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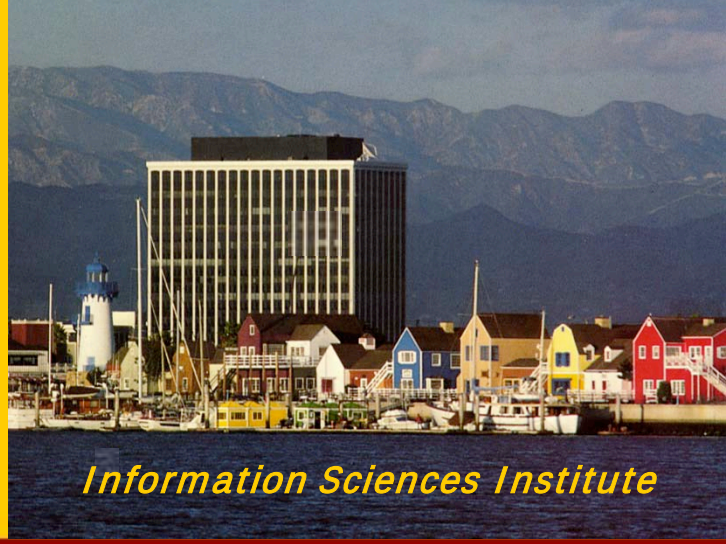


# Exploiting Semantics of Web Services for Geospatial Data Fusion

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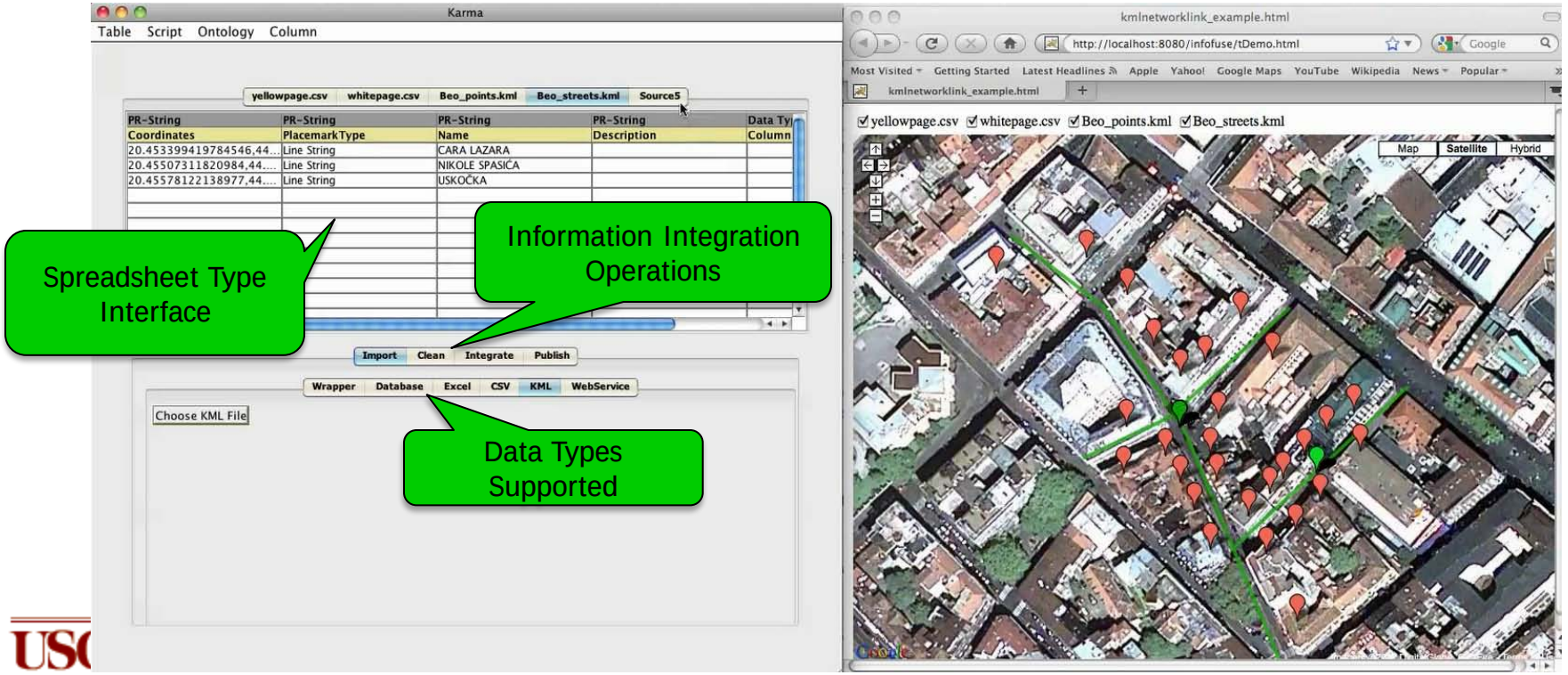
# Introduction



