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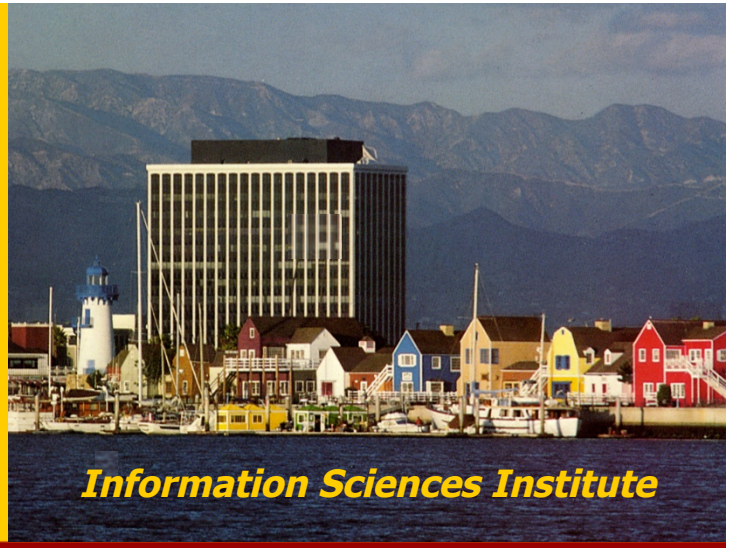

Exploiting Semantics of Web Services for Geospatial Data Fusion

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Introduction

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- 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

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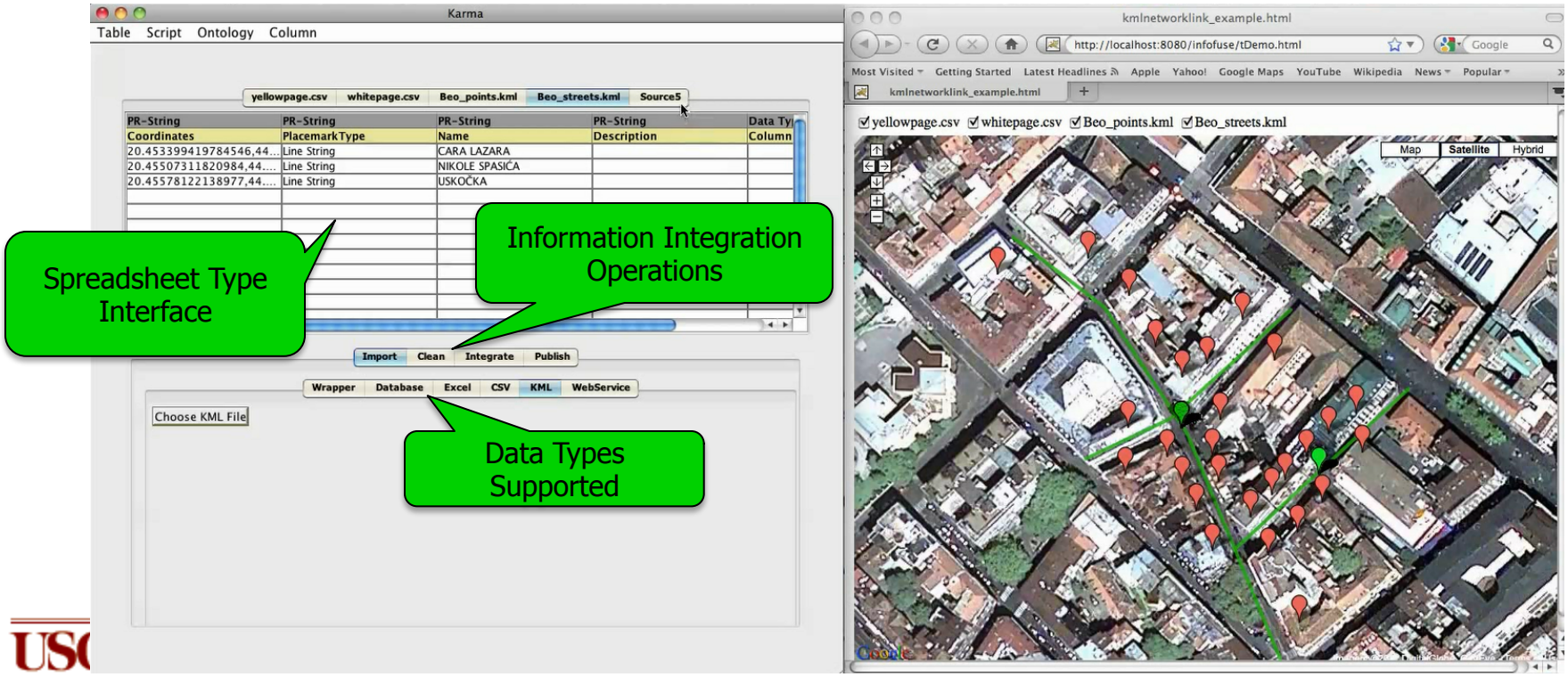
KARMA: A General Information Integration Tool

