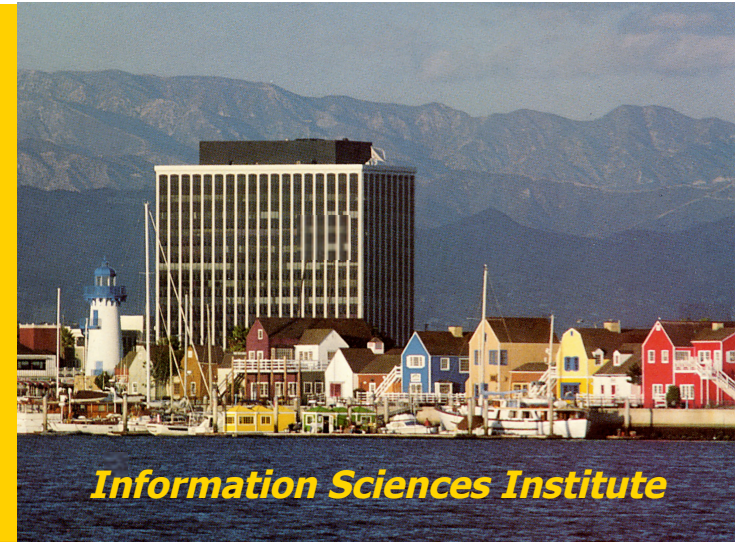


USC Viterbi
School of Engineering



Information Sciences Institute

A Framework for Integrating and Reasoning about Geospatial Data

Shubham Gupta and Craig A. Knoblock
University of Southern California

USC

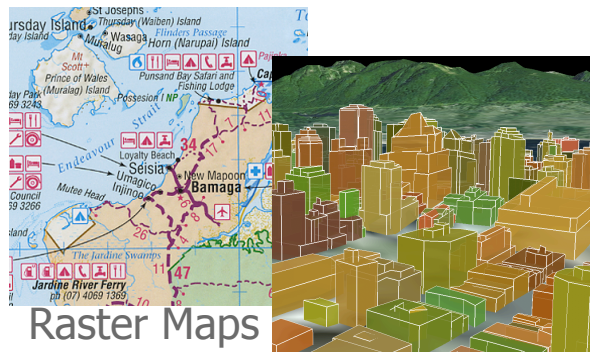
- Large amount of geospatial data available



