

**Information Sciences Institute**  
*Agent of Innovation: from visionary to viable*

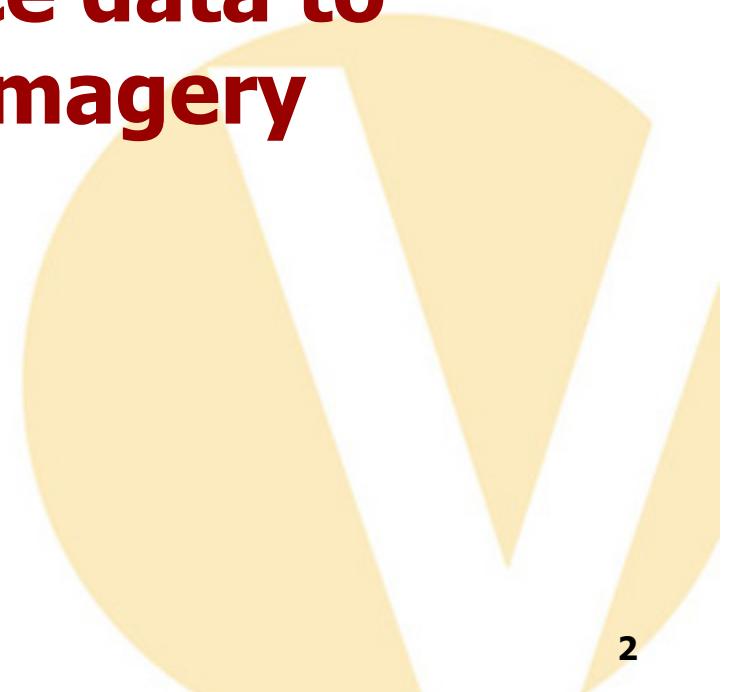
# Exploiting Open Source Data for Imagery Understanding

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**University of Southern California  
and  
Geosemble Technologies**

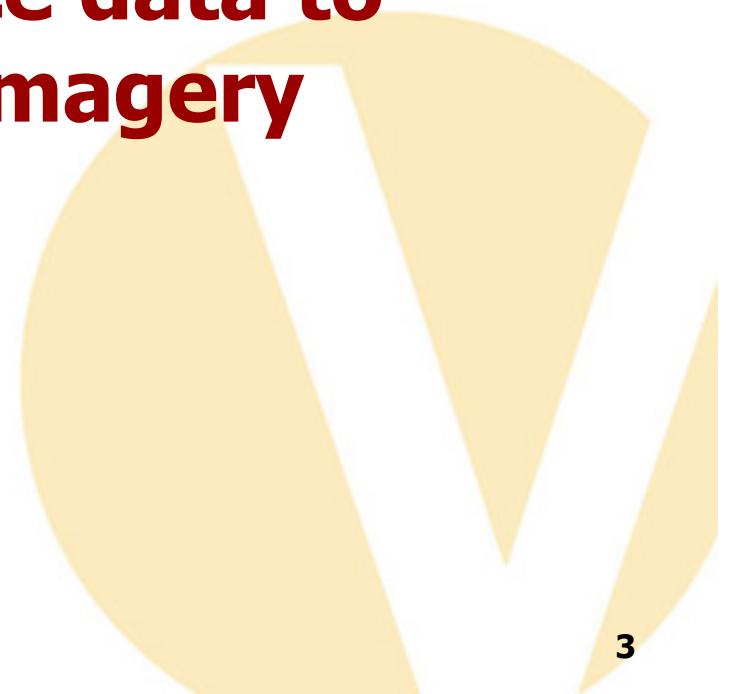
# Talk Outline

- **Fusing open source maps with Imagery**
- **Linking news articles to imagery**
- **Exploiting open-source data to Identify buildings in imagery**



