41542
33039
780058
.....

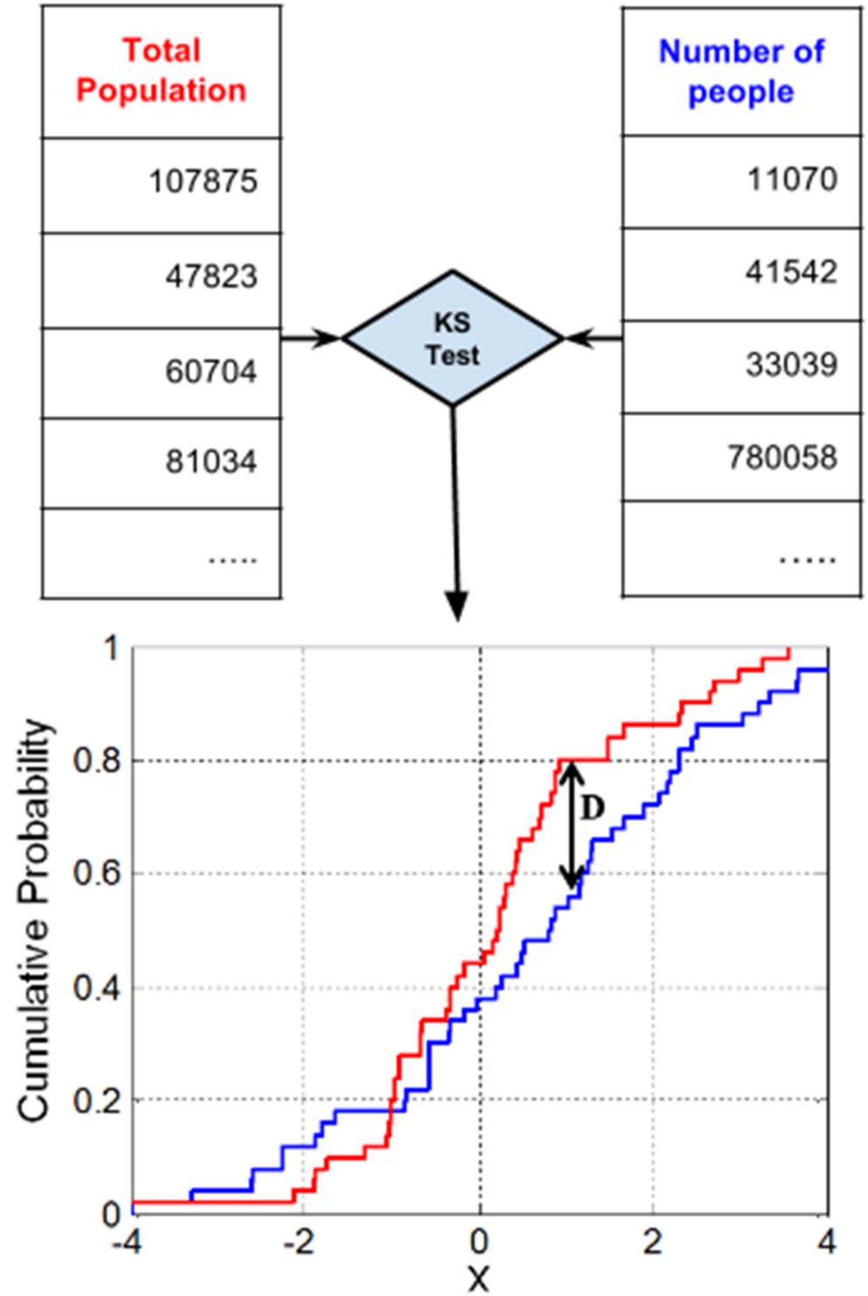
Distribution of values in different semantic type is different

E.g., distribution of population is different from distribution of temperatures

Use Statistical Hypothesis testing to see which distribution fits best

Approaches: Welch's T-test, Mann-Whitney U-test and Kolmogorov-Smirnov Test

Approach for Numeric Data



$$D_{N_1,N_2} = \sup_x |F_{1,N_1}(x) - F_{2,N_2}(x)|$$

Combined Approach

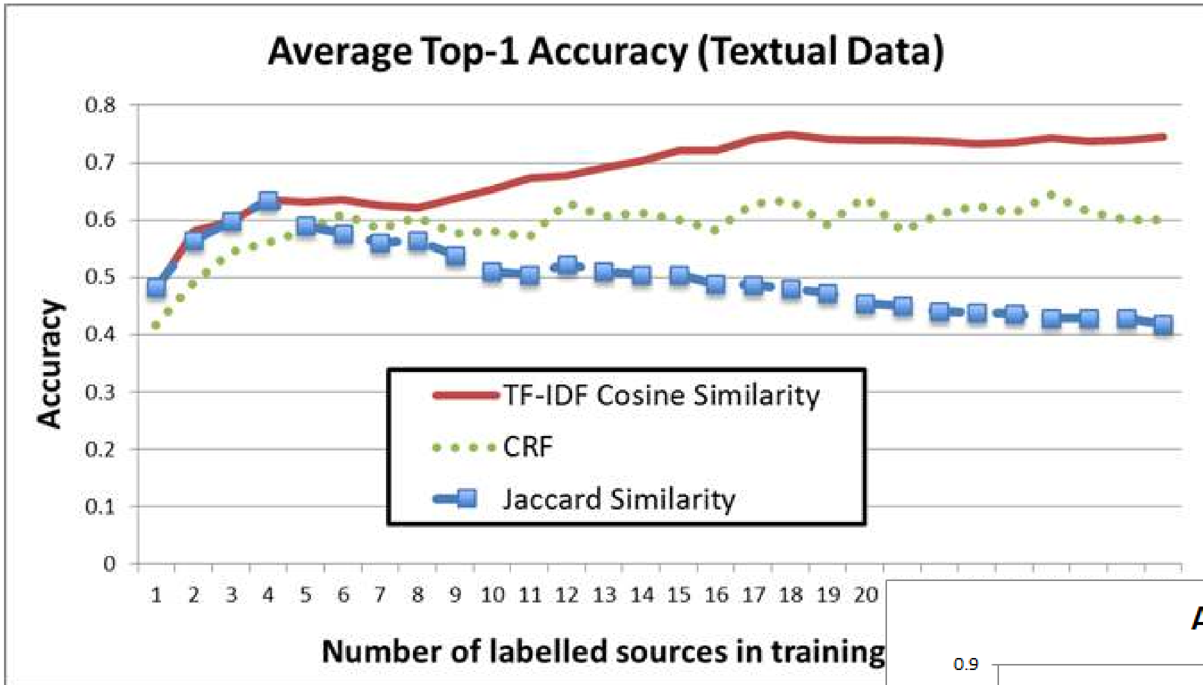
- Combined Approach:
  - Training
    - Add new example data as training for either textual or numeric types
    - If ambiguous, train as both textual and numeric
  - Testing
    - If textual, apply tf/idf
    - If numeric apply KS-test
    - If ambiguous and at least 70% numeric apply KS-test
      - otherwise tf/idf
- Top-k suggestions returned based on the confidence scores