- Decision makers have lots of data available
  - Satellite imagery
  - Street maps
  - Structured online sources (e.g., phone books)
  - Cyber data (e.g., domain registration sites)
  - Social network data (e.g., facebook)
- Difficult to fuse this information into an integrated view
  - Even harder to apply various reasoning techniques
- Our goal
  - An integration framework where users can interactively fuse geospatial and other types of data

# KARMA: A General Information Integration Tool

- Karma [R. Tuchinda, C. A. Knoblock, P. Szekely, Building mashups by demonstration, 2011]
- A fusion-by-example approach for extracting, modeling, cleaning and integrating geospatial sources
  - Does not require any programming or widget knowledge.
  - Focus on data, not on the process
  - Users specify fusion tasks by examples
  - Fusion results automatically displayed on a map



# Motivating Example



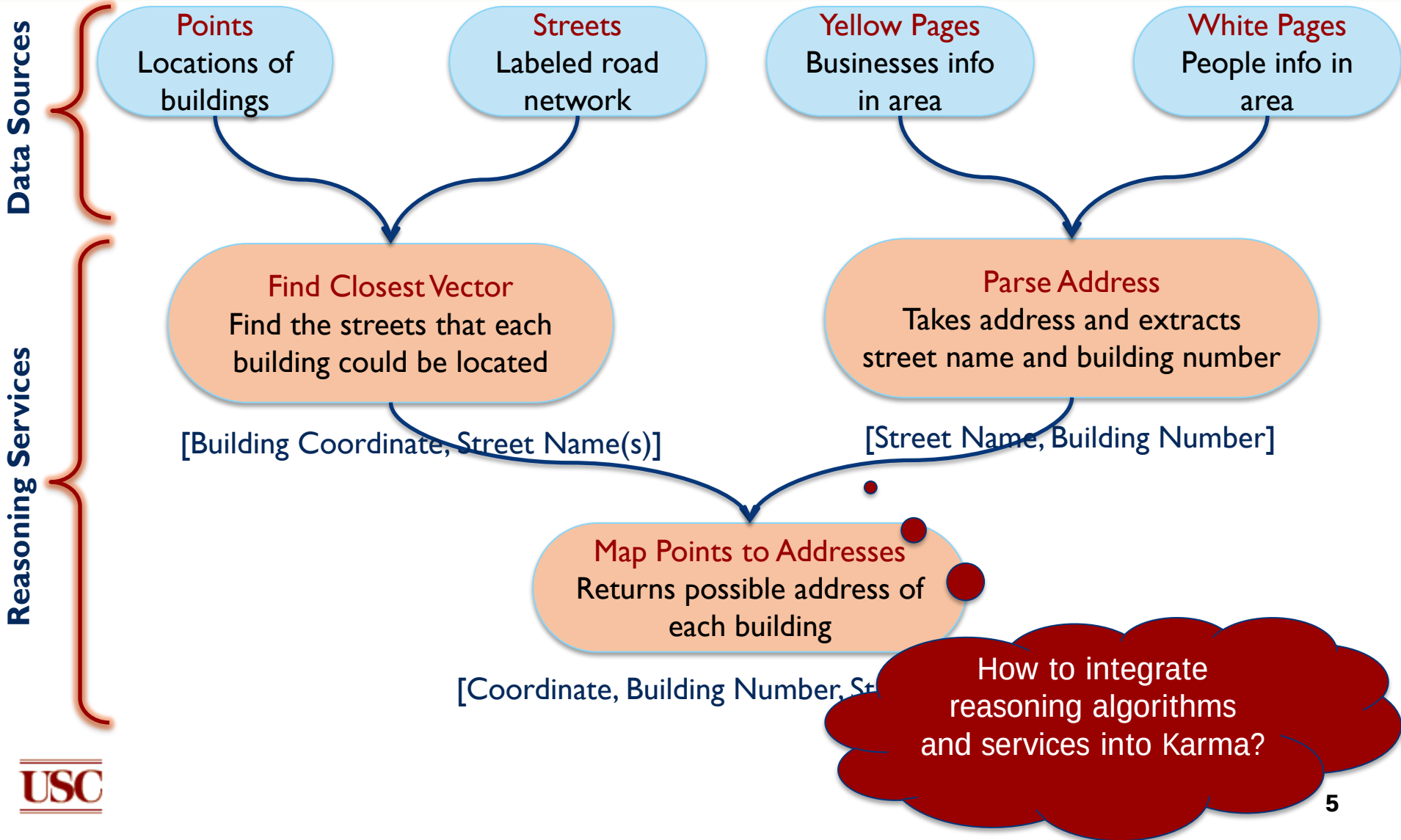
- Problem: Identify the address associated with each building that can be identified in the satellite imagery