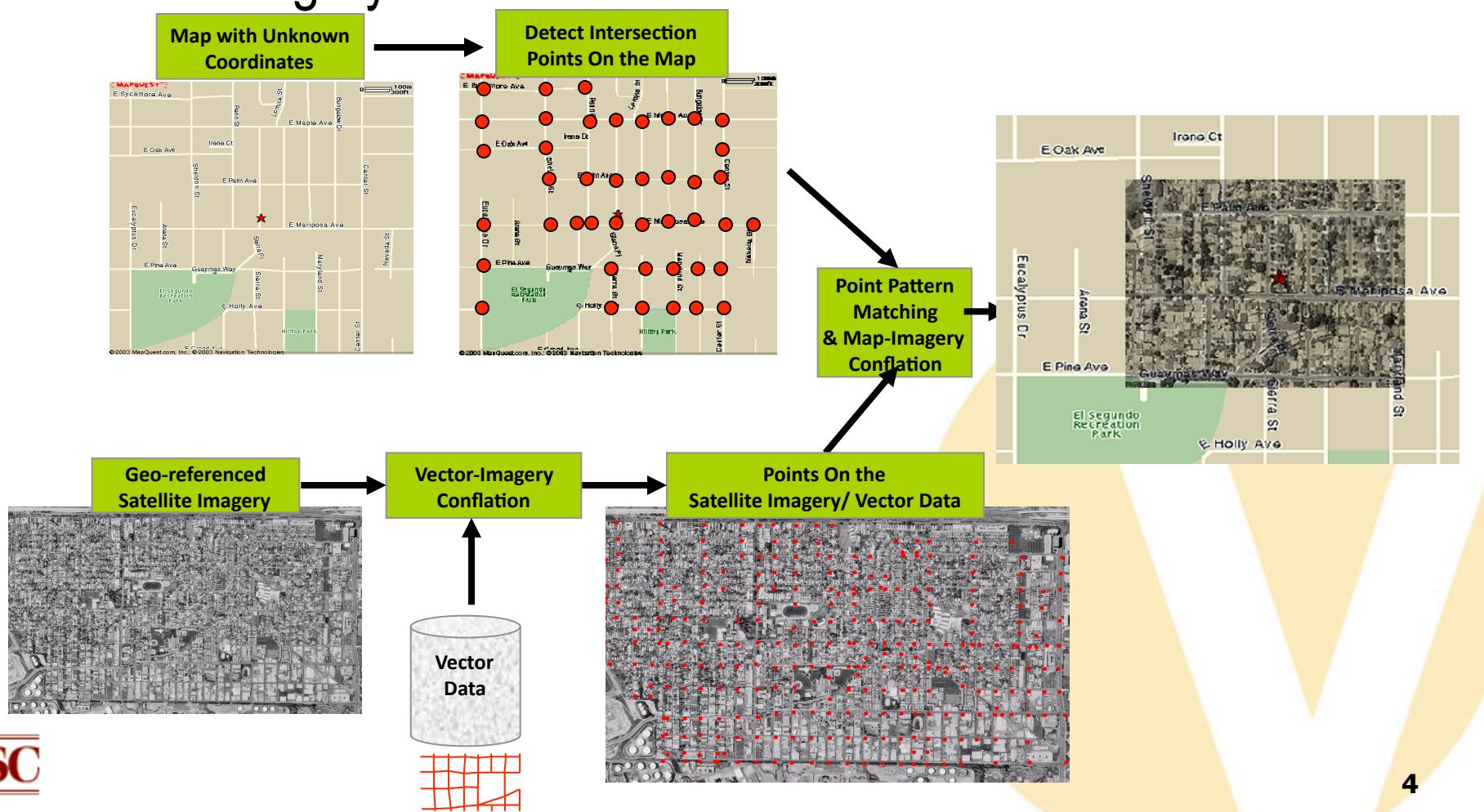
# Talk Outline

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# Fusing Maps & Imagery

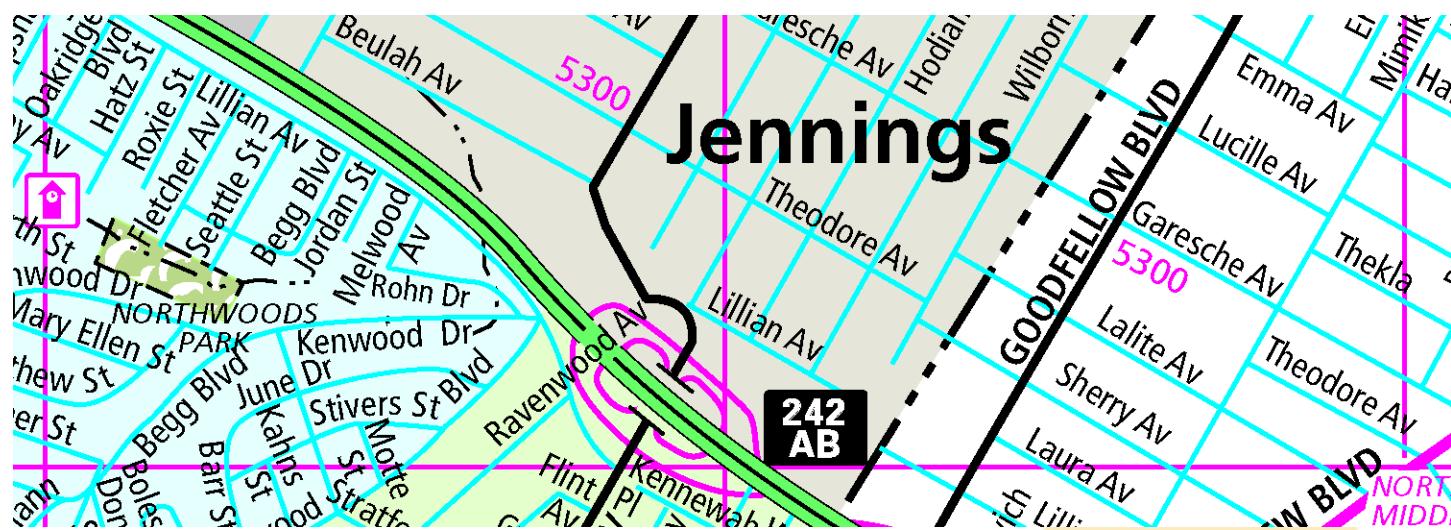
- Exploit layout of intersections to accurately fuse maps with imagery



# Remaining Challenges

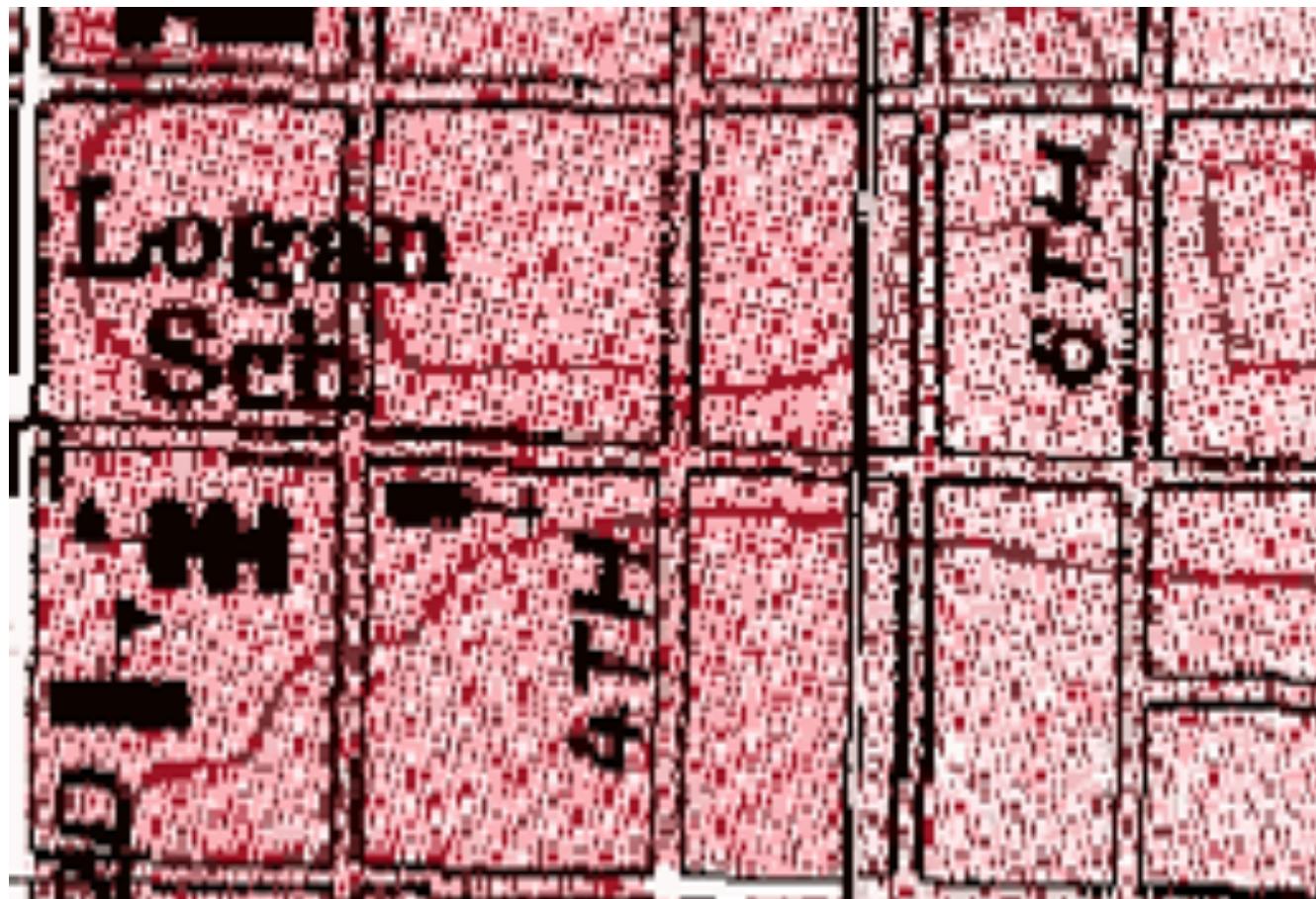
- The extraction of road layers is beyond the current state of the art for some types of maps