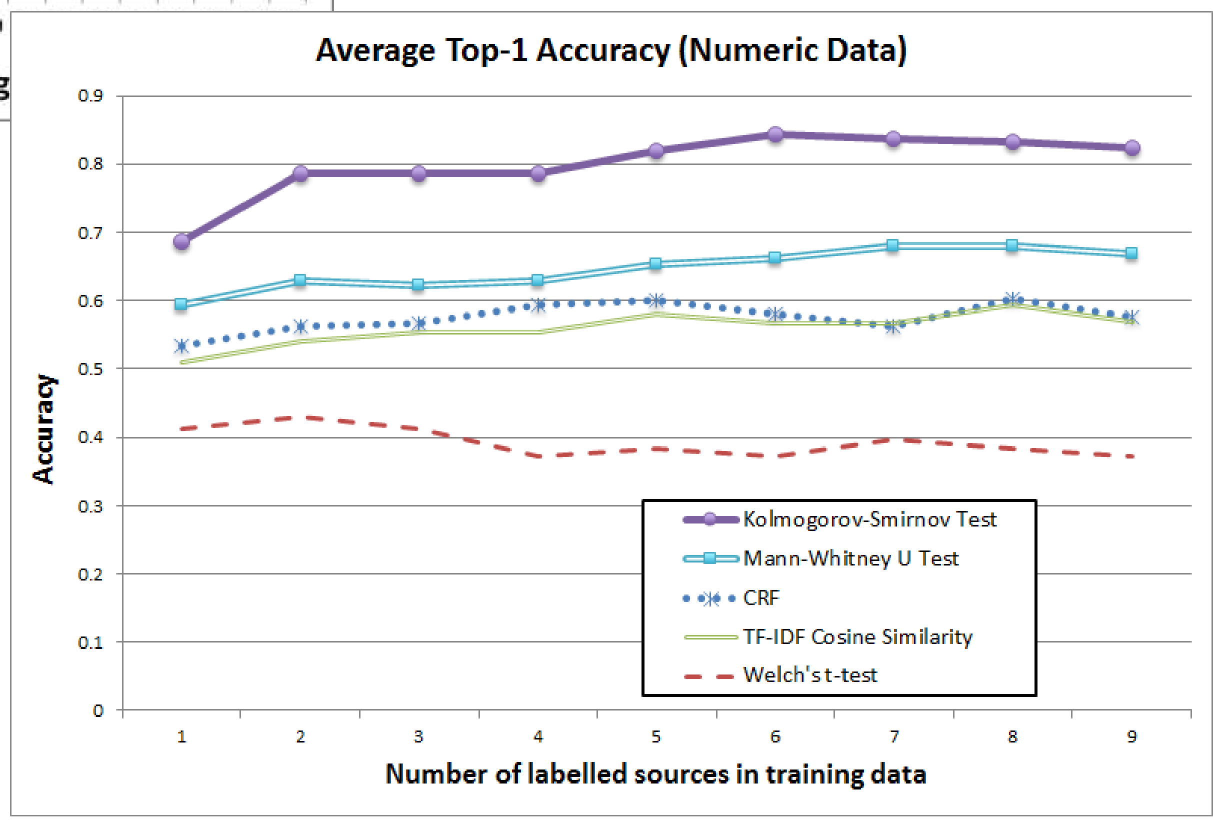
Evaluation of Semantic Typing

- Museum Dataset – 29 data sources from different art museums in the US.
  Ontologies: EDM, AAC, FOAF, SKOS, Dublin Core Metadata Terms, ORE, ElementsGr2

- City Dataset – 10 data sources about various cities in the world - manually extracted from DBpedia.
  Ontology: DBpedia Ontology