- 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



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Motivating Example

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- 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)

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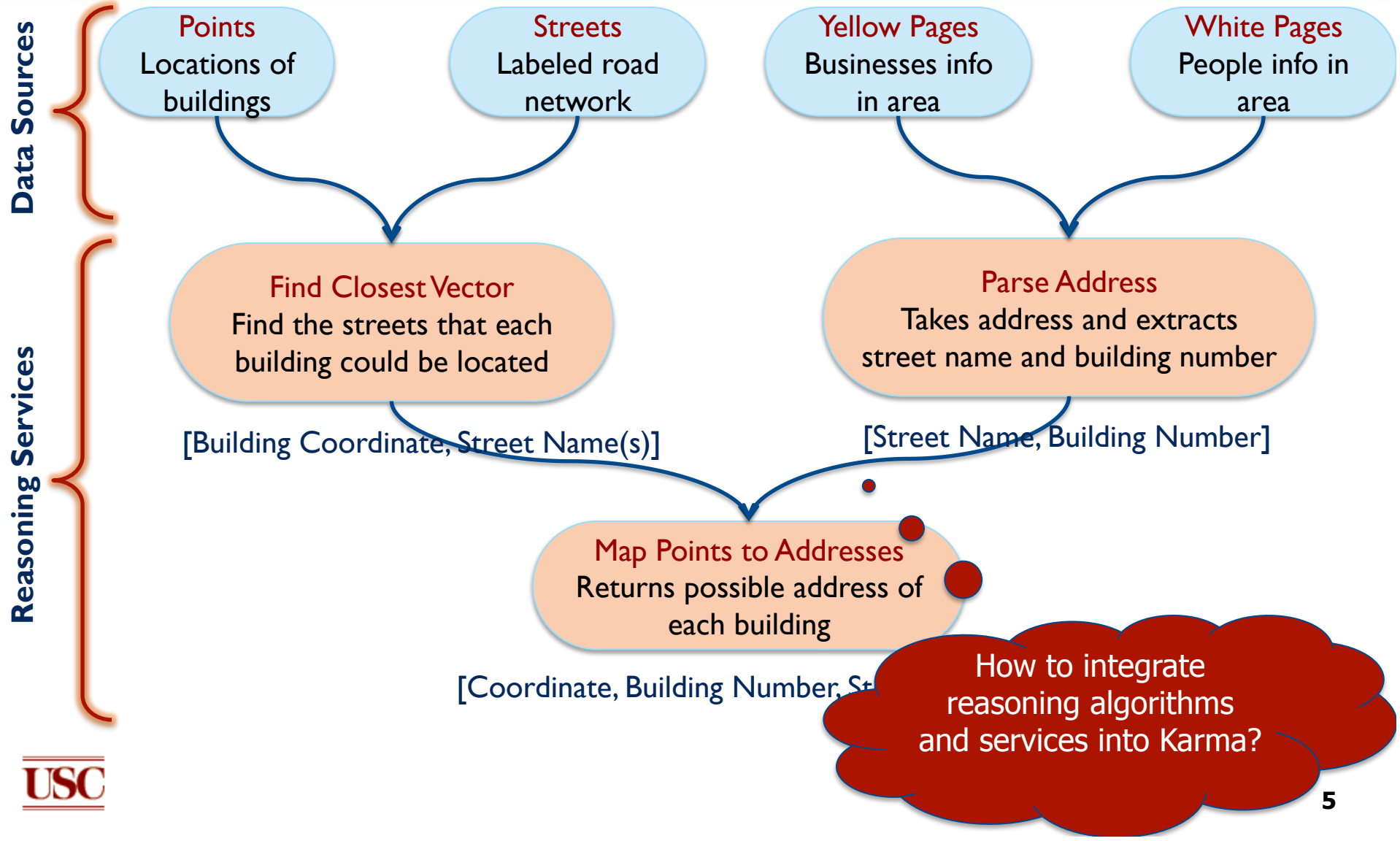
Motivating Example (cont.)