— Multicolor road lines

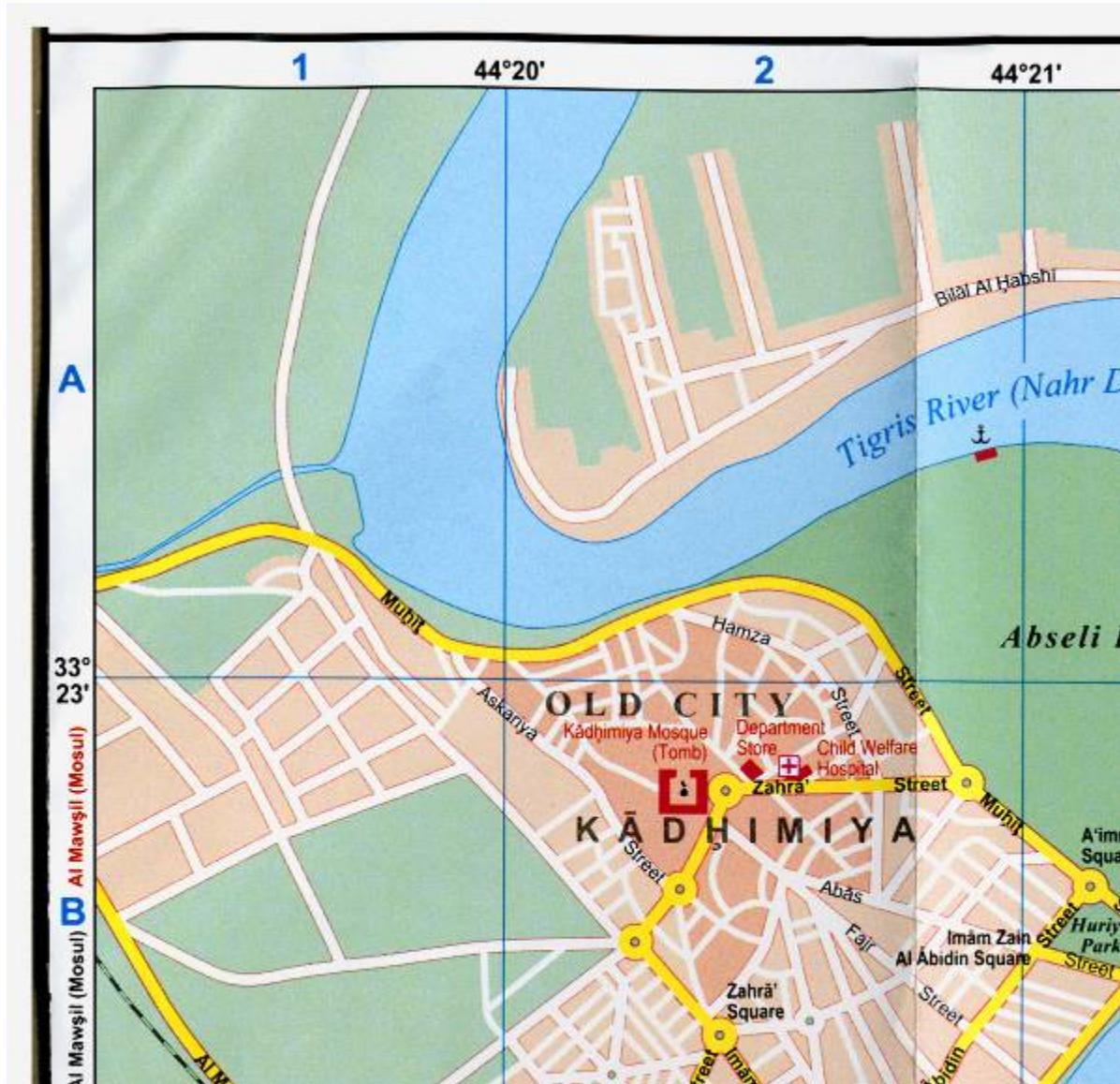


— Compression and scanning noise

# Noise from Compression

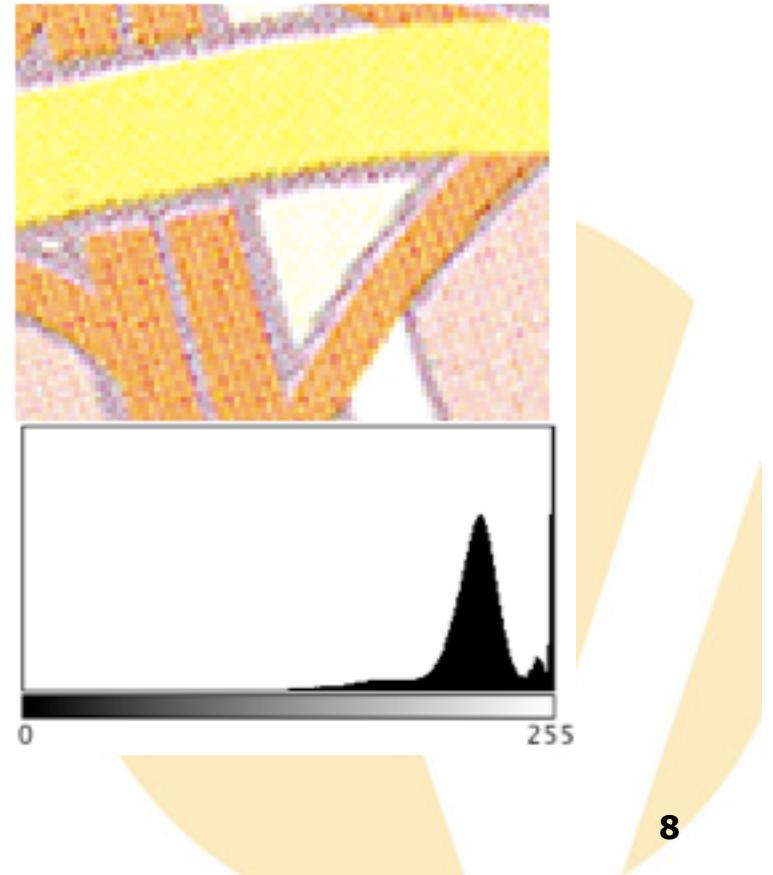
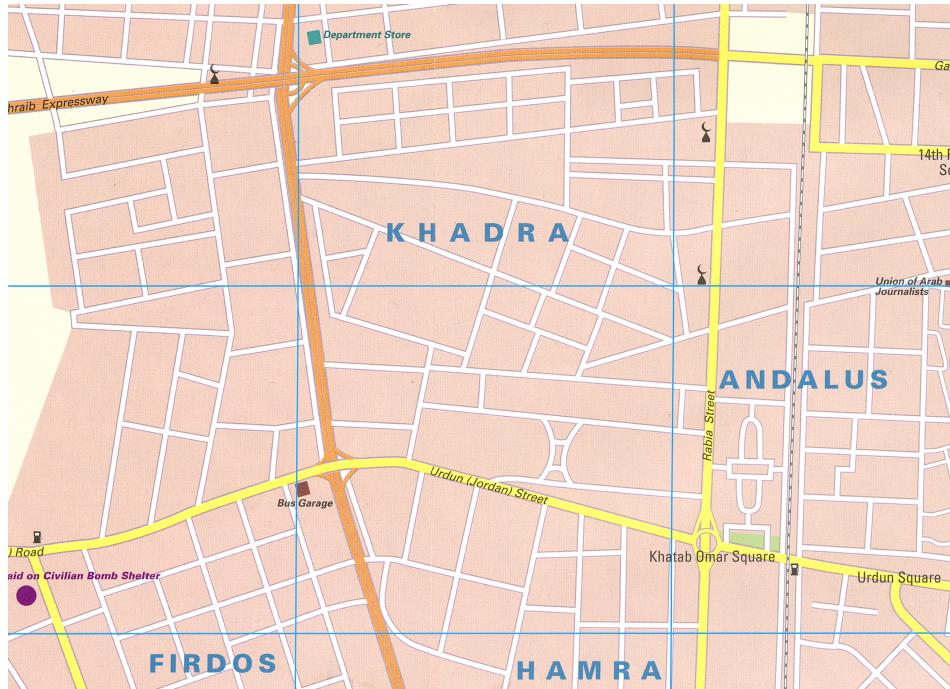


# Noise from Scanning



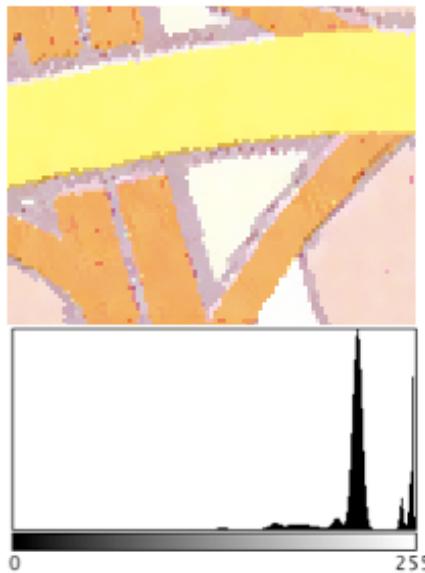
# Color Segmentation

- Raster maps contain numerous colors  