Evaluation

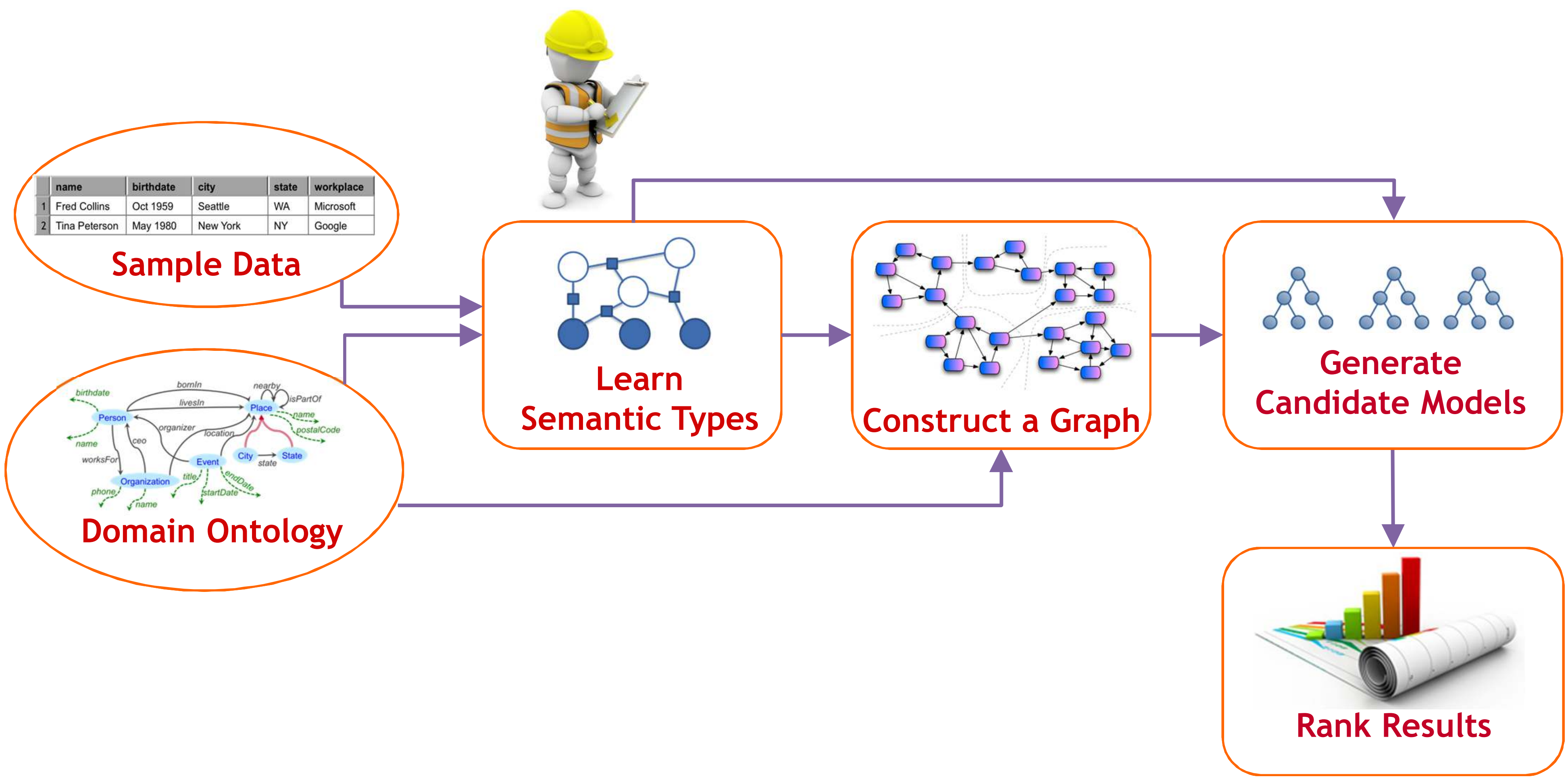




Combined approach achieves 97% accuracy on the top-4 accuracy

Reduced the training time from 110s to 0.45s

Approach

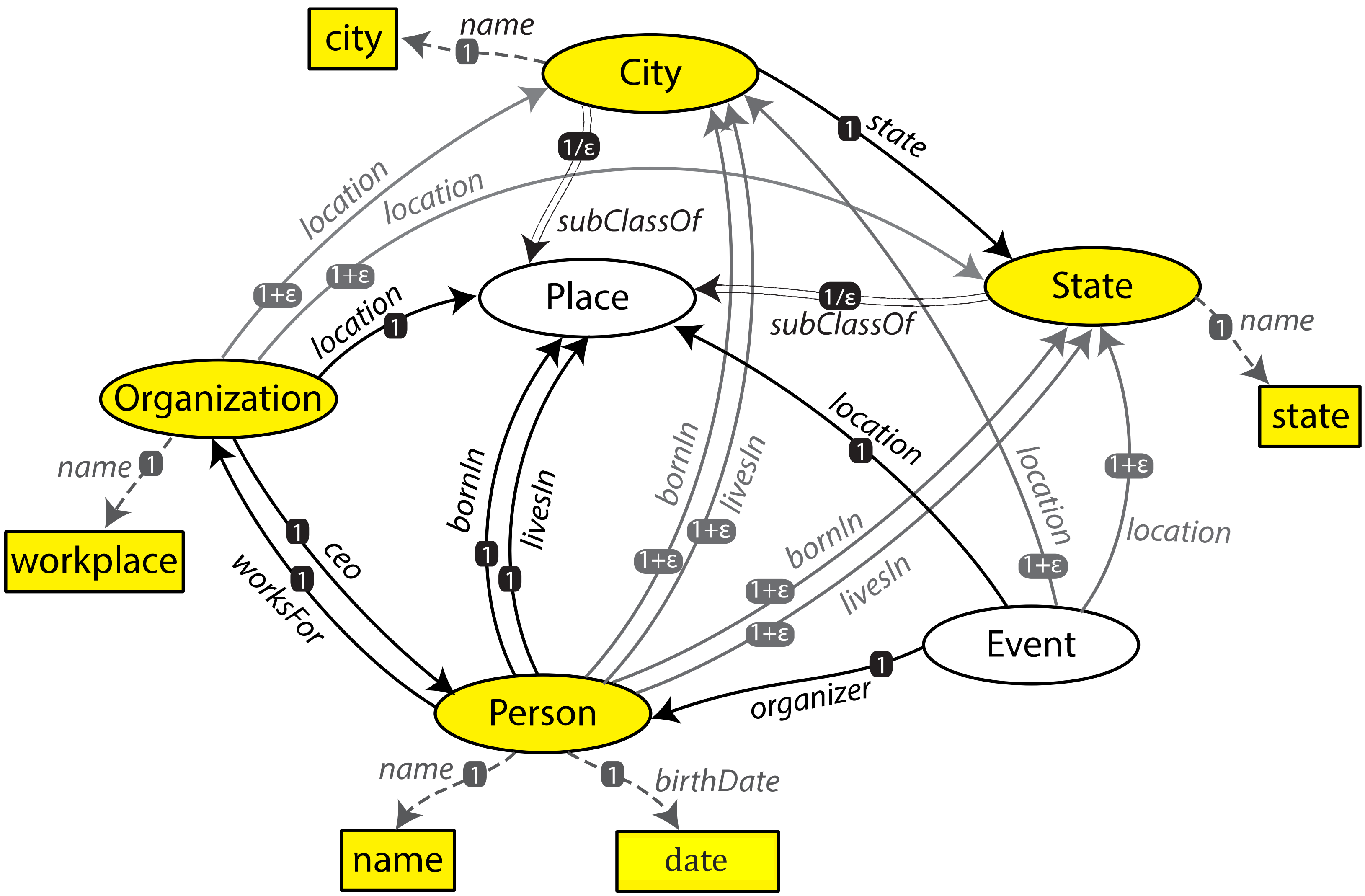


name	birthdate	city	state	workplace
1 Fred Collins	Oct 1959	Seattle	WA	Microsoft
2 Tina Peterson	May 1980	New York	NY	Google

Sample Data
Domain Ontology
Learn Semantic Types
Construct a Graph
Generate Candidate Models
Rank Results

Construct a Graph

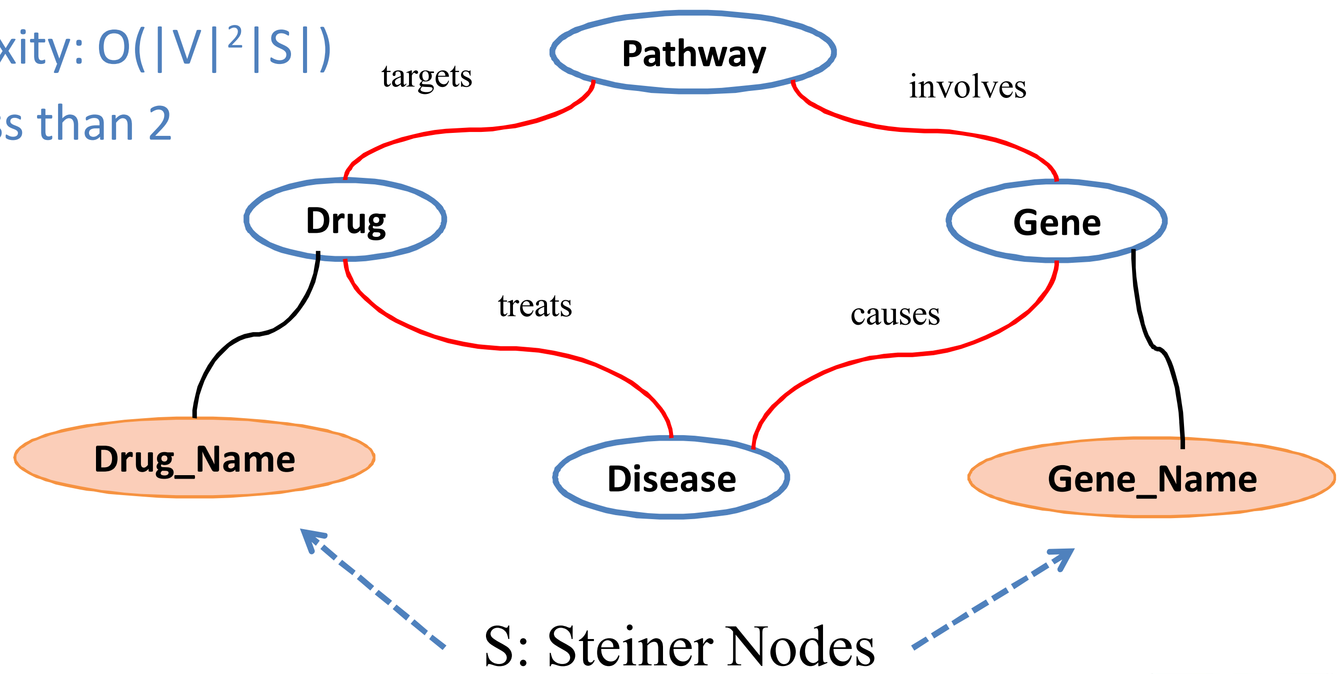
Construct a graph from semantic types and ontology