Before


After

- **Solution:**
  - Step 1: Identify the street vector data, building locations and the phonebook data for the given area (data retrieval task)
  - Step 2: Reasoning over the data to generate a mapping between the addresses and building locations (geospatial reasoning task)

# Motivating Example (cont.)



# Karma's Approach



- Build a semantic model of reasoning services based on provided ontology
  - Data types of inputs and outputs, plus relationships between them
- Interactively invoke services using semantic model of sources and services
  - Which services can be invoked using available data?
  - Which sources can satisfy service inputs?
- Integrate outputs of service invocation with the other data

# Importing Sources

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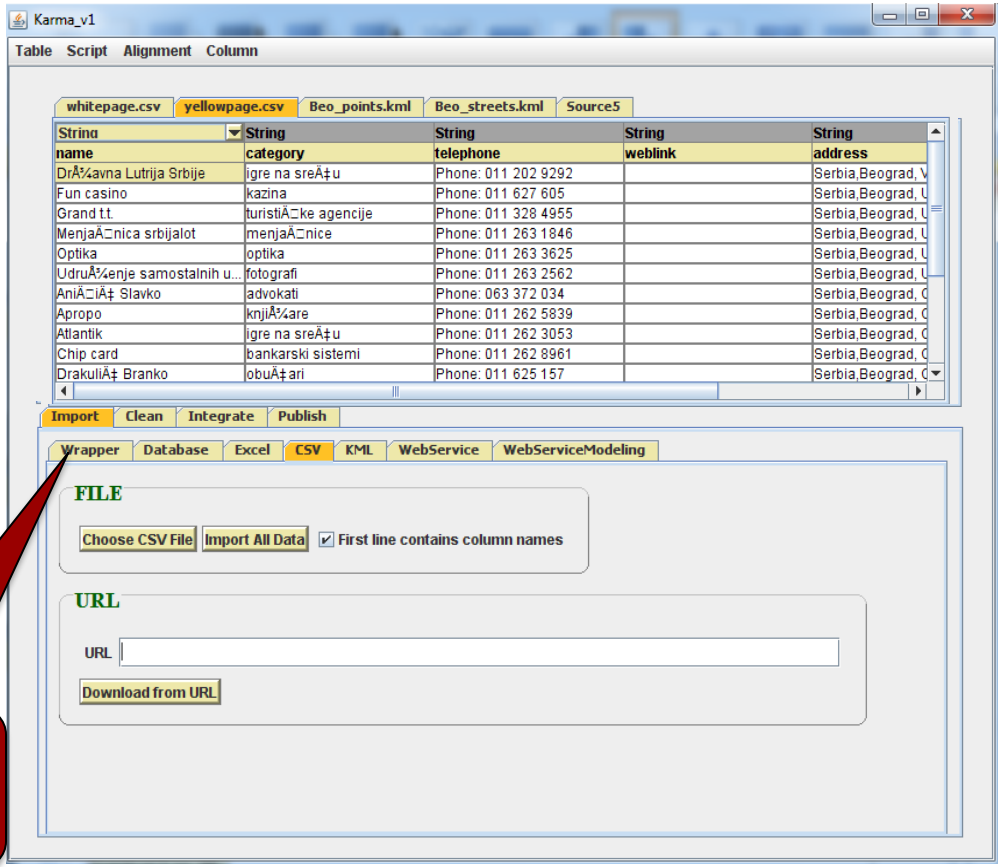


Karma uses wrappers to extract web pages information

# Data Cleaning

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whitepage.csv | Source2 | Cleaning Table

| String | Data Type | Dat |
|---|---|---|
| Column Name | User Defined Values | Fina |
| CARA LAZARA 15/2,BEOGRAD | CARA LAZARA 15/2.BEOGRAD | |
| CARA LAZARA 13/21,BEOGRAD | | |
| NIKOLE SPASIĆA 2,BEOGRAD | | |