**285,735 colors**

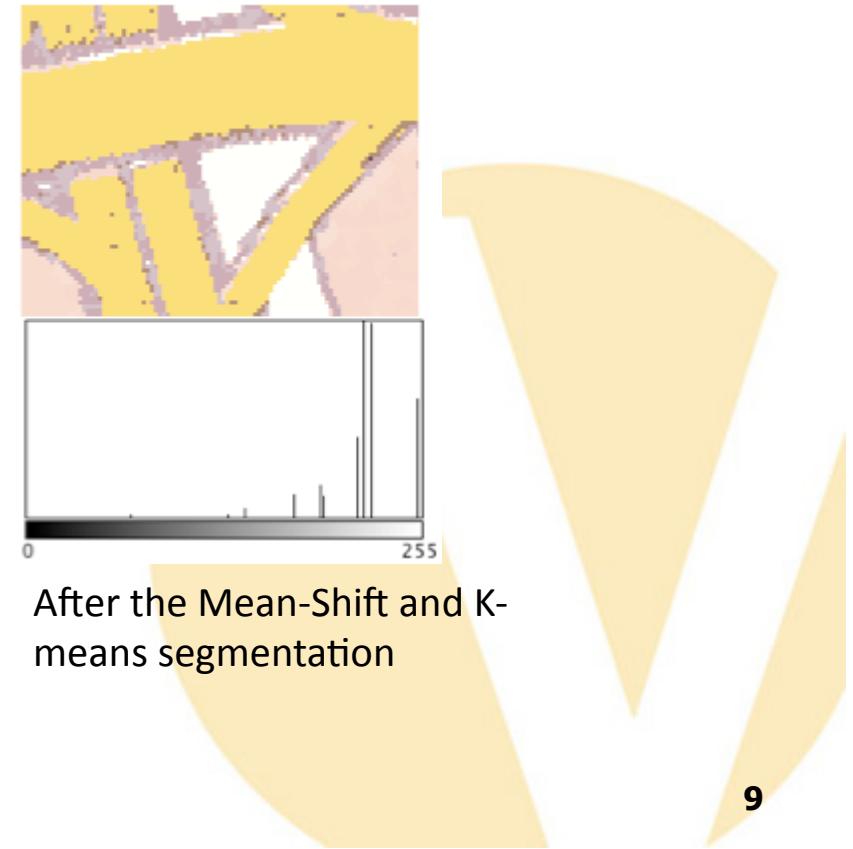


# Color Segmentation

- The Mean-shift algorithm merges two colors into one by considering their distance in the color space as well as in the image space
- The K-means algorithm ensures that the final quantized map has a number of colors that is not larger than K (we use K=10 in our method)



