

A Framework for Integrating and Reasoning about Geospatial Data

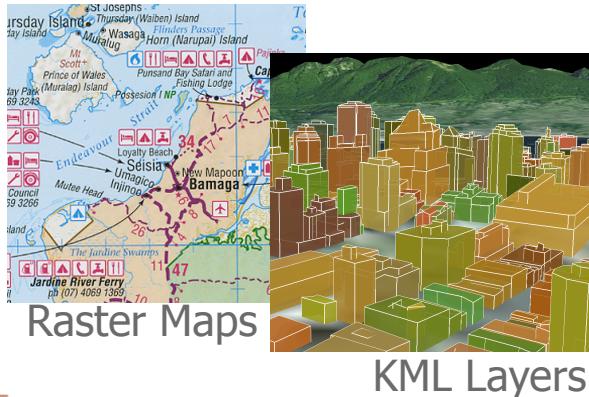
Shubham Gupta and Craig A. Knoblock
University of Southern California

MOTIVATION

- Large amount of geospatial data available



Mapping services



Raster Maps

KML Layers

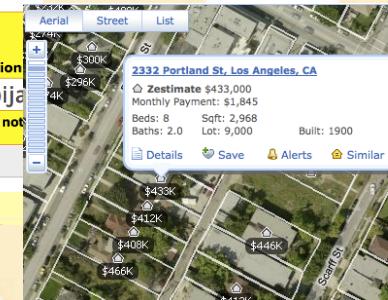
USC Traditional geospatial data sources



Web 2.0 based collaborative projects



Phonebooks



Property Records

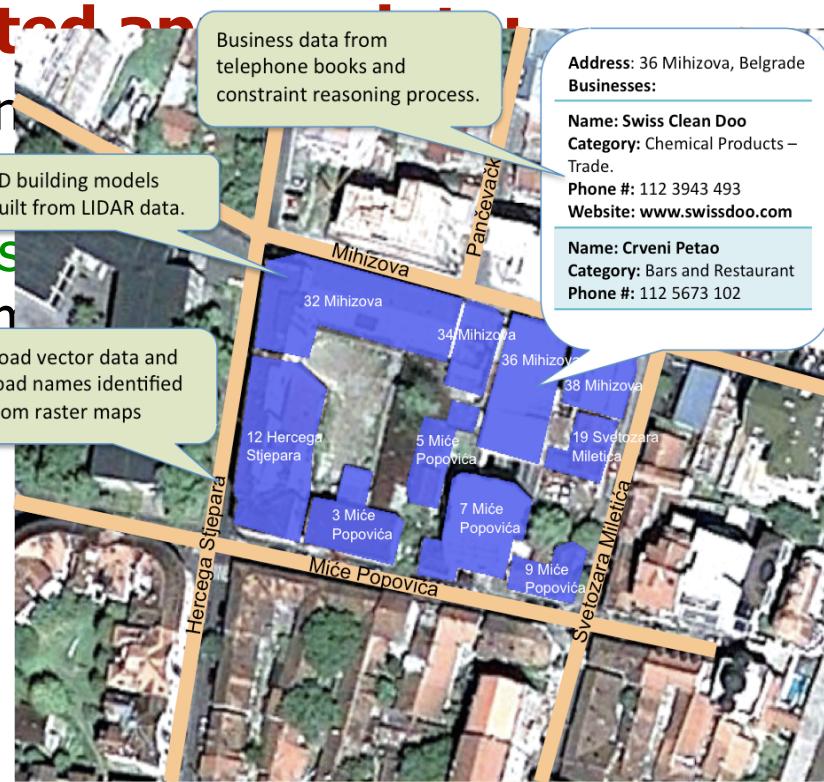
Online data sources

USING THE DATA TO UNDERSTAND A REGION

- To fully exploit these diverse geospatial data sources, we need a framework that provides an interactive and integrated approach.