User provides examples of address without  

Karma uses learned transformation rules to remove all instances of  

whitepage.csv | Source2 | Cleaning Table

| String | Data Type | Dat |
|---|---|---|
| Column Name | User Defined Values | Fina |
| CARA LAZARA 15/2,BEOGRAD | CARA LAZARA 15/2,BEOGRAD | |
| CARA LAZARA 13/21,BEOGRAD | CARA LAZARA 13/21,BEOGRAD | |
| NIKOLE SPASIĆA 2,BEOGRAD | NIKOLE SPASIĆA 2.BEOGRAD | |

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# Source Modeling



- Karma automatically builds models of data according to provided ontology
  - Models help user to process data and integrate them
- Identify the semantic types
  - Supervised machine learning technique (CRF Model)
    - A. Goel, C. A. Knoblock, K. Lerman, Using conditional random fields to exploit token structure and labels for accurate semantic annotation, 2011
- Identify relationships among the data columns
  - Find the minimal tree that connects the semantic types
    - C. A. Knoblock, P. Szekely, J. L. Ambite, S. Gupta, A. Goel, M. Muslea, K. Lerman, Interactively Mapping Data Sources into the Semantic Web, 2011

# Modeling YellowPages Source

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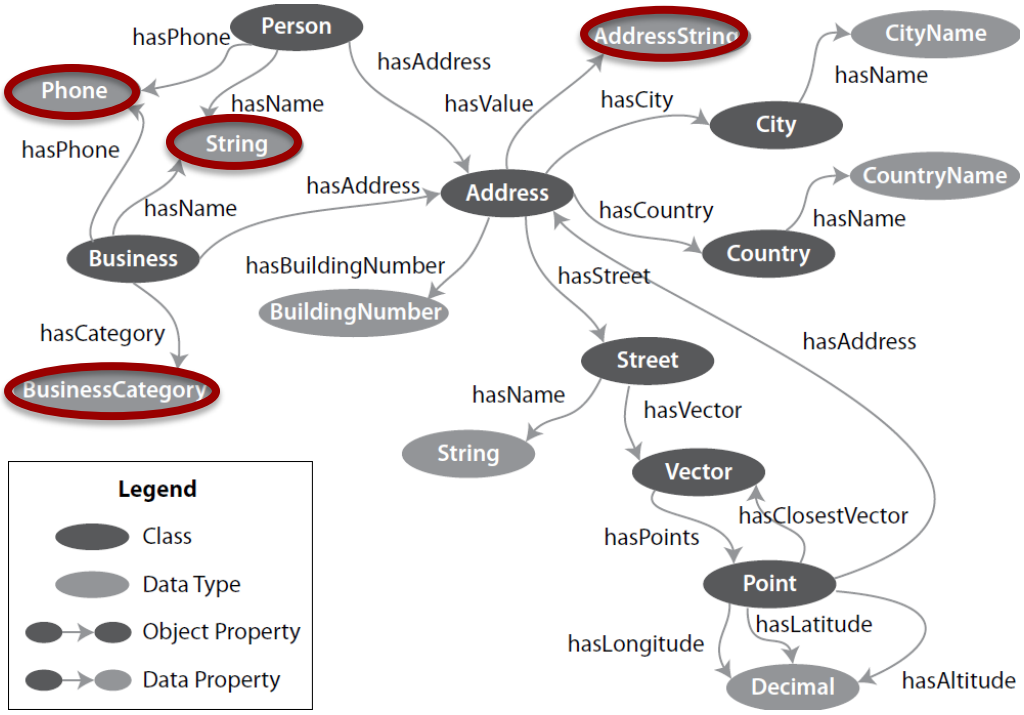
1. Karma uses CRF technique to assign labels to each data column




Semantic Types

| String | BusinessCategory | AddressString | Phone |
|---|---|---|---|
| name | category | address | telephone |
| Državna Lutrija Srbije | igre na sreću | Serbia,Beograd, Vračar, Uskoč... | Phone: 011 202 9292 |
| Fun casino | kazina | Serbia,Beograd, Uskočka 4 | Phone: 011 627 605 |
| Grand t.t. | turističke agencije | Serbia,Beograd, Uskočka 7 | Phone: 011 328 4955 |
| Menjačnica srbijalot | menjačnice | Serbia,Beograd, Uskočka 4 | Phone: 011 263 1846 |

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# Modeling YellowPages Source