Mapping services

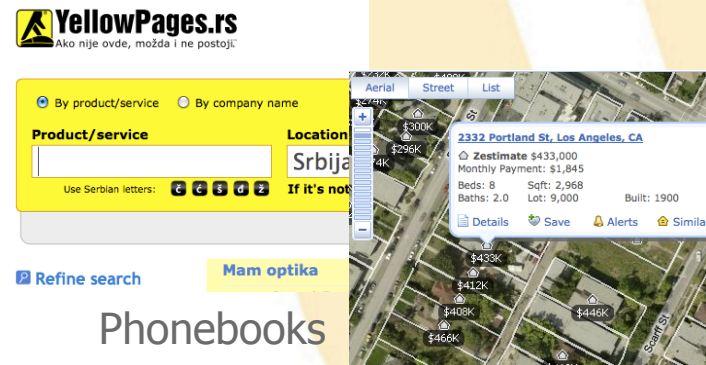


Web 2.0 based collaborative projects



Raster Maps

KML Layers



Phonebooks

Property Records

USC Traditional geospatial data sources

Online data sources

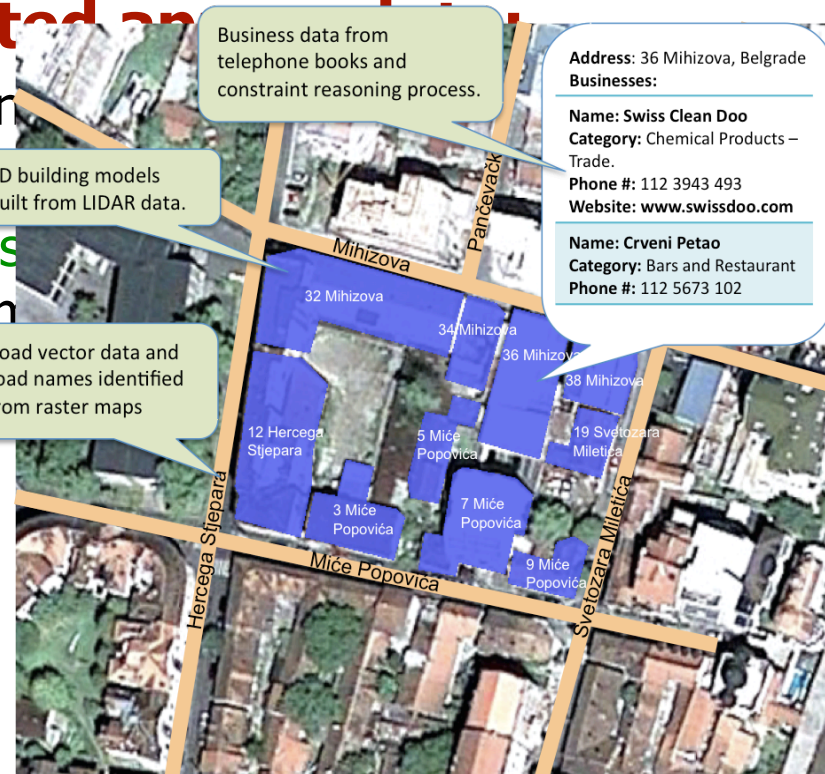
USING THE DATA TO UNDERSTAND A REGION

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

Example results: visualization tasks that infer information from these sources

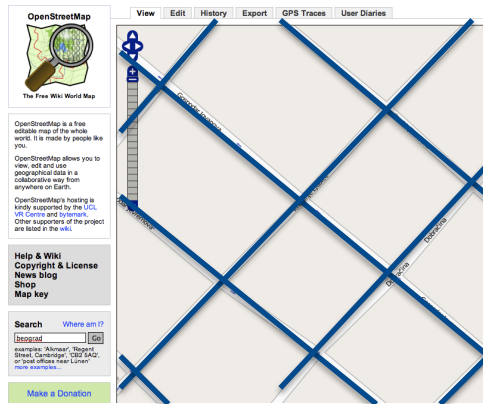


Before

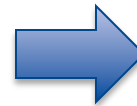


After

- The data retrieval tasks involve gathering the available geospatial data



OpenStreetMap



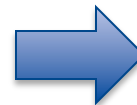
Street vector data as KML layer



Page number 1 2 3 4 5

| | |
|--|---------------|
| ALABANDA, VLADETA USKOČKA 7, BEOGRAD | ☎ 011 2631495 |
| ALABANDA, VLADETA USKOČKA 7/002, BEOGRAD | ☎ 011 2621250 |
| ANDRIĆ, MILETA USKOČKA 2, LAZAREVAC | ☎ 011 8120911 |
| BLAGOJEVIĆ, ZORAN USKOČKA 3, MALI POŽAREVAC | ☎ 011 8256471 |

Phonebook website



```

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>
  </Entry>

```

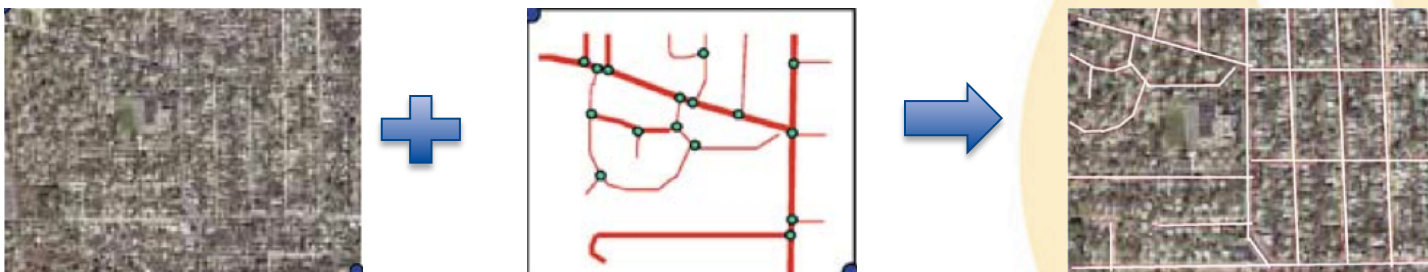
Phonebook data as XML file

- **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 conflation of 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)
 $D = \{DV_1, DV_2, \dots, DV_n\}$ → Set of Addresses
- C is a set of constraints, $C = \{C_1, C_2, \dots, C_l\}$ → Set of Constraints
 $C_{Va, Vb, \dots, Vi} = \{(x, y, \dots, z)\} \subseteq DV_a \times DV_b \times \dots \times DV_i$
E.g. Addresses increases West