Inferring the Relationships

- Search for minimal explanation (source description)
- Steiner tree connecting semantic types over ontology graph
  - Given graph G=(V,E), nodes $S \subset V$, cost $c: E \rightarrow \Re$
  - Find a tree of G that spans S with minimal total cost
  - Unfortunately, NP-complete
- Approximation Algorithm [KMB, 1981]
  - Worst-case time complexity: $O(|V|^2|S|)$
  - Approximation Ratio: less than 2

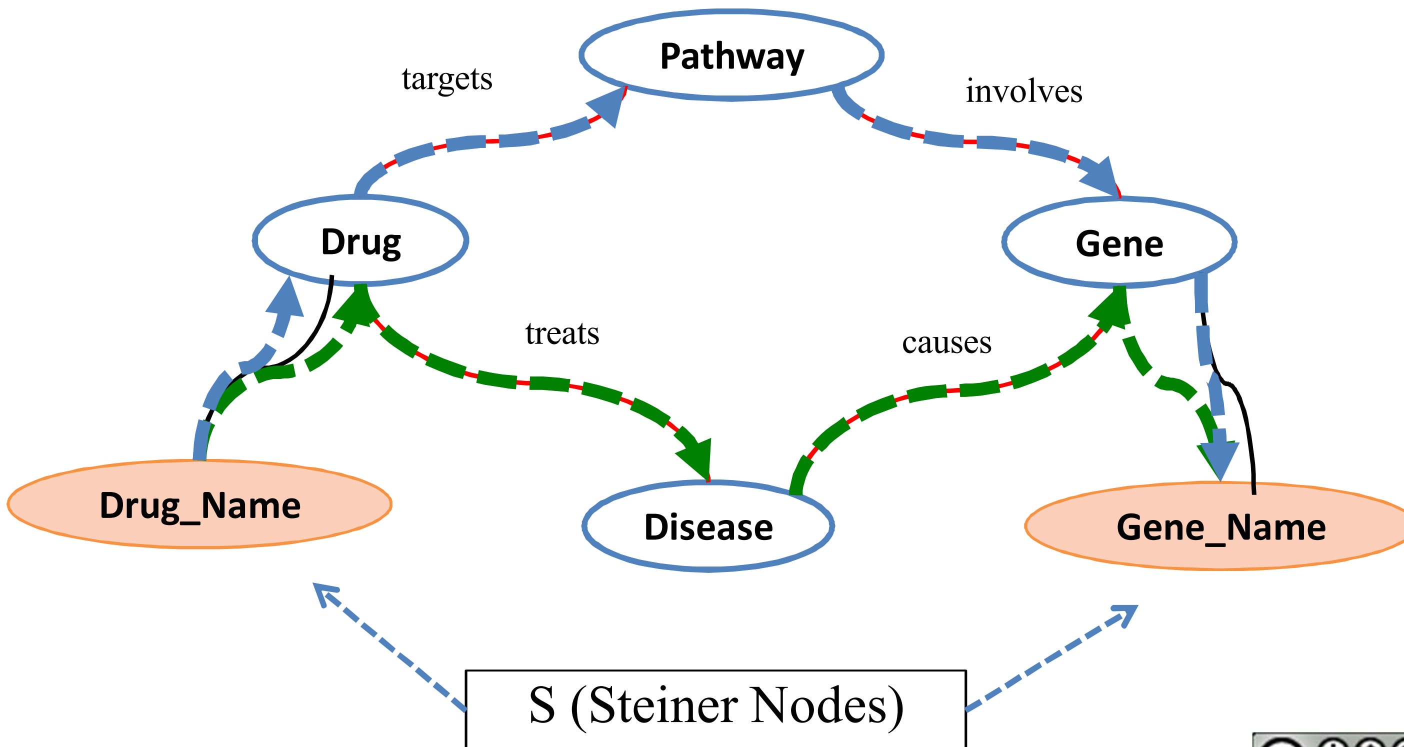
Drug_Name	Gene_Name
Antineoplastic	ABCB1
Antineoplastic	ABCC4
Atorvastatin	ABCB1



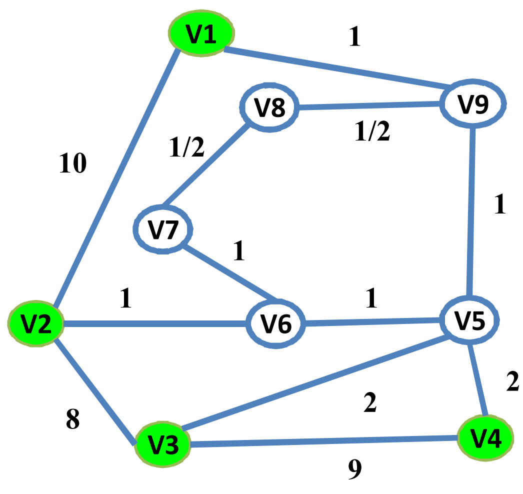
Inferring the Relationships

- Search for minimal explanation (source description)
- Multiple explanations:
  - Drug that targets pathway that involves gene ( )
  - Drug that treats disease caused by gene ( )

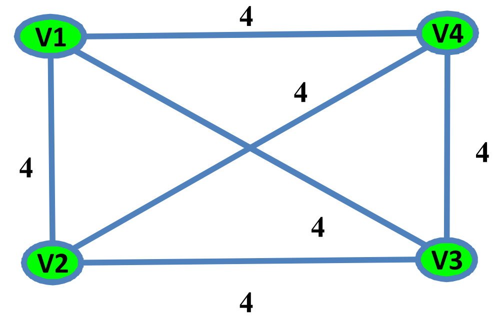
Drug_Name	Gene_Name
Antineoplastic	ABCB1
Antineoplastic	ABCC4
Atorvastatin	ABCB1



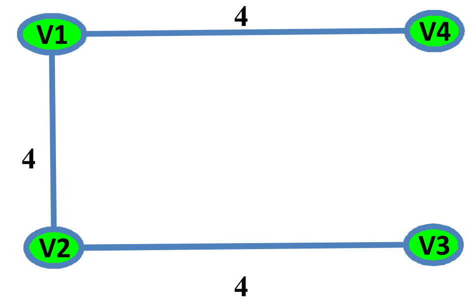
Steiner Tree Algorithm



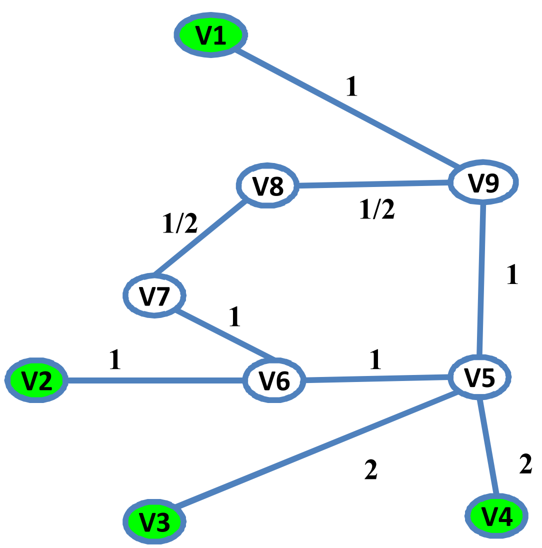
Steiner nodes: {V1, V2, V3, V4}



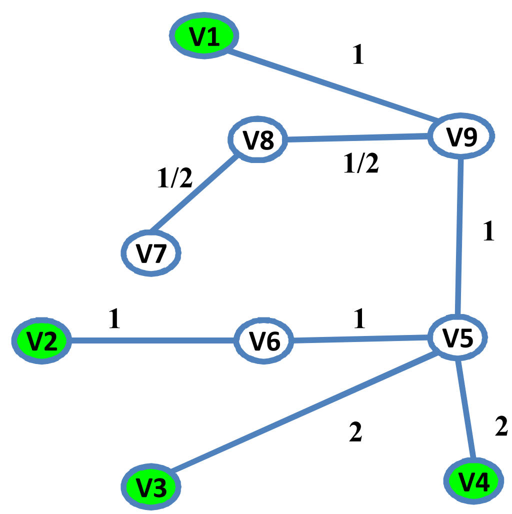
1. construct the complete graph (Nodes: Steiner Nodes, Links Weights: shortest path from each pair in original G)