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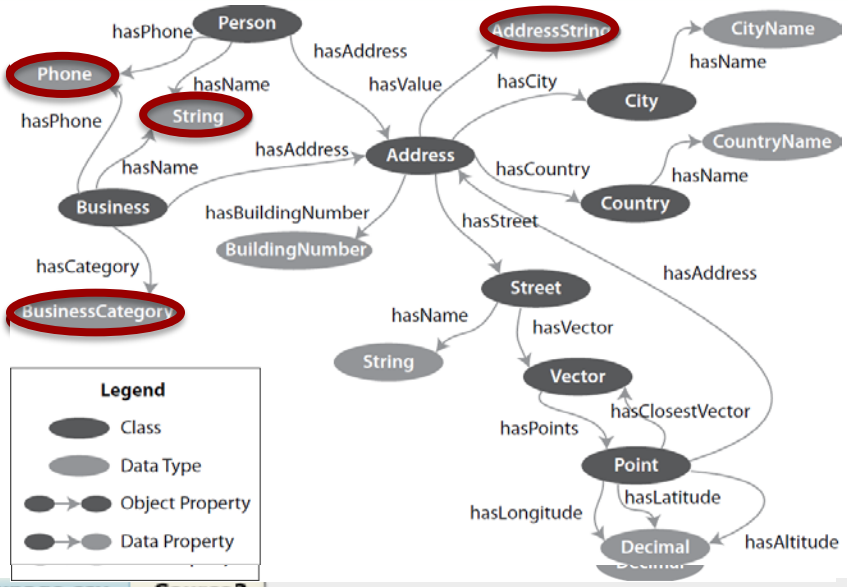
II. Karma selects the smallest tree that connects these semantic types and shows it at the top of the data worksheet.




Relationships between columns

yellowpage.csv | Source2

**Business**

| (hasName) String | (hasCategory) BusinessCategory | (hasAddress) Address / (hasValue) AddressString | (hasPhone) Phone |
|---|---|---|---|
| **String** | **BusinessCategory** | **AddressString** | **Phone** |
| **name** | **category** | **address** | **telephone** |
| Državna Lutrija Srbije | igre na sreću | Serbia,Beograd, Vračar, Uskoč... | Phone: 011 202 9292 |
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# Modeling Web Services