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Karma's Approach

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- 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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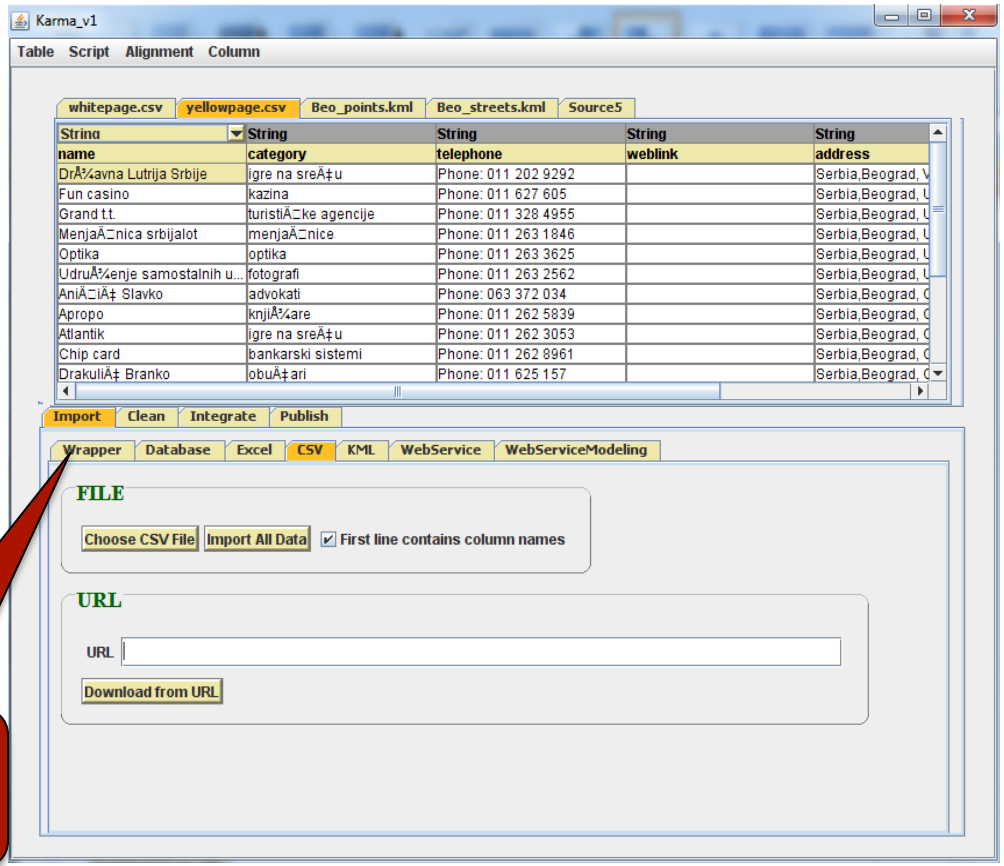