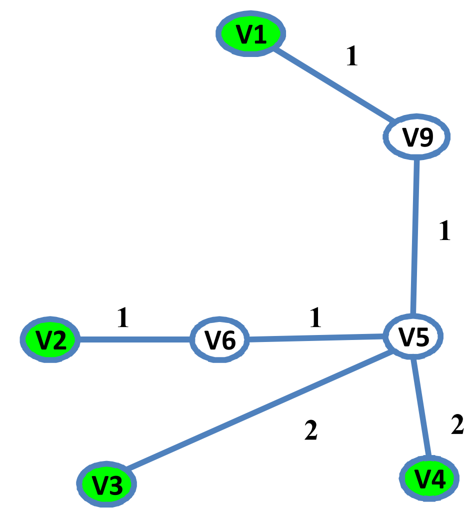
2. Compute MST



3. replace each link with the corresponding shortest path in original G



4. Compute MST



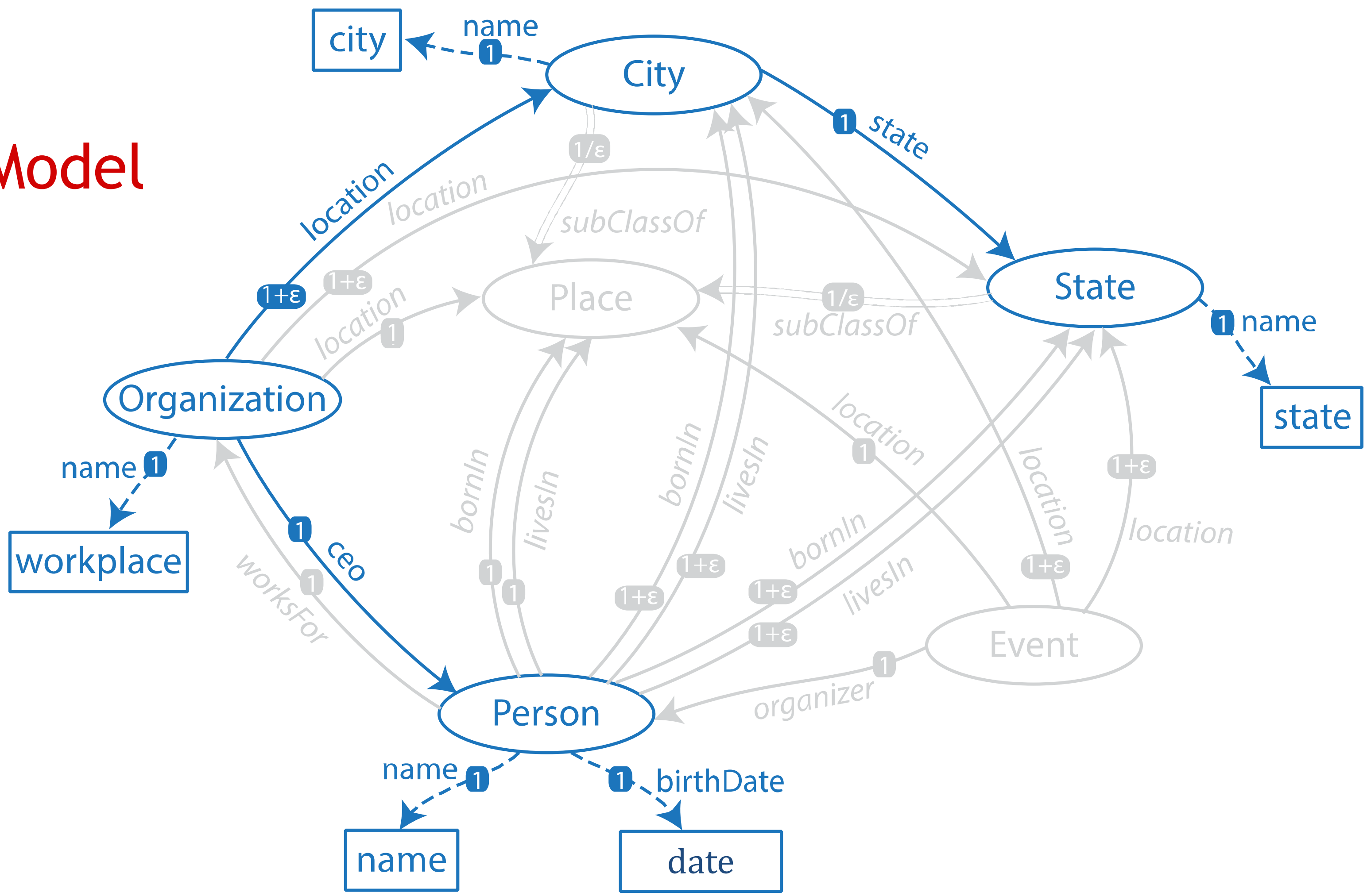
5. remove extra links until all leaves are Steiner nodes

Determine Relationships

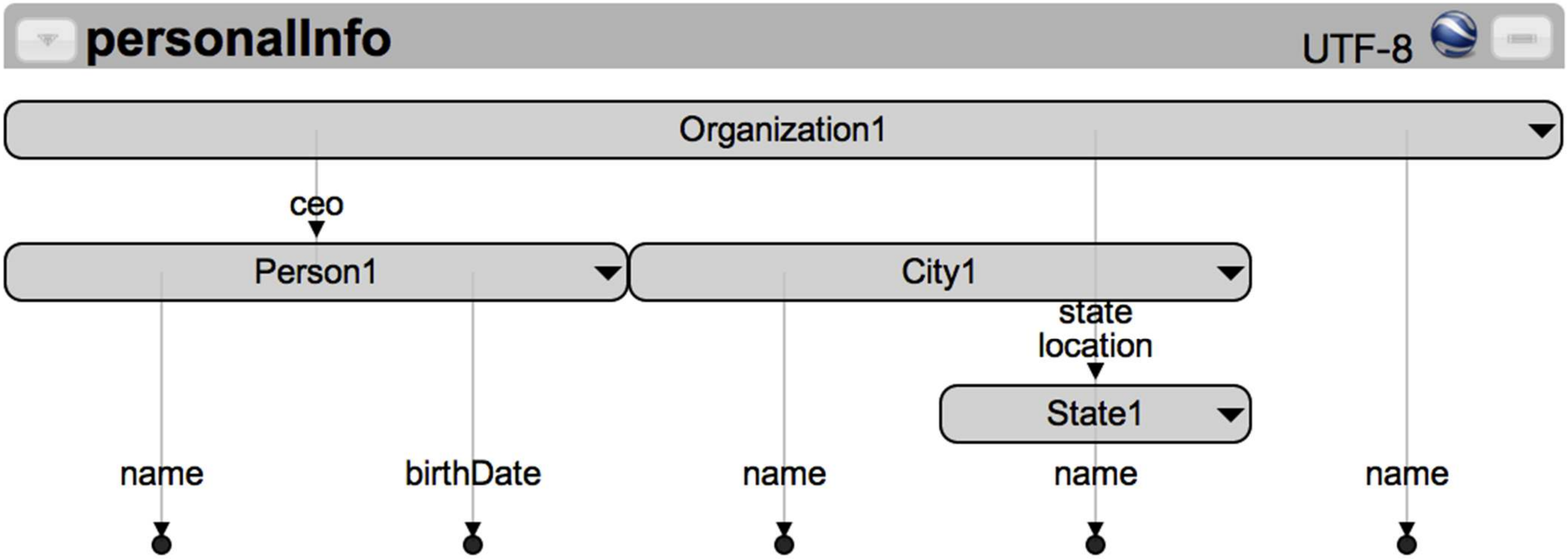
Select minimal tree that connects all semantic types