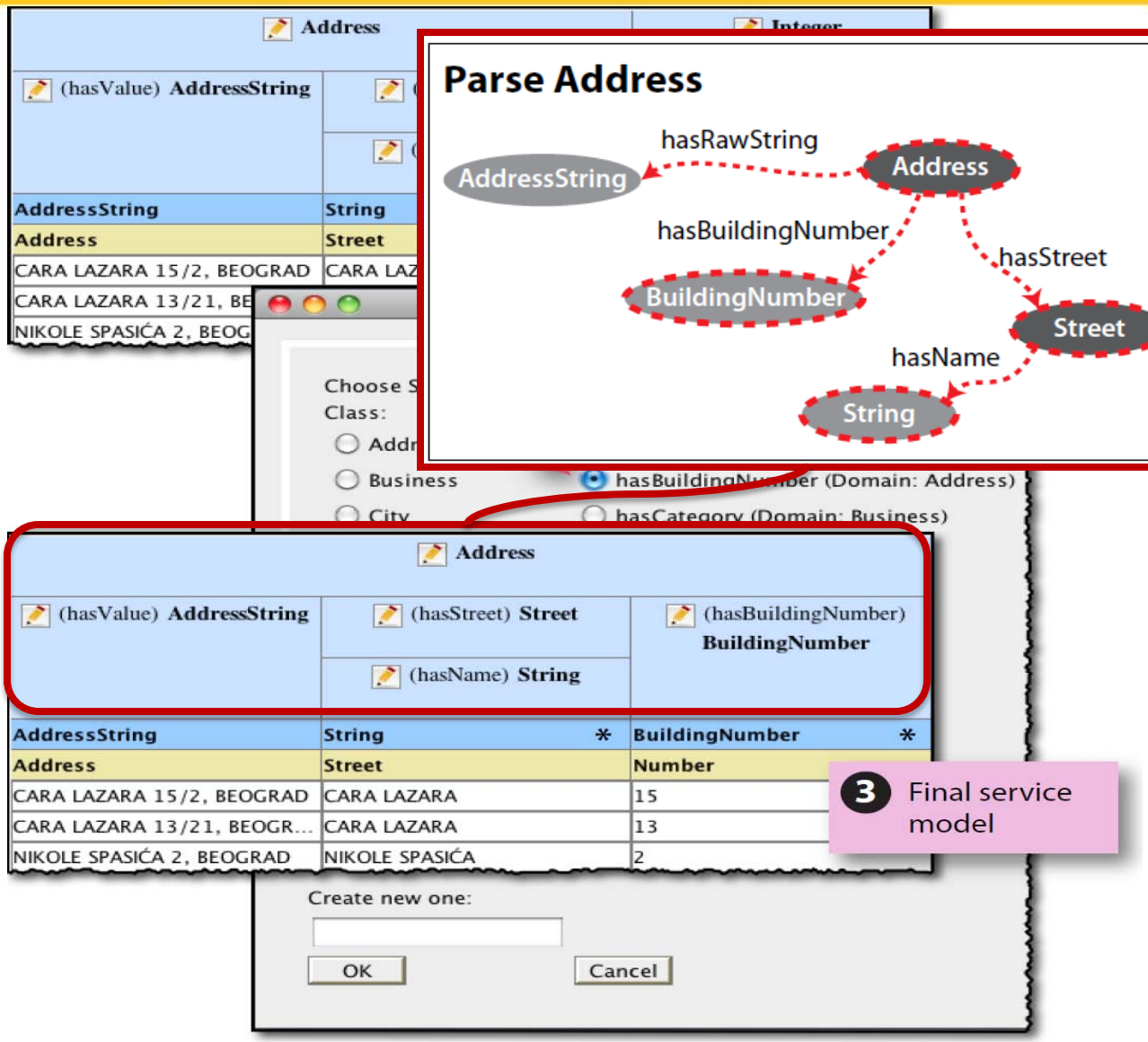


- Semantic models of web services facilitate service invocation, discovery, and composition

- Karma allow the user to interactively build a model
  - User provides examples of service input and output
  - Modeling services can be done like data sources

# Modeling of Parse Address Service in Karma



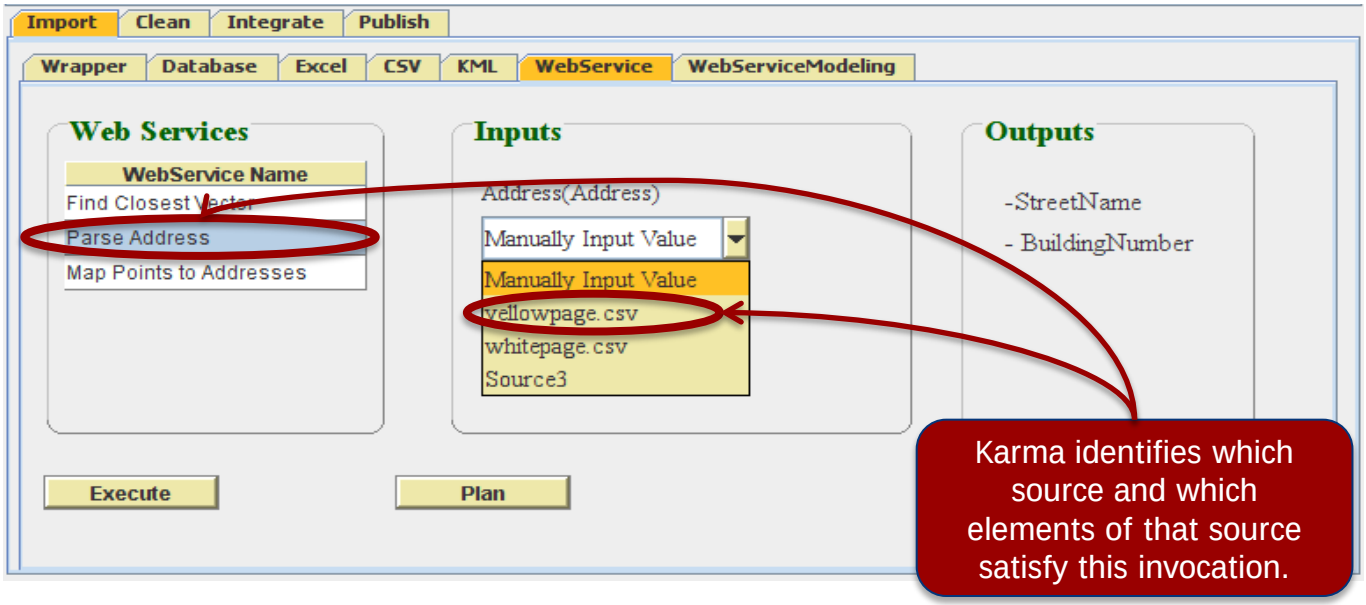


# Data Fusion



- Ability for users to interactively invoke services on other data sources

- Semantic models make it possible to:
  - Automatically determine which services apply to the available data
  - Perform automatic transformations on data to get it into the required format to apply a service
  - Automatically compose services and sources to generate required data