Vector Data

1. OpenStreetMap
2. KML, shapefiles etc
3. Manually Created



Information from Phone Book Data

Yellow and White Pages



Information from Image Or Map



CSP Model



CSP Solver



Street and address assignment for each building in an image

[Michalowski & Knoblock 2005]

INFOFUSE INTEGRATION SOFTWARE

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

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**

Imagery ©2010 DigitalGlobe, GeoEye, Earthstar (IGNITE), IGN, Mapbox, Aeri, USDA, Fidelity Investments

SELECT AN AREA

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IDENTIFY THE STREETS IN IMAGE METHOD 1: INTERACTIVELY DRAW THE STREETS OVER IMAGE

Map Satellite Hybrid

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Imagery ©2009 DigitalGlobe, GeoEye - Terms of Use

IDENTIFY THE STREETS IN IMAGE METHOD 2: IMPORT OPENSTREETMAP DATA

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

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OTHER OPTIONS

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IDENTIFY THE BUILDING LOCATIONS METHOD 1: MANUALLY IDENTIFY THE POINTS

Map Satellite Hybrid

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Select an area on map using mouse

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



STEP 1: SELECT AN AREA

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EXTRACT AND LINK BUILDING ADDRESSES TO ROADS

s and white
on
nd made

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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- View Maps Online

988info.rs
Telefonski imenik

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

Advanced search: By address By brand By phone

Location Srbija **Address** Uskočka **No**

Use Serbian letters: **č ć š đ ž** **If it's not here, maybe it doesn't exist.™**

Residential Customers

Select search options

Area code: Beograd 011

Town: all

Phone: _____ Street: Uskočka

Name: _____ Number: _____

Last name: _____ **Search**

Molimo Vas koristite srpske karaktere (Please use Serbian characters) - š, č, ć, đ, dž

VAŽNO: Za probleme prilikom pokretanja pretrage i promene mrežne grupe, omogućite prihvatanje Cookies - Pom...

| | Page number | 1 | 2 | 3 | 4 | 5 |
|--|-------------|---|---|---|---|---------------|
| ALABANDA, VLADETA USKOČKA 7, BEOGRAD | | | | | | ☎ 011 2631495 |
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| ANDRIĆ, MILETA USKOČKA 2, LAZAREVAC | | | | | | ☎ 011 8120911 |

Refine search

Industries

- Photographers
- Gambling
- Casinos
- Exchange offices
- Optics
- Beekeeping
- Travel agencies

Državna Lutrija Srbije

Location: Beograd, Vračar, Uskočka 4-6
Industry: Gambling
Category: Entertainment and arts
Recommendations: Read recommendations; Write recommendation
Državna Lutrija Srbije Srbija, Državna Lutrija Srbije in Srbija, I
Državna Lutrija Srbije in Beograd

Fun casino

Location: Beograd, Uskočka 4
Industry: Casinos
Category: Entertainment and arts
Recommendations: Read recommendations; Write recommendation
Fun casino Srbija, Fun casino in Srbija, Fun casino Beograd, Fun cas