- A customized **Steiner tree algorithm** [Kou & Markowsky, 1981]

Initial Model



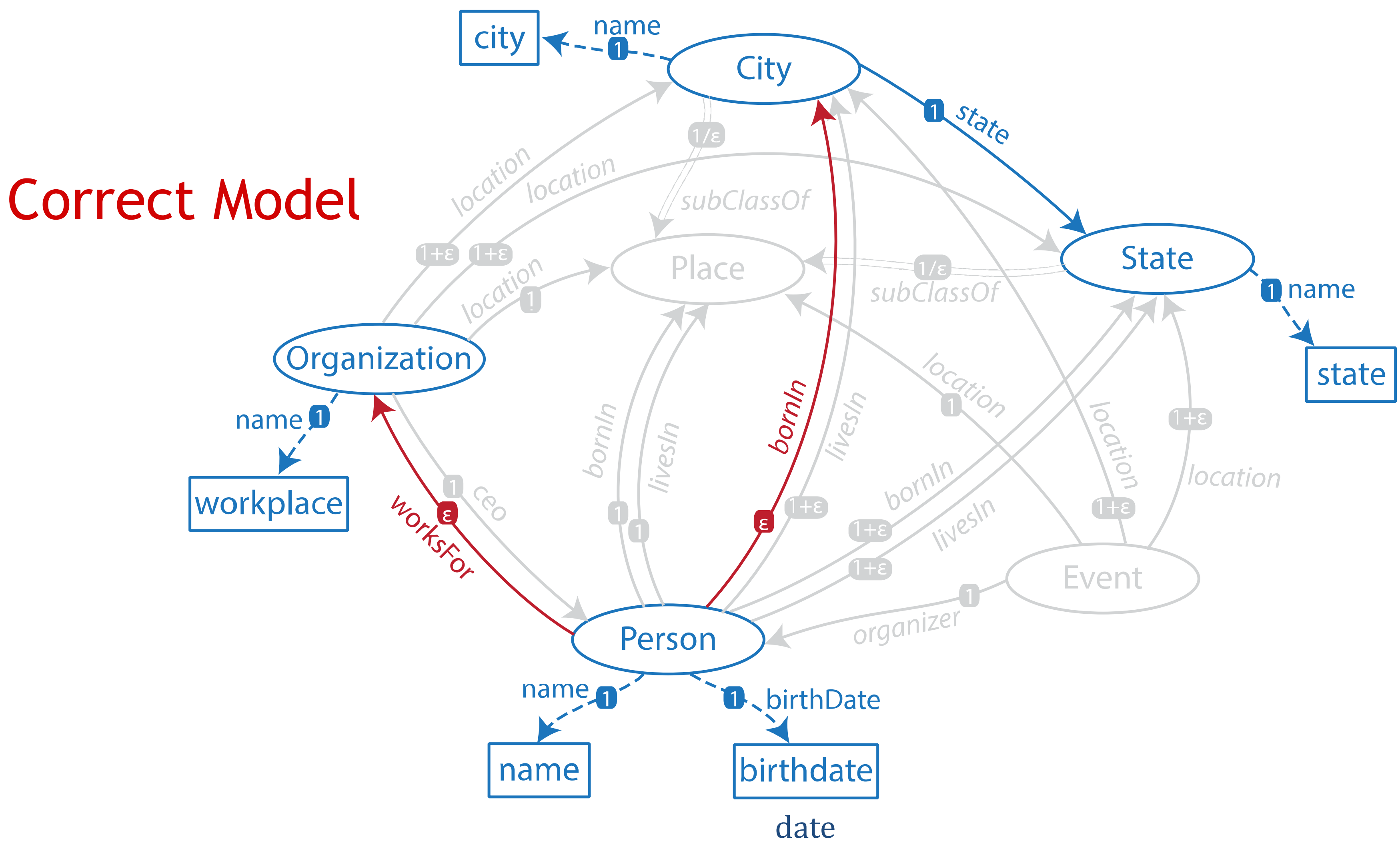
Result in Karma



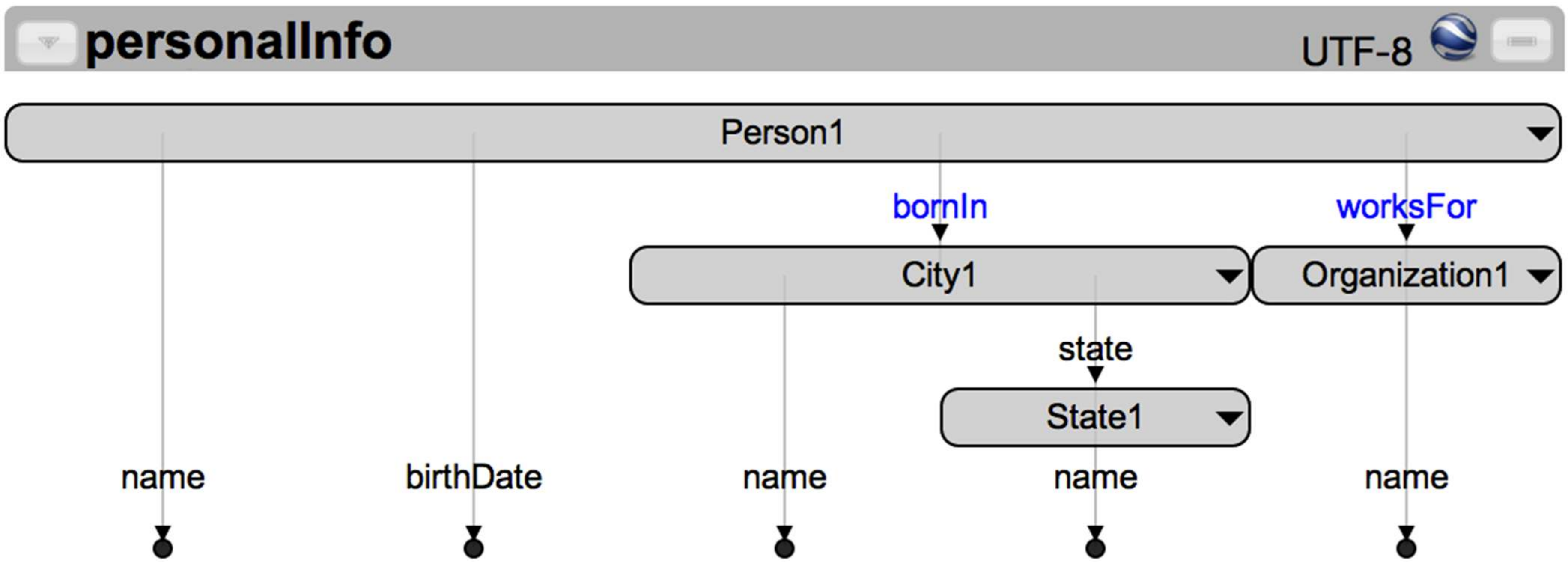
name	date	city	state	workplace
Fred Collins	Oct 1959	Seattle	WA	Microsoft
Tina Peterson	May 1980	New York	NY	Google
Richard Smith	Feb 1975	Los Angeles	CA	Apple