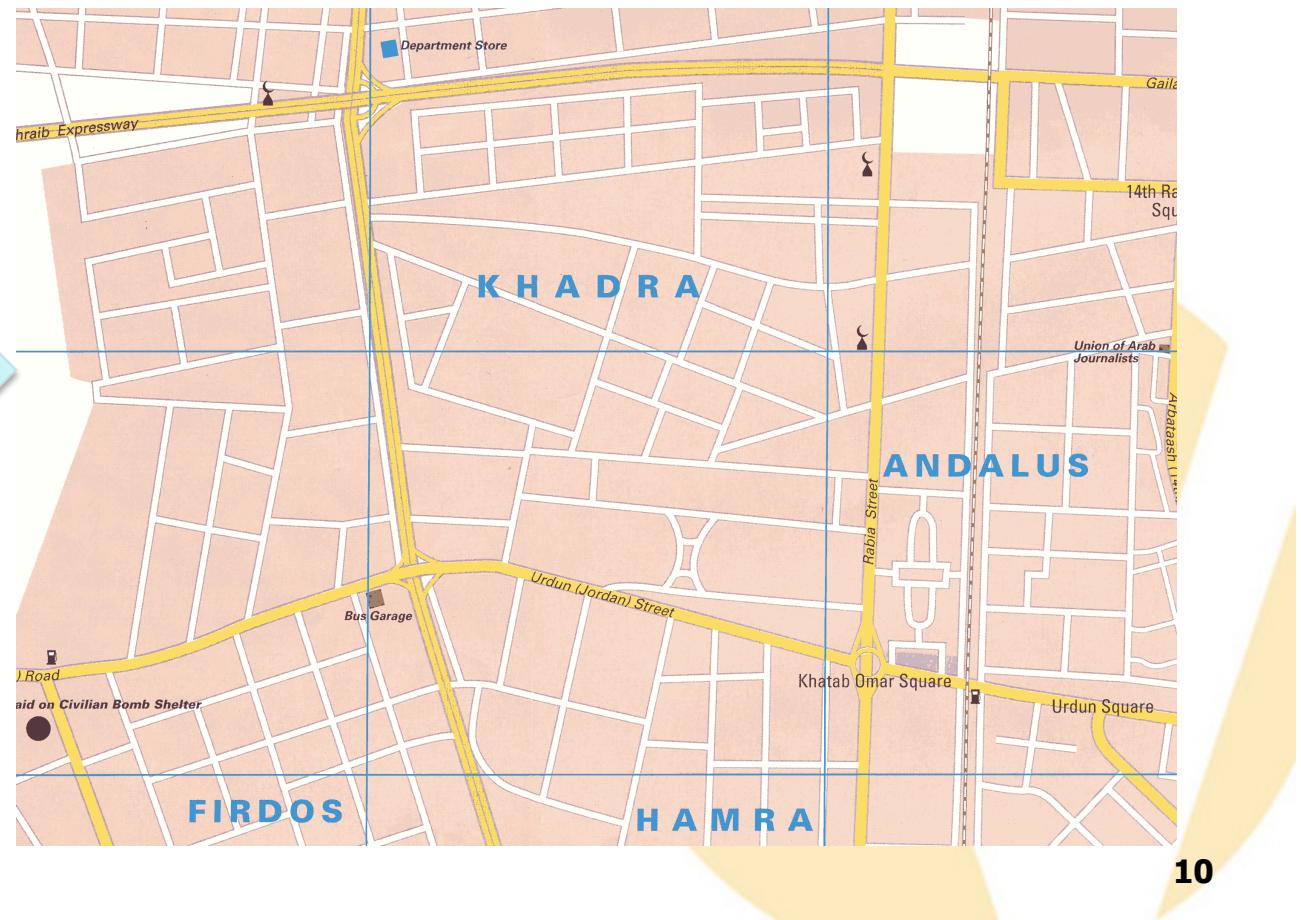
After the Mean-Shift segmentation the number of colors is reduced by 50% (i.e., 155,299 colors)



After the Mean-Shift and K-means segmentation

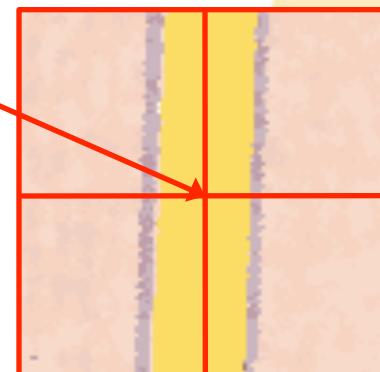
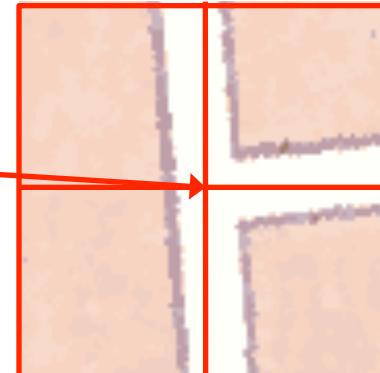
# Quantized map

- The quantized map has 10 colors (compared to 285,735 colors in the original map)



# User Labeling

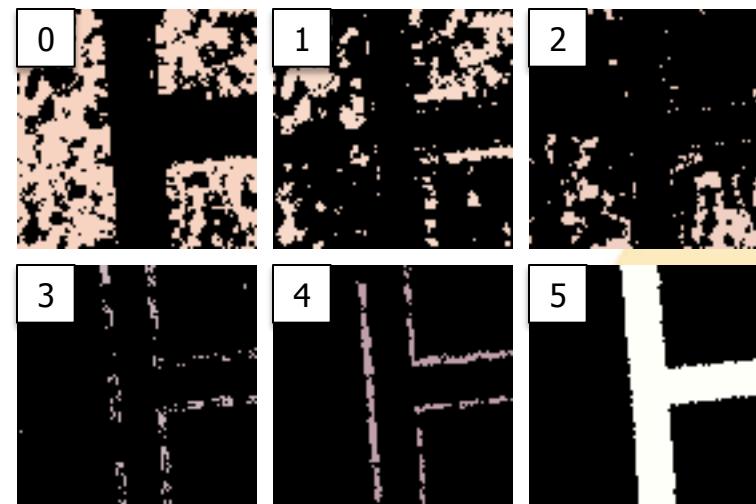
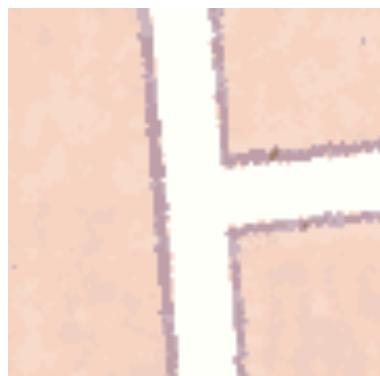
- User needs to provide a user label for each road color (at most K colors)