Karma uses wrappers to extract web pages information

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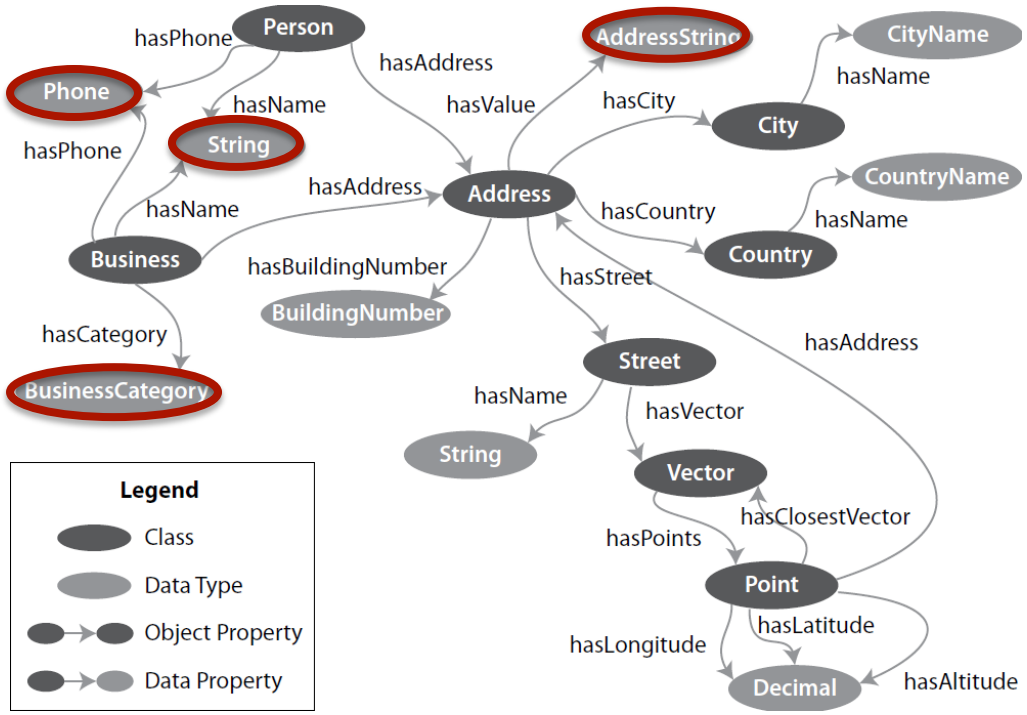
1. Karma uses CRF technique to assign labels to each data column



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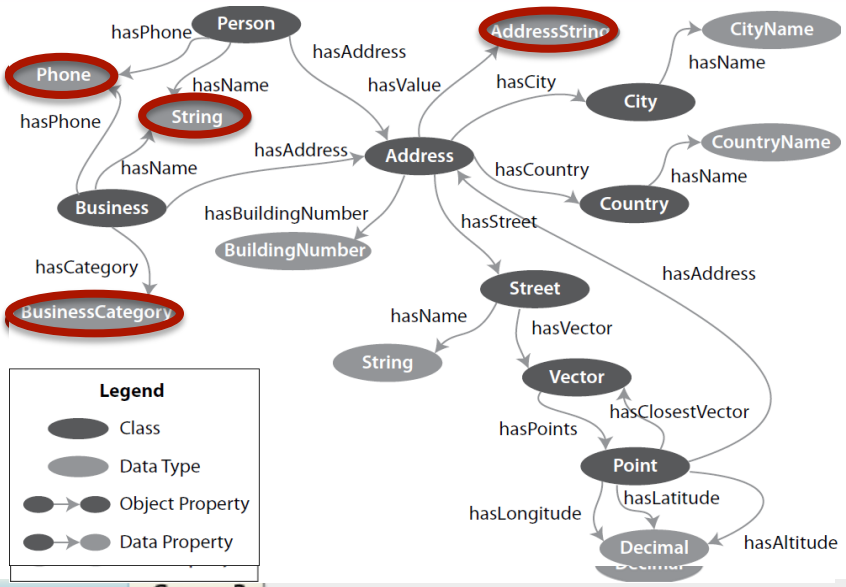
II. Karma selects the smallest tree that connects these semantic types and shows it at the top of the data worksheet.