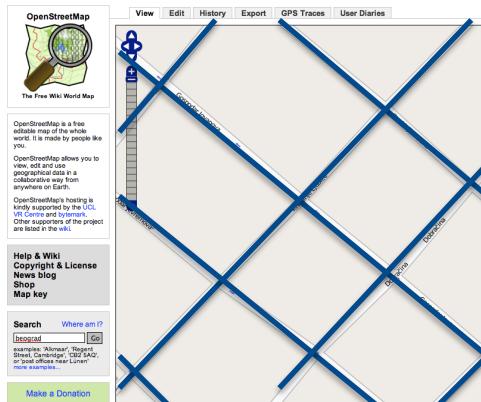
Example integration tasks that involve:

from these sources



DATA RETRIEVAL

- The data retrieval tasks involve gathering the available geospatial data



OpenStreetMap



Street vector data as KML layer

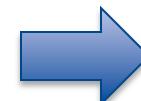
```
phoneBook.xml
<PhoneBookData>
  <Entry>
    <Name>ALABANDA, VLADETA</Name>
    <Address> USKOČKA 7, BEOGRAD</Address>
    <PhoneNumber> 011 2631495</PhoneNumber>
  </Entry>
  <Entry>
    <Name>ALABANDA, VLADETA</Name>
    <Address> USKOČKA 7/002, BEOGRAD</Address>
    <PhoneNumber>011 2621250</PhoneNumber>
  </Entry>
  <Entry>
    <Name>ANDRIĆ, MILETA</Name>
    <Address> USKOČKA 2, LAZAREVAC</Address>
    <PhoneNumber>011 8120911</PhoneNumber>
  </Entry>
  <Entry>
    <Name>BLAGOJEVIĆ, ZORAN</Name>

```

Phonebook data as XML file



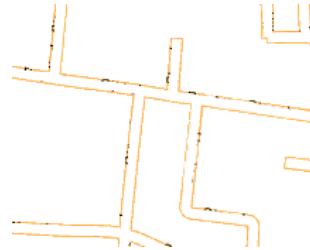
Phonebook website



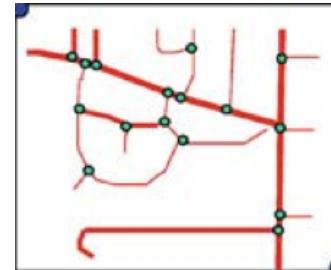
GEOSPATIAL REASONING PROCESSES

- Geospatial reasoning processes infer new and useful knowledge about a region by applying various reasoning methods over the integrated data.

Examples:



Extraction of road layers and text labels from raster map (Chiang et al. 2010)



Automatic conflating road vector data with orthoimagery (Chen et al. 2006)

A FRAMEWORK FOR INTEGRATING AND REASONING ABOUT GEOSPATIAL DATA

- **Various geospatial layers are integrated on top of a base layer, such as the satellite imagery for a given area**



- **The system imports other data into the system and converts them into a uniform representation:**
 - This uniform approach hides the heterogeneity present in the input data formats
- **The reasoning methods exploit the integrated data**
 - Supports interoperability of the reasoning methods on the input data
- **Results are presented on a map or image using this framework**

EXAMPLE: IDENTIFY BUILDINGS IN SATELLITE IMAGERY

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



Before



After

- **Approach:**

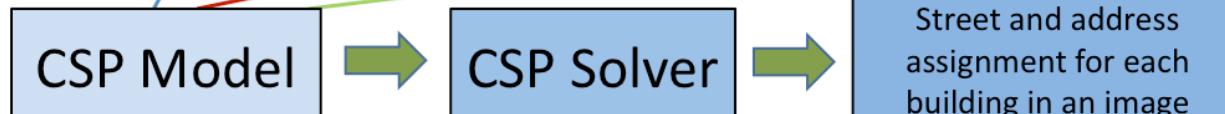
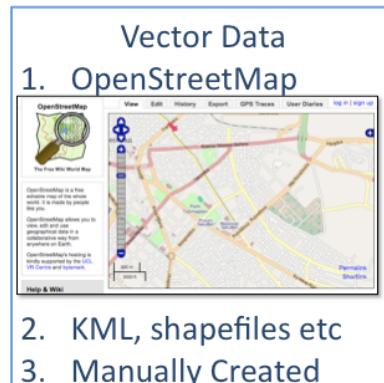
- Identify the street vector data, building locations and the phonebook data for the given area (**data retrieval task**)
- Reasoning using a CSP over the data to generate a mapping between the addresses and building locations (**geospatial reasoning task**)