IDENTIFY THE INTERSECTION BUILDINGS

Map Satellite Hybrid

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

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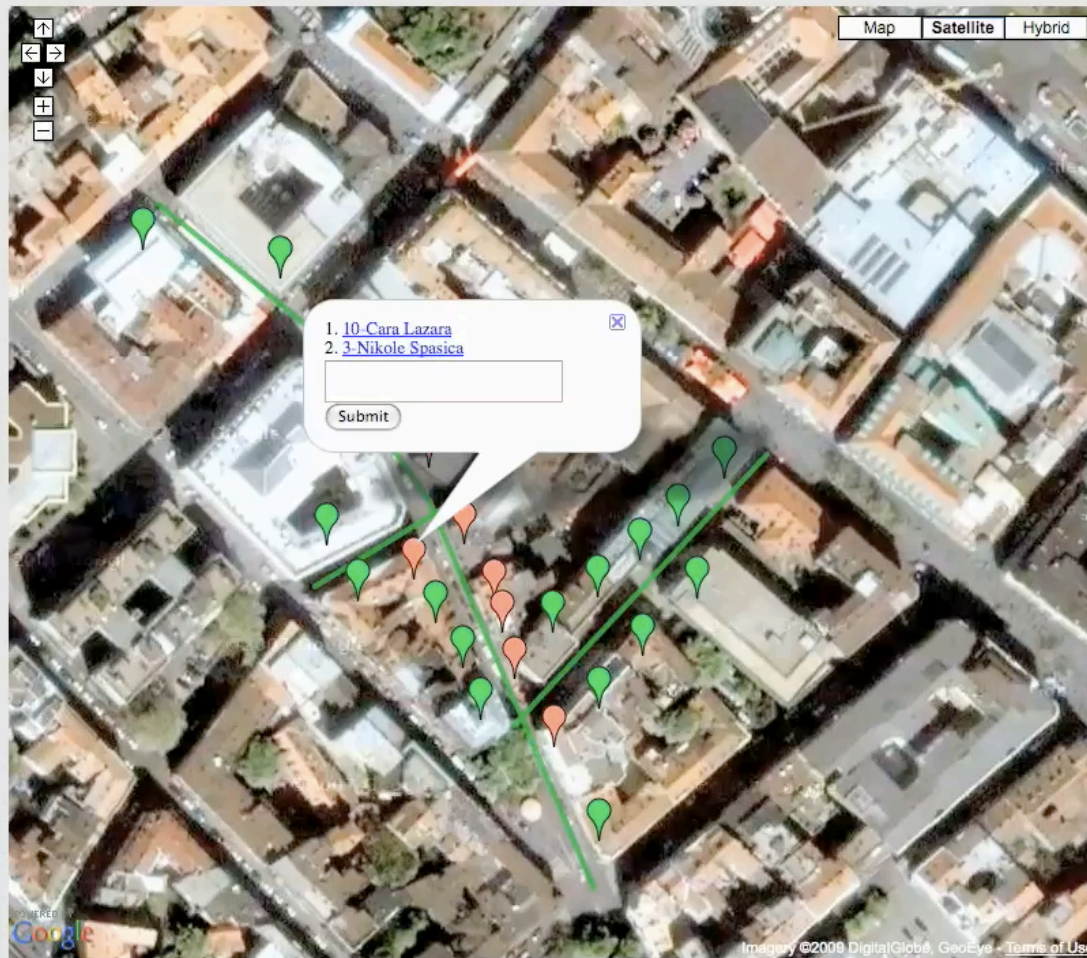
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AMBIGUITY IN MAPPING DUE TO UNCERTAINTY IN INPUT DATA