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
Fun casino	kazina	Serbia,Beograd, Uskočka 4	Phone: 011 627 605
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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

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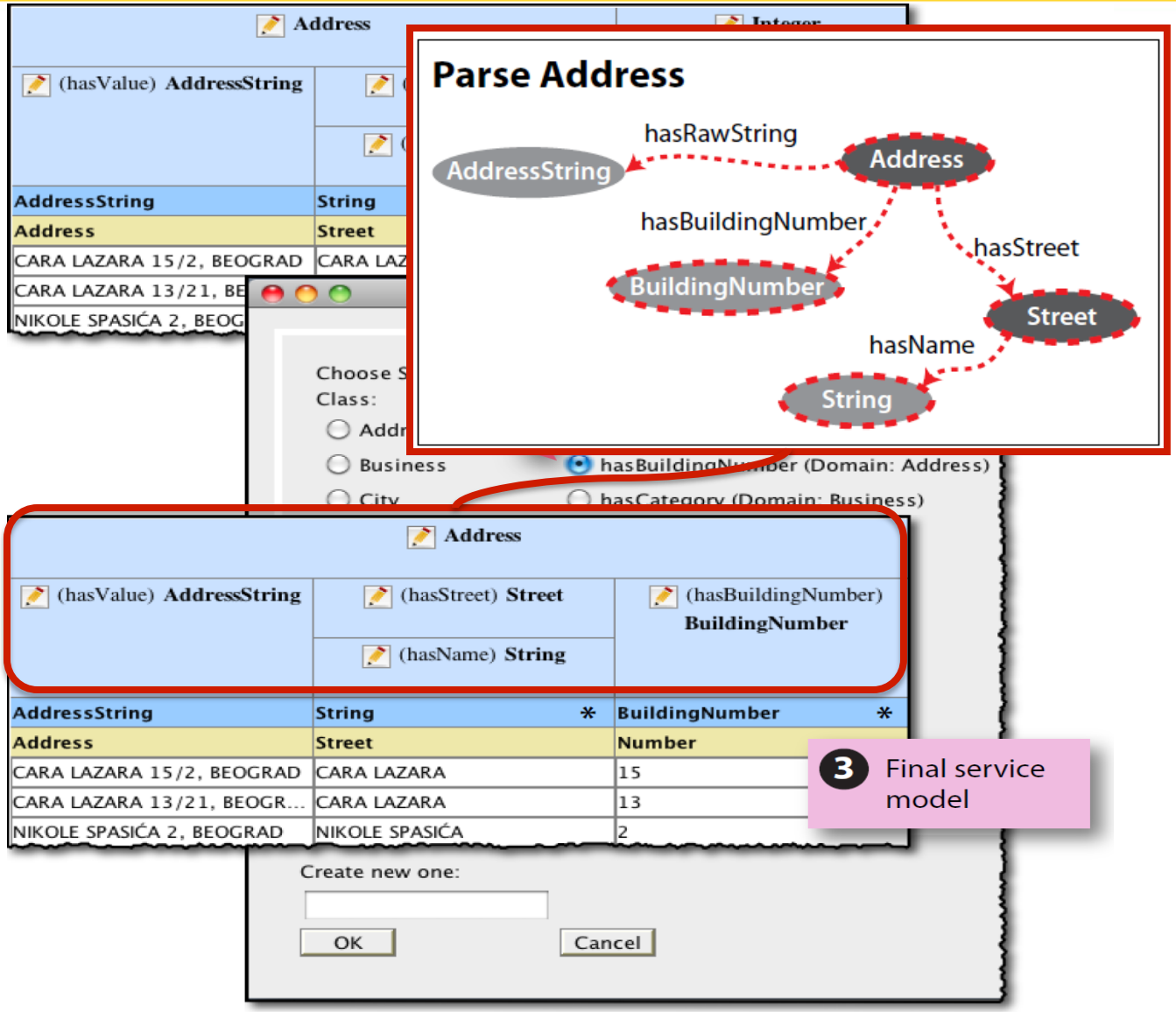
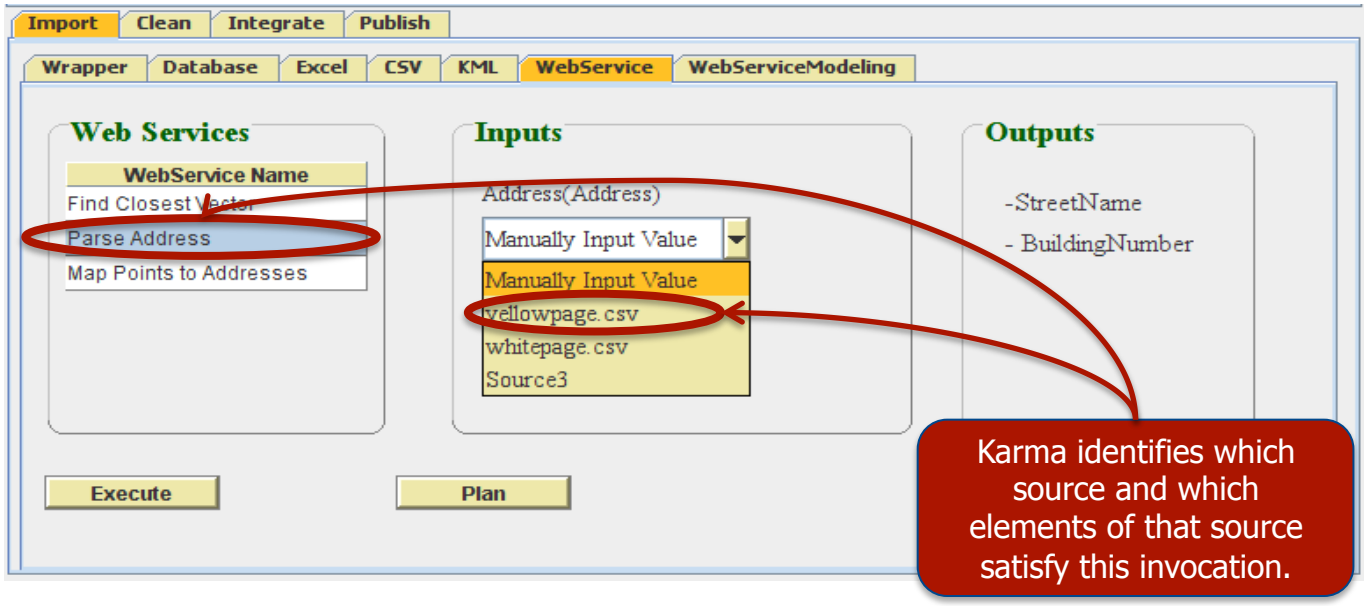