PROBLEM: IDENTIFY BUILDINGS IN SATELLITE IMAGERY

- CSP Model formulation for building identification problem**

BID PROBLEM

- V is a set of variables, $V = \{V_1, V_2, \dots, V_n\}$ → Set of Buildings
- D is a set of variable domains (domain values) $D = \{D_{V_1}, D_{V_2}, \dots, D_{V_n}\}$ → Set of Addresses
- C is a set of constraints, $C = \{C_1, C_2, \dots, C_l\}$ → Set of Constraints
 $CV_a, V_b, \dots, V_i = \{(x, y, \dots, z)\} \subseteq DV_a \times DV_b \times \dots \times DV_i$
E.g. Addresses increases West



[Michalowski & Knoblock 2005]

INFOFUSE INTEGRATION SOFTWARE



STEP 1: SELECT AN AREA

Select an area on map using mouse

STEP 2: IDENTIFY STREETS

- Draw Street Manually [ADD MORE](#)
- Label Streets Manually
- Import KML File
- View Maps Online
- Load OpenStreetMaps Data

STEP 3: IDENTIFY BUILDING LOCATIONS

- Draw Points [DONE](#)
- Draw Polygon [ADD MORE](#)
- Import KML File
- Process LiDAR Data
- Import WikiMapia Layer

STEP 4: IDENTIFY BUILDING ADDRESSES

- Load Phone Book Data
- Predict Intersection Buildings
- Exploit Constraints
- Exploit Map Sources

OTHER OPTIONS

- [EXPORT KMLs](#)
- [SAVE CURRENT SESSION DATA](#)
- [LOAD PREVIOUS SESSION'S DATA](#)

SELECT AN AREA



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IDENTIFY THE STREETS IN IMAGE

METHOD 1: INTERACTIVELY DRAW THE STREETS OVER IMAGE

Map Satellite Hybrid

STEP 1: SELECT AN AREA

Select an area on map using mouse

STEP 2: IDENTIFY STREETS

Draw Street Manually ADD MORE

Label Streets Manually

Import KML File

View Maps Online

Load OpenStreetMaps Data

DONE ADD MORE

STEP 3: IDENTIFY BUILDING LOCATIONS

Draw Points DONE

Draw Polygon ADD MORE

Import KML File

Process LIDAR Data

Import WikiMapia Layer

STEP 4: IDENTIFY BUILDING ADDRESSES

Load Phone Book Data

Predict Intersection Buildings

Exploit Constraints

Exploit Map Sources

OTHER OPTIONS

EXPORT KMLs SAVE CURRENT SESSION DATA LOAD PREVIOUS SESSION'S DATA

Enter Street Name:
Uskocka
Submit

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IDENTIFY THE STREETS IN IMAGE

METHOD 2: IMPORT OPENSTREETMAP DATA



STEP 1: SELECT AN AREA

Select an area on map using mouse

STEP 2: IDENTIFY STREETS

- Draw Street Manually [ADD MORE](#)
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IDENTIFY THE BUILDING LOCATIONS

METHOD 1: MANUALLY IDENTIFY THE POINTS



The screenshot shows a satellite map of a residential area. A large black rectangular selection box is drawn over a cluster of buildings. Numerous small red location pins are scattered across the map, primarily within the selected area. A thick green polygon is drawn over a specific group of buildings in the center. A cursor is visible near the bottom center of the green polygon. The map interface includes a zoom control on the left, a navigation bar at the top with 'Map', 'Satellite', and 'Hybrid' options, and a copyright notice at the bottom: 'Imagery ©2009 DigitalGlobe, GeoEye - Terms of Use'. The application has a light blue header and sidebar.