User label should be (approximately) centered at a road intersection or at the center of a road line

# Identify Road Colors – Color Decomposition

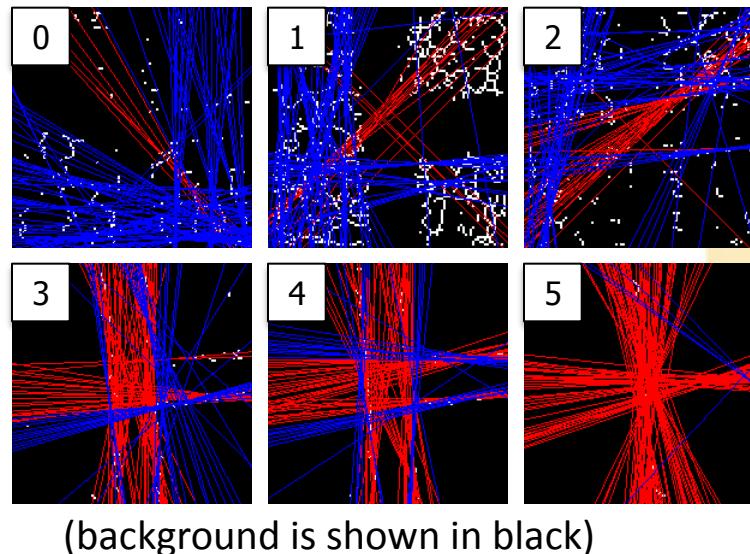
- Decompose each user label into color images so that every color image contains only one color



(background is shown in black)

# Identify Road Colors – Detect Hough Lines

- **Detect Hough Lines**
  - Apply the thinning operator to extract the skeletons of every connected object, and apply the Hough transformation to detect Hough lines
- **The Hough lines that are within a distance threshold to the image centers are drawn in red and others are drawn in blue**



# Identify Road Colors – Road Line Template

- Generate a road line template using the images of classified road colors



(background is shown in black)

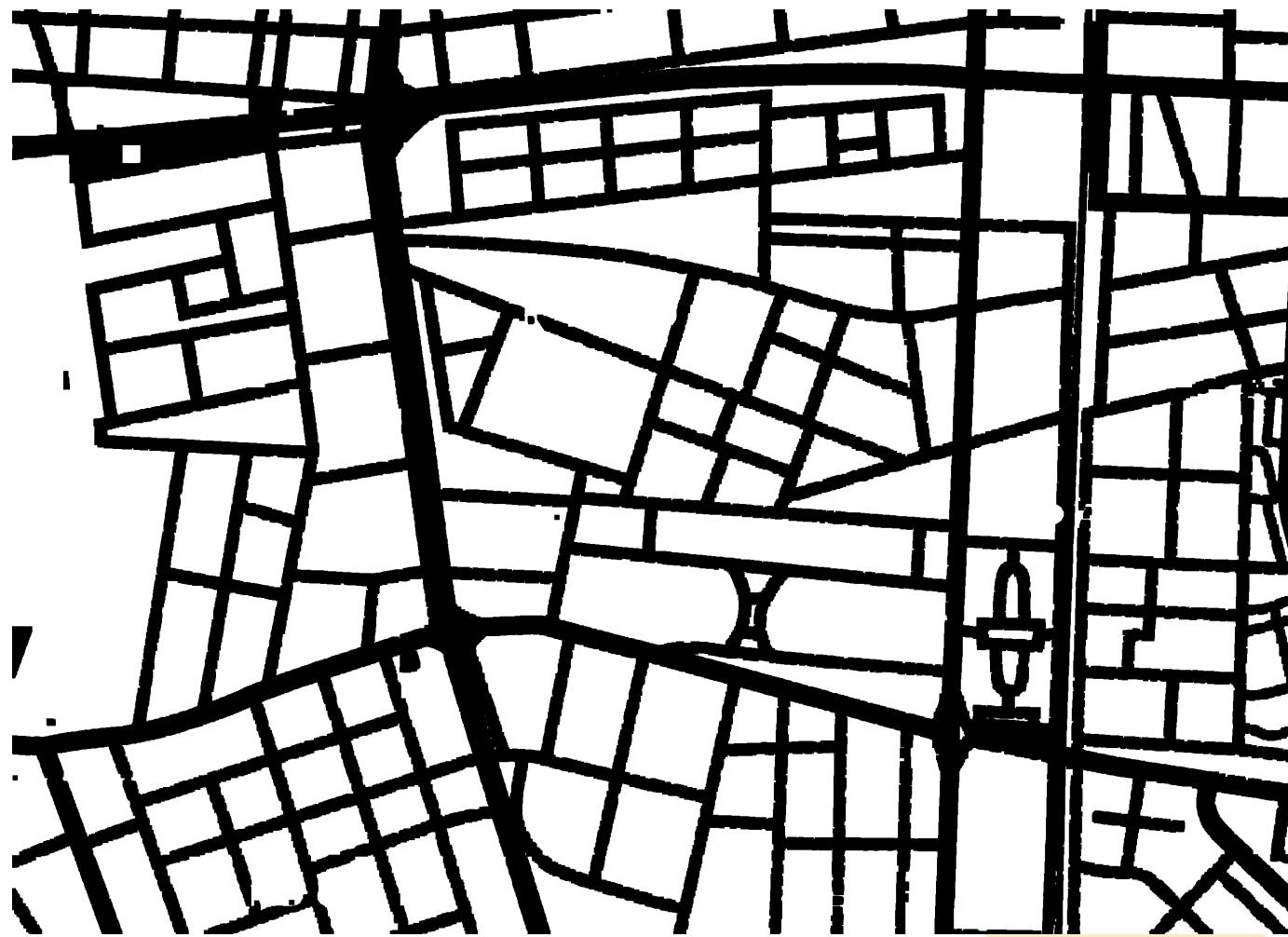


# Generate a Color Filter

- Every user label is processed and a set of road colors is identified for each label
- All of the identified road colors are then added up to generate a color filter
- The colors in the quantized map that are not in the color filter are filled with white pixels and the others are filled up with black pixels