# Matching Sources and Services

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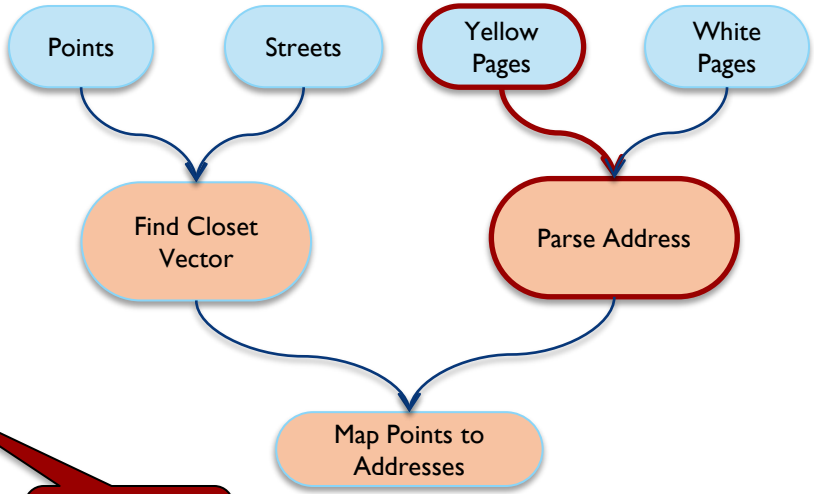
Yellow Pages

yellowpage.csv | Source2

Business

| (hasName) String | (hasCategory) BusinessCategory | (hasAddress) Address / (hasValue) AddressString | (hasPhone) Phone |
|---|---|---|---|
| String | BusinessCategory | AddressString | Phone |
| name | category | address | telephone |
| Državna Lutrija Srbije | igre na sreću | Serbia,Beograd, Vračar, Uskoč... | Phone: 011 202 9292 |
| Fun casino | kazina | Serbia,Beograd, Uskočka 4 | Phone: 011 627 605 |
| Grand t.t. | turističke agencije | Serbia,Beograd, Uskočka 7 | Phone: 011 328 4955 |
| Menjačnica srbijalot | menjačnice | Serbia,Beograd, Uskočka 4 | Phone: 011 263 1846 |

Input




Output

Address

| (hasValue) AddressString | (hasStreet) Street / (hasName) String | (hasBuildingNumber) BuildingNumber |
|---|---|---|
| AddressString | String | BuildingNumber |
| Address | Street | Number |
| CARA LAZARA 15/2, BEOGRAD | CARA LAZARA | 15 |
| CARA LAZARA 13/21, BEOGR... | CARA LAZARA | 13 |
| NIKOLE SPASIĆA 2, BEOGRAD | NIKOLE SPASIĆA | 2 |

Parse Address

# Invocation Results

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- Results of invocation are returned as another source that can be refined, integrated with other sources, visualized or published

GeoFusionResult | Source2

| Point | | |
|---|---|---|
| (hasLongitude) Decimal | (hasLatitude) Decimal | (hasAddress) Address<br>(hasValue) AddressString |
| Decimal | Decimal | AddressString |
| Longitude | Latitude | AddressList |
| 20.45329213142395 | 44.81892469068898 | 4-CARA LAZARA |
| 20.45383930206299 | 44.8189931839843 | 1-CARA LAZARA |
| 20.45408606529236 | 44.81883336616863 | 3-CARA LAZARA |
| 20.454246997833252 | 44.81861266464735 | 5-CARA LAZARA |
| 20.454407930374146 | 44.81848328750073 | 7-CARA LAZARA, 2A-NIKOLE... |
| 20.45408070087433 | 44.81826638986837 | 4-NIKOLE SPASICA |