STEP 1: SELECT AN AREA
Select an area on map using mouse

STEP 2: IDENTIFY STREETS

- Draw Street Manually [ADD MORE](#)
- Label Streets Manually
- Import KML File
- View Maps Online
- Load OpenStreetMaps Data

STEP 3: IDENTIFY BUILDING LOCATIONS

- Draw Points [DONE](#) [ADD MORE](#)
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- Process LIDAR Data
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STEP 4: IDENTIFY BUILDING ADDRESSES

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OTHER OPTIONS

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IDENTIFY THE BUILDING LOCATIONS METHOD 2: IMPORT AN EXISTING KML LAYER



The screenshot shows a Google Earth-style interface for identifying building locations. A large blue 'X' is overlaid on a satellite image of a residential neighborhood, indicating an imported KML layer. The interface includes several steps and options:

- STEP 1: SELECT AN AREA**
Select an area on map using mouse
- STEP 2: IDENTIFY STREETS**
 - Draw Street Manually [ADD MORE](#)
 - Label Streets Manually
 - Import KML File
 - View Maps Online
 - Load OpenStreetMaps Data
- STEP 3: IDENTIFY BUILDING LOCATIONS**
 - Draw Points [DONE](#) [ADD MORE](#)
 - Draw Polygon
 - Import KML File
 - Process LIDAR Data
 - Import WikiMapia Layer
- STEP 4: IDENTIFY BUILDING ADDRESSES**
 - Load Phone Book Data
 - Predict Intersection Buildings
 - Exploit Constraints
 - Exploit Map Sources
- OTHER OPTIONS**
 - [EXPORT KMLs](#)
 - [SAVE CURRENT SESSION DATA](#)
 - [LOAD PREVIOUS SESSION'S DATA](#)

EXTRACT AND LINK BUILDING ADDRESSES TO ROADS

The diagram illustrates a process flow for address extraction and linking:

- 988info.rs (Telefonski imenik):** Shows a search interface for residential customers. A blue arrow points from the "Street: Uskočka" field to the "YellowPages.rs" search results.
- YellowPages.rs:** Shows search results for "Srbija" and "Uskočka". A blue arrow points from the "Location" and "Address" fields to the "988info.rs" search results.
- Map Overlay:** Shows a map of a street with a green line highlighting a segment. A callout box displays "White Pages Data" and "Yellow Pages Data" for the street "Uskočka".
- Map Interface:** Shows a map with a selection box, labeled "STEP 1: SELECT AN AREA". Below it, "STEP 2: IDENTIFY STREETS" lists options: Draw Street Manually, Label Streets Manually, Import KML File, and View Maps Online.

IDENTIFY THE INTERSECTION BUILDINGS

Map Satellite Hybrid

Street Assigned: Nikole Spasica,Cara Lazara
Click submit button if I am Non-Intersection building!

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STEP 1: SELECT AN AREA
Select an area on map using mouse

STEP 2: IDENTIFY STREETS

Draw Street Manually

Label Streets Manually

Import KML File

View Maps Online

Load OpenStreetMaps Data

STEP 3: IDENTIFY BUILDING LOCATIONS

Draw Points

Draw Polygon

Import KML File

Process LIDAR Data

Import WikiMapia Layer

STEP 4: IDENTIFY BUILDING ADDRESSES

Load Phone Book Data

Predict Intersection Buildings

Exploit Constraints

Exploit Map Sources

OTHER OPTIONS

APPLY CSP REASONING TO MAP ADDRESSES TO THE BUILDINGS

Map Satellite Hybrid

2A-Uskocka

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STEP 1: SELECT AN AREA
Select an area on map using mouse

STEP 2: IDENTIFY STREETS

Draw Street Manually [ADD MORE](#)

Label Streets Manually

Import KML File

View Maps Online

Load OpenStreetMaps Data

STEP 3: IDENTIFY BUILDING LOCATIONS

Draw Points [DONE](#) [ADD MORE](#)