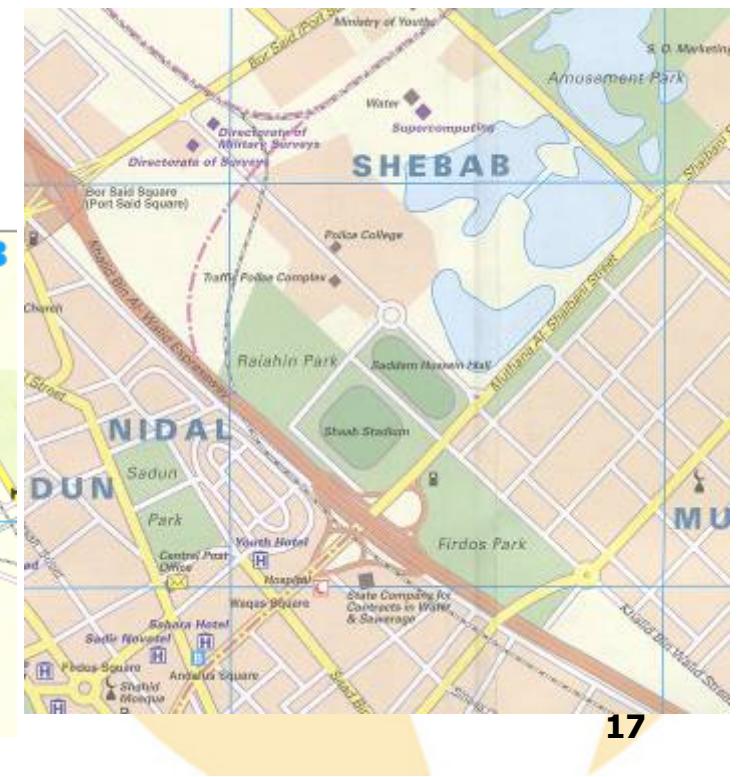
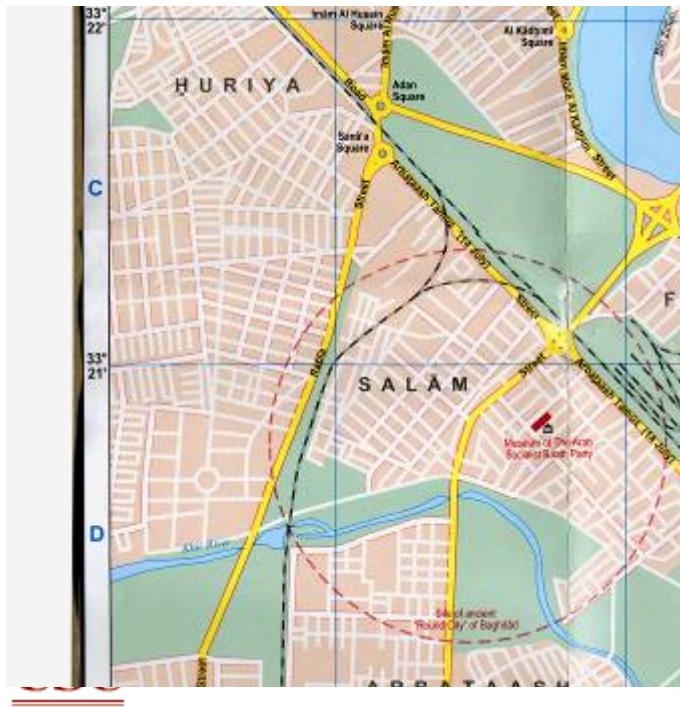


# Use the Color Filter



# Experiments- Scanned Iraq Maps

- **60 maps (2000x2000 pixels each) cropped from 3 different scanned maps (350dpi) covering Bagdad, Iraq**
- **The original paper maps has been folded, there were folding lines that caused shadows and color differences on the scanned raster maps**



# Experimental Results

- We successfully extracted the road layers from all maps
- The average number of user labels per map was under 4
- The average computation time per map was below 5 (s.)
  - enabled us to generate a real-time preview of the result after each user labeling

Map Set	Map Count	Avg. User Labels	Avg. Computation Time (s.)
1. Scanned Iraq maps	12	2.7	2.7
2. Scanned Iraq maps	18	2.1	3.3
3. Scanned Iraq maps	30	2.6	4.2
4. USGS topo. maps	19	1.5	1.5
5. USGS topo. maps	5	1.6	1.2
6. USGS topo. maps	6	1.8	1.8
7. Rand McNally maps	10	3.9	2.4

# Next Step: Extracting Text Layers

- **Generalize OCR techniques to apply to maps**
  - Identify individual characters regardless of orientation
  - Group the characters into labels
  - Associate labels with map objects



# Talk Outline

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- **Linking news articles to imagery**
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# Linking News to Imagery

- **Visualize various media in a geospatial context to better understand the context of an area**
  - Possible media includes databases, text documents, maps, audio recordings, video, etc
  - E.g., reports of illegal border crossing incidents, news articles from local papers, television news reports, etc.

The screenshot illustrates the integration of geospatial data (satellite map) with news media (web browser). A red arrow highlights the connection between the map location and the news article, demonstrating how to visualize news stories in a spatial context.

**FBO sees future in new hangar.** | Journal Record (font style="color:blue; background-color:white;">Get Features Get News

http://hydra.fetch.com:9090/GessembleNews/showNews?epName=Global&keywords='Tulsa', 'OK', 'TULSA', 'SHERIDAN RO

**FBO sees future in new hangar.**

29,595,358 articles in the following categories:

Arts, Business, Consumer News, Culture & Society, Education, Government, Personal Interest, Health, News, Science & Technology

Ads by Google

**Fly In Your Own Jet**  
Own an Eclipse 500 very light jet. Affordable private jet ownership.  
[www.edipaveaviation.com](http://www.edipaveaviation.com)

**West Valley Flying Club**  
Sensibly priced, superior flight instruction & aircraft rental  
[www.wvfc.org](http://www.wvfc.org)

**Aerospace & Defense**  
Sales & Divestitures, M&A, Raising Capital And

**KING AEROSPACE** Aircraft Interiors, Painting, and Modifications.

**"Helicopter Specialists"** Aerial Units for the Motion Picture Indus Credits

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Byline: Kirby Lee Davis

**TULSA** ??? Aircraft and Turbine Support expects a \$3.5 million expansion to spur a 66-percent boost in revenue in just one ye "All of our customers have been asking when we're moving forward," said Vice President Joe Cole. "This is their official notice ?? we are moving ahead." If weather holds, the 14-employee fixed-base operator at **Tulsa** International Airport, which in April finally secured a 20-year lease for its 20,000 square feet at 2701 N. **Sheridan Road**, will break ground...