Data Fusion

- 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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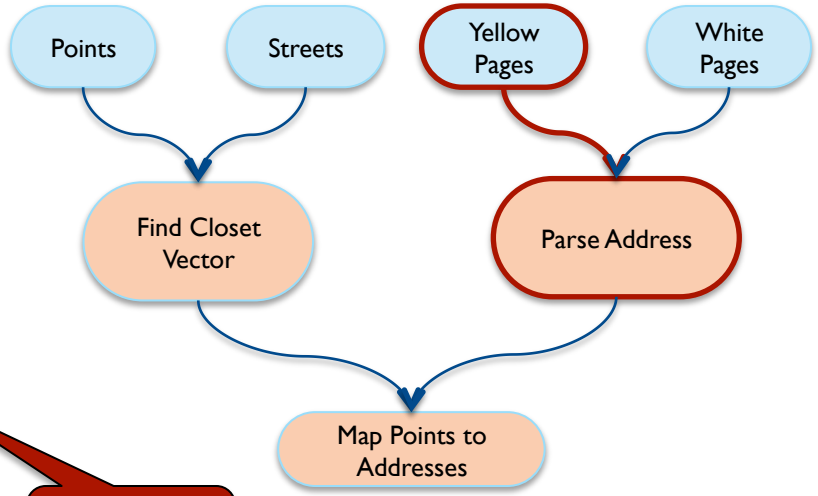
Yellow Pages