Refining the Model

Impose constraints on Steiner Tree Algorithm

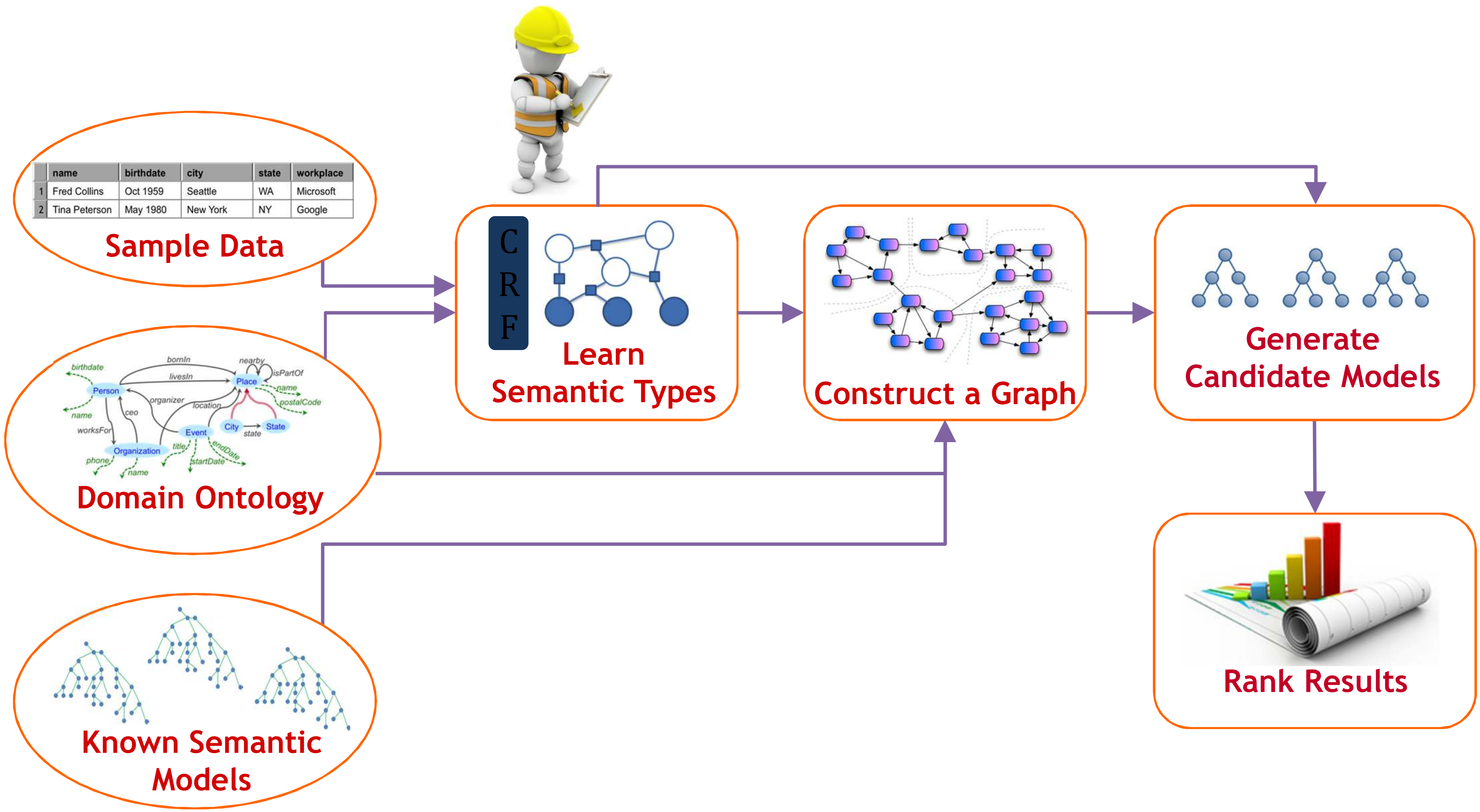


Final Semantic Model



name	date	city	state	workplace
Fred Collins	Oct 1959	Seattle	WA	Microsoft
Tina Peterson	May 1980	New York	NY	Google
Richard Smith	Feb 1975	Los Angeles	CA	Apple

Improved Approach
Taheriyan et al., ISWC 2013, ICSC 2014



Results on 17 Geospatial Sources

Source Signature	#Attributes	GED	
		Previous work	Current Approach
nearestCity(lat, lng, city, state, country)	5	6	1
findRestaurant(zipcode, restaurantName, phone, address)	4	1	0
zipcodesInCity(city, state, postalCode)	3	3	1
parseAddress(address, city, state, zipcode, country)	5	6	1
citiesOfState(state, city)	2	1	0
ocean(lat, lng, name)	3	2	1
postalCodeLookup(zipCode, city, state, country)	4	6	1
country(lat, lng, code, name)	4	2	0
companyCEO(company, name)	2	1	0
personalInfo(firstname, lastname, birthdate, brithCity, birthCountry)	5	4	1
businessInfo(company, phone, homepage, city, country, name)	6	10	8
restaurantChef(restaurant, firstname, lastname)	3	2	1
findSchool(city, state, name, code, homepage, ranking, dean)	7	8	6
employees(organization, firstname, lastname, birthdate)	4	1	2
education(person, hometown, homecountry, school, city, country)	6	9	4
administrativeDistrict(city, province, country)	3	4	1
capital(country, city)	2	2	1
TOTAL	**68**	**68**	**29**