Draw Polygon

Import KML File

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Load Phone Book Data

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OTHER OPTIONS

[EXPORT KMLs](#)

[SAVE CURRENT SESSION DATA](#)

[LOAD PREVIOUS SESSION'S DATA](#)

AMBIGUITY IN MAPPING DUE TO UNCERTAINTY IN INPUT DATA

Map Satellite Hybrid

1. 10_Cara Lazara
2. 3-Nikole Spasica

Submit

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STEP 1: SELECT AN AREA
Select an area on map using mouse

STEP 2: IDENTIFY STREETS

- Draw Street Manually ADD MORE
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- Draw Points DONE
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OTHER OPTIONS

- EXPORT KML
- SAVE CURRENT SESSION DATA
- LOAD PREVIOUS SESSION'S DATA

EXPLOIT MAPS FOR DISAMBIGUATION

The image consists of two main parts. On the left is a map from YellowPages.rs showing a street layout with several green-shaded areas representing different business locations. A blue dot marks the location of "SAT". A red rectangular box highlights a specific area on the map, which is later shown in detail on the right. On the right is a screenshot of a website for "Omladinska zadruga 'SAT'". The header includes the logo "cat" and navigation links for HOME, O NAMA, PRAVILA, ČLANSTVO, POSLOVI, and GALERIJA. The main content features a woman dancing against a background of colorful clock icons. Below this is a section titled "DO ĐOŠLI" with text about the organization's services. A sidebar on the right contains sections for CENOVNIK, KALKULATOR, and NOVOSTI, along with a "LOKACIJA" section that includes a map icon and a red box highlighting the same area as on the map.

YellowPages.rs
Ako nije ovde, možda i ne postoji.

Omladinska zadruga "SAT"

DO ĐOŠLI

Vam je novac, a imate slobodnog vremena. Stupite u kontakt sa nama.

"SAT" obavezuje članovima zadruge raznovrsne, privremene i povremene poslove kod velikog broja svojih komitenata. Na vreme isplaćujemo uplaćene zarade svojim članovima. Za sve informacije dodjite kod nas, pozovite nas telefonom ili pošaljite E-mail.

Vam na raspolaganju, uverite se u efikasnost i poslovnost OZ "SAT".

OMLADINSKA ZADRUGA SAT

Nikole Spasića 3/III, 11000 Beograd
Tel/Fax : 011/ 2181-064
Tel : 011/ 3283-854, 3283-641, 3283-642, 3283-855

Location: Beograd
Phone: Data is not available
Keywords: Data is not available
Category: Business organizations
Category: Business world

Opening hours: Data is not available

Maps can be visually interpreted to determine the exact address

MapFinder service (Goel et al. 08) is used to classify the images as maps or non-maps address for the business

Business websites contain maps to depict their location.

USER MANUALLY ENTERS THE ADDRESS TO RESOLVE AMBIGUITY

Map Satellite Hybrid

1. 7 Cara Lazara
2. 9 Cara Lazara
3. Nikole Spasic ★
3-Nikole Spasic

Submit

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STEP 1: SELECT AN AREA
Select an area on map using mouse

STEP 2: IDENTIFY STREETS

Draw Street Manually ADD MORE
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OTHER OPTIONS

EXPORT KMLs SAVE CURRENT SESSION DATA LOAD PREVIOUS SESSION'S DATA

RESULTS PROPAGATED TO FURTHER REDUCE AMBIGUITY

The map displays a residential area with buildings and streets. Green location markers are placed along a street, and a red circle highlights the address "1. 10-Cara Lazara". A legend in the bottom left corner identifies the markers: green for buildings, orange for roads, and blue for other features.

Map Satellite Hybrid

1. 10-Cara Lazara

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DISCUSSION

- **Described initial work on interactively retrieving, integrating, and reasoning about about geospatial data**
- **Developing a general information fusion framework that can be applied to a variety of tasks**
 - Rapid integration of new data sources
 - Incorporation of new reasoning methods that can interoperate on the available data
 - User control of the integration process
 - Visualization of the results to provide immediate feedback