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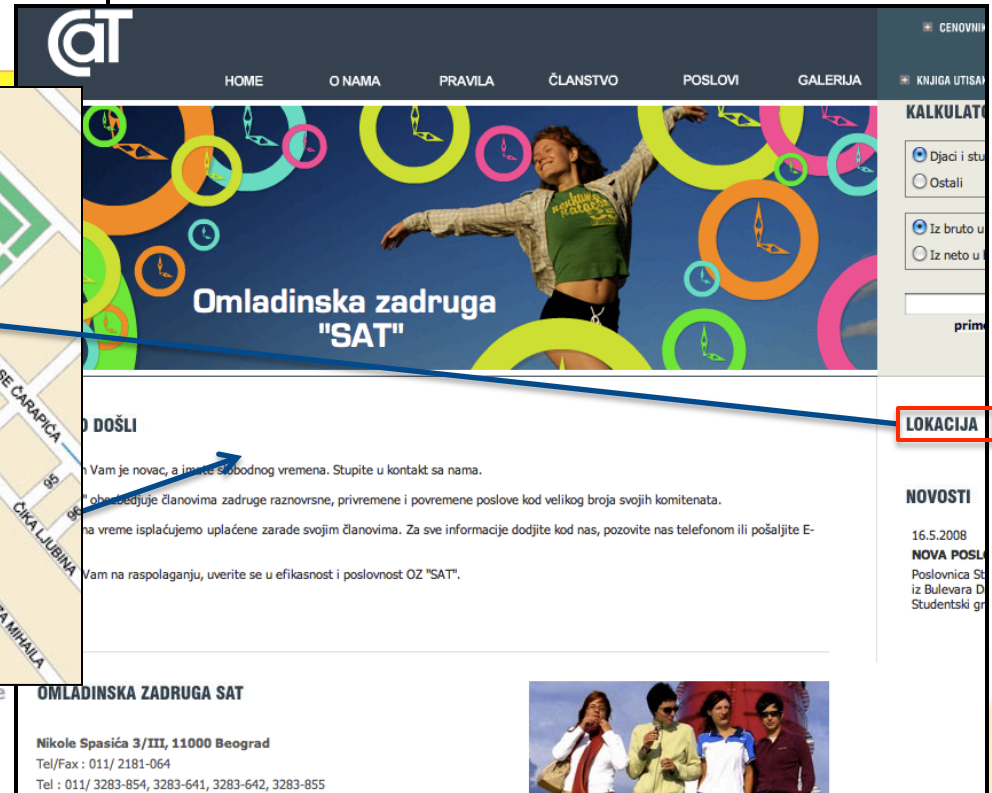
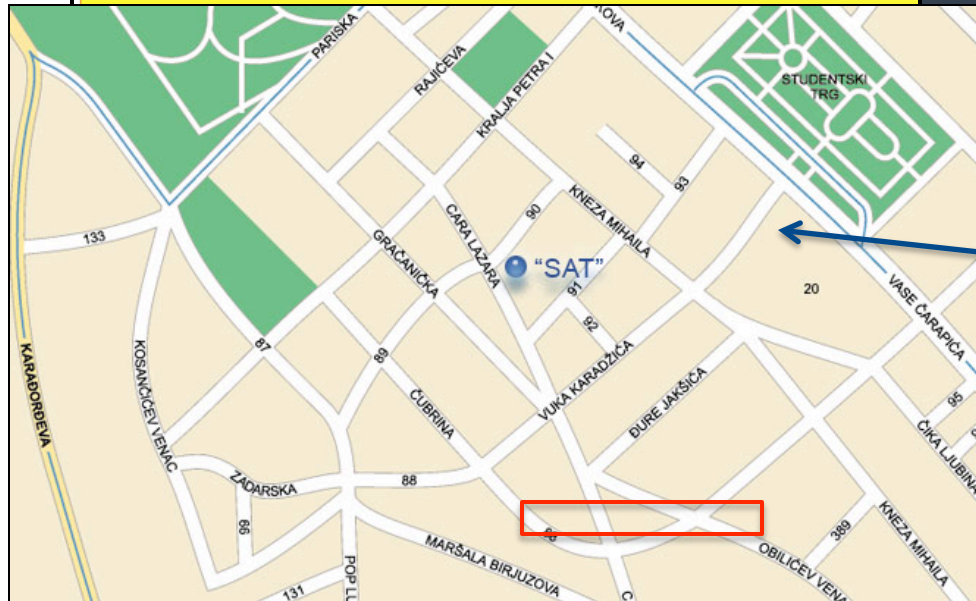
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OTHER OPTIONS

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

EXPLOIT MAPS FOR DISAMBIGUATION



- Location: Beograd
- Opening hours: Data is not available
- Maps: Data is not available
- Keywords: Data is not available
- Category: Business world

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
Yellow pages contains the website 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. [3-Nikole Spasica](#) ★
4.
Submit

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EXPORT KMLs

SAVE CURRENT SESSION DATA

LOAD PREVIOUS SESSION'S DATA

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RESULTS PROPAGATED TO FURTHER REDUCE AMBIGUITY

The screenshot displays a satellite map of a city block with several green and orange pins. A white callout box points to a specific location, displaying the text "1. 10-Cara Lazara". The map interface includes a top navigation bar with "Map", "Satellite", and "Hybrid" options, and a bottom status bar with "Imagery ©2009 DigitalGlobe, GeoEye - Terms of Use".

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- **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