57% improvement

GED = Graph Edit Distance

Results on 6 Museum Sources

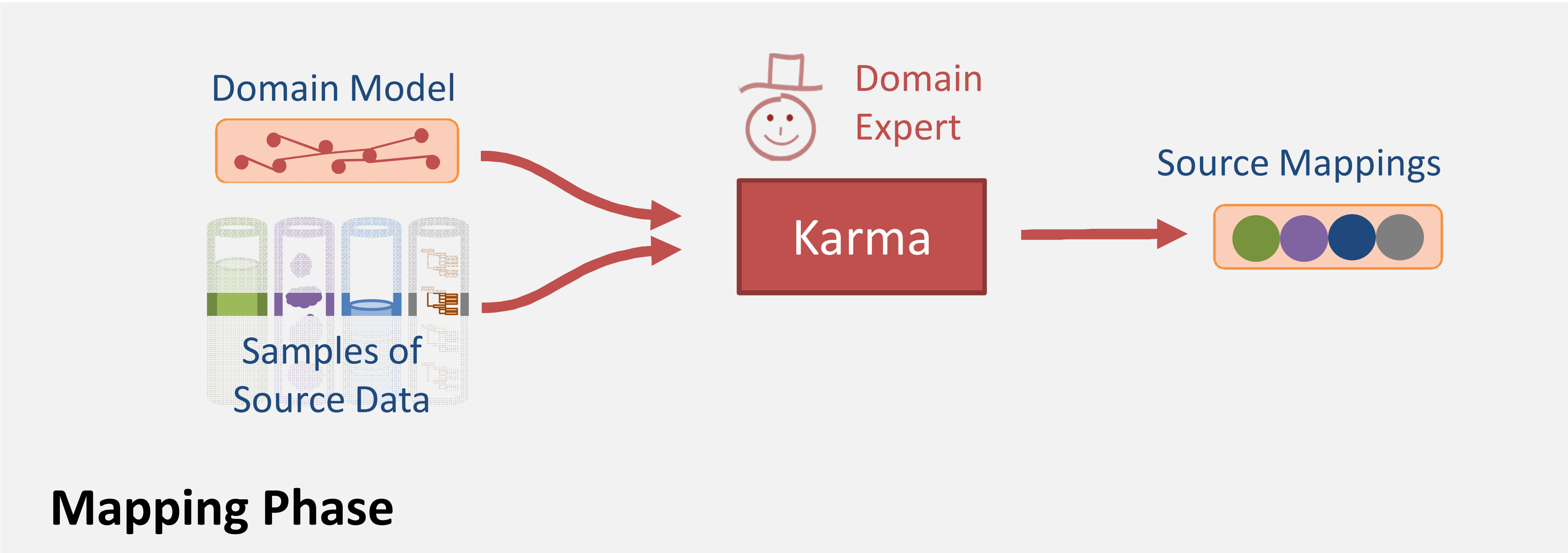
Source Signature	#Attributes	GED	
		Previous work	Current Approach
S1(Attribution, BeginDate, EndDate, Title, Dated, Medium, Dimensions)	7	1	0
S2(ObjectID, ObjectTitle, ObjectWorkType, ArtistName, ArtistBirthDate, ArtistDeathDate, ObjectEarliestDate, ObjectRights, ObjectFacetValue1)	9	2	3
S3(death, birth, name)	3	0	0
S4(accessionNumber, artist, creditLine, dimensions, imageURL, materials, relatedArtworksURL, creationDate, provenance, keywordValues)	10	9	6
S5(AccessionNumber, Classification, CreditLine, Date, Description, DimensionsOrphan, WhatValues, Who, image, relatedArtworksValues)	10	9	5
S6(Artist, ArtistBornDate, ArtistDiedDate, Classification, Copyright, CreditLine, Image, KeywordValues, Ref, SitterValues)	10	8	6
TOTAL	**49**	**29**	**20**

GED = Graph Edit Distance

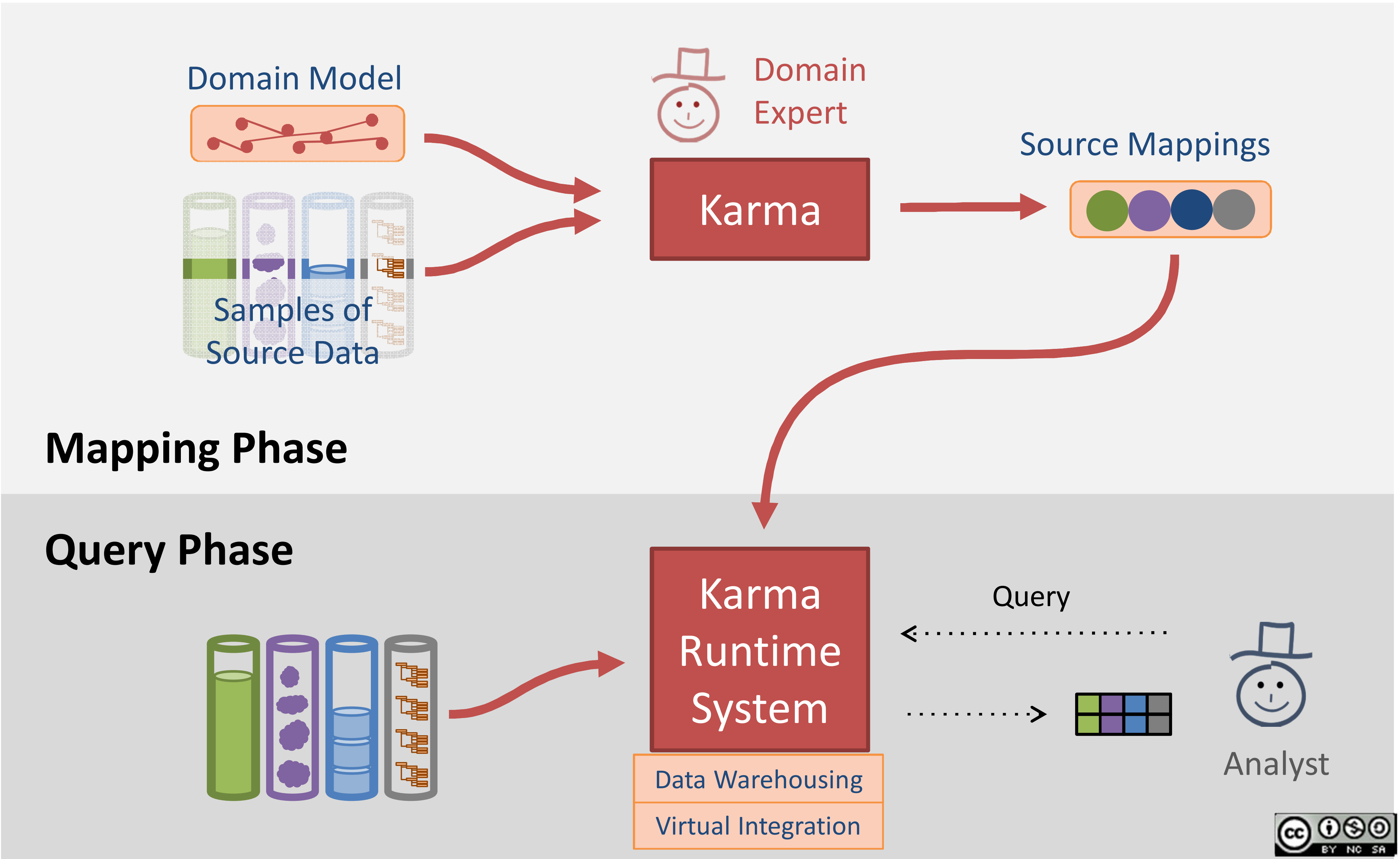
31% improvement

Karma Use Cases

Source Mapping Phase



Source Mapping and Query Time



Related Work

- Mapping Databases into RDF
  - D2R & R2R [Bizer & Cyganiak, 2006, Bizer & Shultz, 2010]
  - Semion [Nuzzolese, Gangemi, Presutti, & Ciancarini, 2010]
    - Maps a database into RDF using the DB schema
    - Mannually defines the mappings of triples to another ontology
- Ontology Matching
  - [Doan et al., 2000]
    - Learn mappings to the ontology using data, but would be analogous to just doing the semantic typing
- Schema Matching
  - [Rahm et al., 2001]
    - Generates alignments between schemas, not a fine-grained model of the data
- Schema mapping
  - Interactively builds detailed mappings, but limited to relational data (Clio [Fagin et al., 2009])
- Semantic Integration of Bioinformatics Data
  - Bio2RDF [Belleau et al., 2008]
    - Manual conversion of sources into RDF

Links

http://www.isi.edu/integration/karma/