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

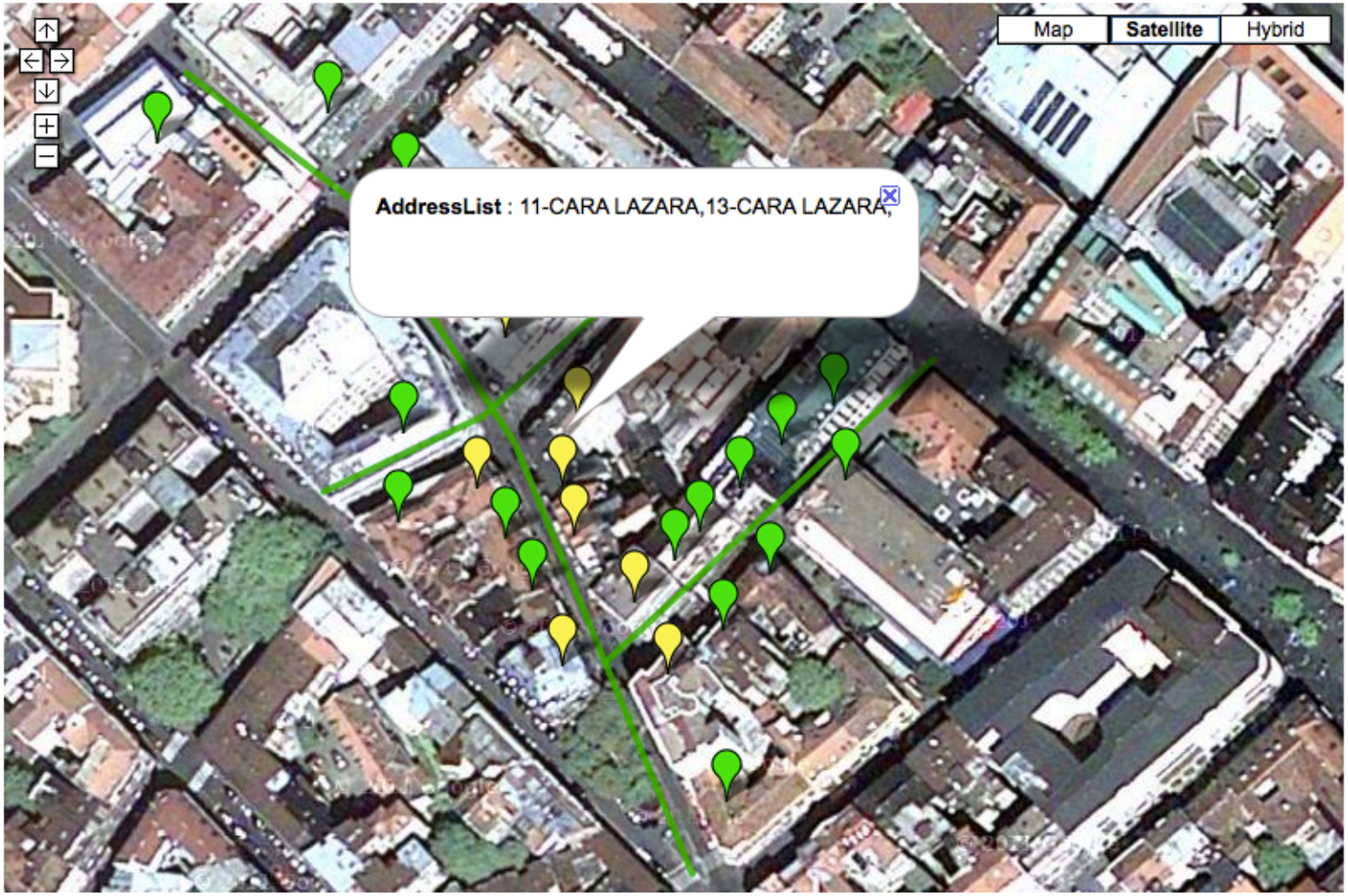
- Results of invocation are returned as another source that can be refined, integrated with other sources, visualized or published

GeoFusionResult | Source2

Point		
(hasLongitude) Decimal	(hasLatitude) Decimal	(hasAddress) Address (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

Visualize Final output

yellowpage.csv whitepage.csv Beo_streets.kml Beo_points.kml Find Closest vector Parse Address Map Points to Addresses



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Related Work

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- 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

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Discussion

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- 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

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Future Work

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- 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