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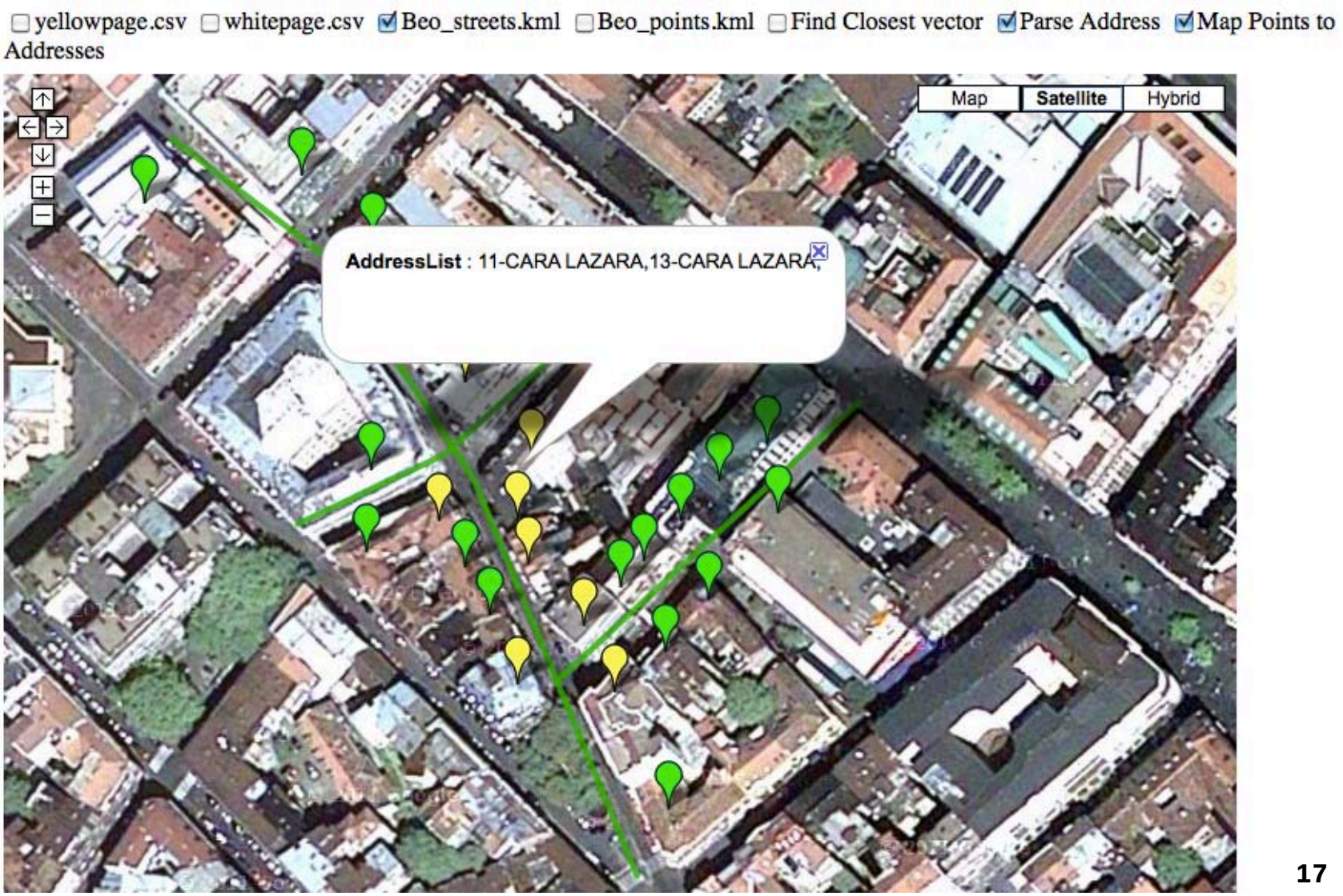
# Visualize Final output





# Related Work



- Exploit ontologies to attach semantics to geospatial services
  - [L. Di, et. al., 2006], [P. Yue, et. al. , 2010]
  - User has to manually annotate the services according to an ontology like OWL-S
  - They model input and output types but not relationship among them

- Linked Open Services (LOS)
  - [B. Norton, R. Krummenacher, 2010]
  - Services that consume linked data as input and also return linked data as output
  - Use SPARQL to describe service inputs and outputs
  - Describing services might be easy for Linked Data community, but not for average Internet users

- Google Fusion Tables
  - [H. Gonzalez, A. Halevy, et al. 2010]
  - Import data from various source types and invoke web services
  - Allows advanced visualization
  - Integrating data from different sources is possible but without exploiting semantics

# Discussion



- Karma allows users to quickly and easily dynamically fuse a wide variety of geospatial data sources
- Modeling geospatial services is a big step in geospatial data fusion
- Based on provided ontology, Karma semi-automatically builds a semantic model of reasoning services including both input/output datatypes and their relationships
- Semantic descriptions enable user to easily find the desired service and invoke it using available data sources

# Future Work



- Applying the service modeling techniques to available REST web services
  - Create the service model just based on service invocation samples
- Answer queries like "Can I have the street names of the cities whose distance to Los Angeles is less than 50 miles?"
  - Automatically compose available web services using loaded data sources
- Publishing semantic description of web services in formats such as LOS

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# More Information

ISI Information Sciences Institute

- More information available on Karma:
  - http://www.isi.edu/~knoblock
- Contact:
  - pszekely@isi.edu
  - knoblock@isi.edu
  - shubhamg@isi.edu
  - mohsen@isi.edu
  - bowu@isi.edu
- Software:
  - Software will be available as open source under the Apache license as soon as we complete the next version