21

# Approach

- **Link the online documents to an image by identifying the geographic features shown in the image, and then searching text sources to find documents relevant to the specific features**
  - The traditional approach is to process each possible document and associate the geographic references
    - *It requires preprocessing the documents and does not support fine-grained linking*
  - Our technology starts with an area, rather than a document
    - *It scales well with high accuracy and the linking to online documents can be done on-the-fly*



Traditional approach



Our unique approach

# Text-to-Image Linking

1  
Area of interest  
(with known coordinates)



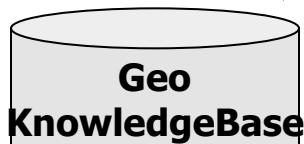
2  
Annotated image



3  
Text-fused image



Geospatial knowledge  
about the area



Off-line process to  
import geospatial data



**USC** Available  
geospatial data

Online textual  
knowledge

Google  
News

News

elpasotimes.com

El Paso Times Inside El Paso

Home | New & Updated | News | Communities | Living | Sports | Business | Opinion

Nation/World · Education · Politics · Weather · Times Media · Traffic · Blogs

del.icio.us Digg Reddit YahooMyWeb Google What's this?

Border agent shoots, kills man near Rio Grande

Zahira Torres / El Paso Times

Article Launched: 08/09/2007 03:19:48 PM MDT

A Mexican national shot by a Border Patrol agent Wednesday night died in Juarez, U.S. Customs and Border Protection officials said.

The shooting happened around 9:45 p.m. along the Rio Grande at DELTA and DELTA streets when a Border Patrol agent responded to a call of four people trying to enter the U.S. illegally.

While the agent was there, Alejandro Ortiz Casillas, 27, a street cutter, picked up the agent, officials said.

The agent shot Ortiz Casillas back into Juarez while the woman, who was with Escarcega by Juan's custody.

Marco Antonio Torrez, 28, a street cutter in Juarez, was incident Wednesday night found dead in Juarez after he was shot by a Border Patrol agent.

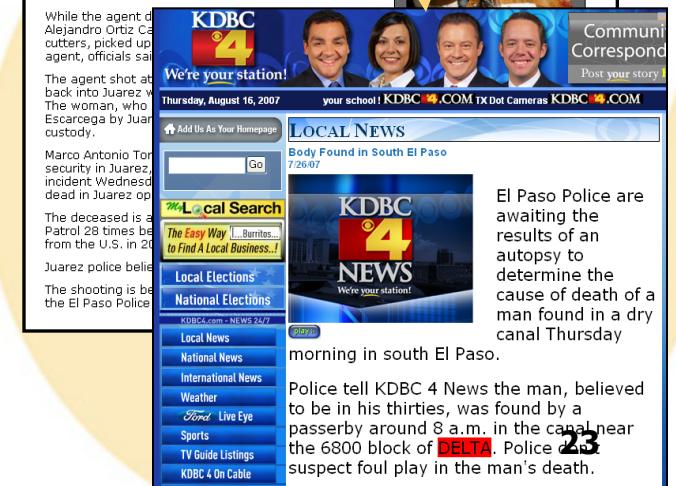
The deceased is a Mexican national shot by a Border Patrol agent 28 times before he died from his injuries in the U.S. in 2007.

Juarez police believe the shooting is related to the El Paso Police.

The shooting is believed to have been caused by the El Paso Police.

El Paso Police are awaiting the results of an autopsy to determine the cause of death of a man found in a dry canal Thursday morning in south El Paso.

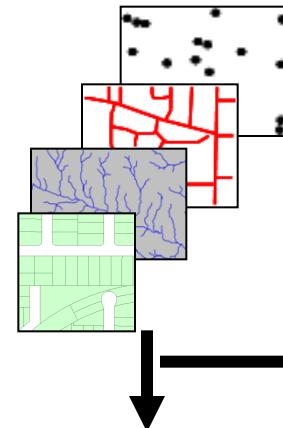
Police tell KDBC 4 News the man, believed to be in his thirties, was found by a passerby around 8 a.m. in the canal near the 6800 block of DELTA. Police suspect foul play in the man's death.



# Building Geospatial Knowledgebase

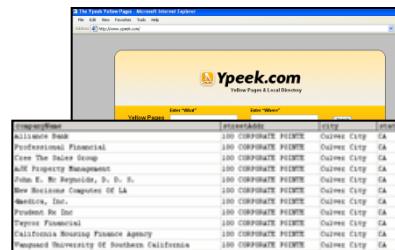
## Available geospatial vector sources

- NGA gazetteers
- USGS gazetteers
- Parcel data
- US Census Tiger Files (e.g., road networks, hydrographic data)



## Other sources relevant to geographic info.

- Phone books
- City business list



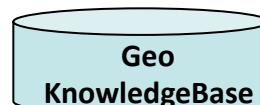
Parcel data

## Integrating vector sources

Geospatial features

## Mapping data to buildings

Businesses with geographic info.



Name	Type	Coordinate
USC	Point	(34.3, -118.15)
Vine St.	Polygon	(34.21, -118.13) (34.22, -118.15) (34.25, -118.2)
...	...	...

# Exploiting the Knowledgebase for Linking

- The geospatial knowledge base is used to associate text features with the image being viewed
- The text features can then be used for linking documents



# Linking Text Documents to Imagery

- **Given the text features, we can then search for relevant documents**
- **Documents can come from a variety of sources**
  - News repositories
  - Search engines
  - Databases of incident reports
  - Video archives with closed caption text
- **Documents are linked using information retrieval techniques**
  - TF/IDF (term frequency / inverse document frequency)

# System GUI

**MAP FEATURES**

- All
- Company
- Entertainment
- Hotel
- Parking
- Public Spaces
- Restaurant/Bars
- Shopping

[Help](#) [Get Features](#)

**Area: Features Found**

147 locations found, 30 made news

- Aenaria, L L C
- Agustin G. & Mayra M. Prado
- Akasha
- Alandales
- Ampco System Parking
- Arkin & Weissman
- Arnold Sherwood
- B M S Properties
- Bahay
- Bank Of America, N. A. - 366
- Bank Of The West
- Beachwood Services Inc
- Behnam Rafalian
- Belford Optical Lab Inc
- Bistro De L' Hermitage

**Whole Life Times Akasha Restaurant - Mozilla Firefox**

Powered by Google Maps

[Home](#) [About](#) [Deliveries](#) [Bookings](#) [Take Out](#)

Recommended data from Google Local Business

**PRACTICE RANDOM ACTS OF E-MAIL AND SENSELESS ACTS OF IMing.**

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**whole life** [wholelife.com](#)

**AKASHA**

**AKASHA Restaurant**

Earthwise comfort food In Culver City

By Michael Kaufman

In years Culver City has been described as “dormant,” “the next Diamond in the rough,” and “the new Hollywood,” making it a perfect spot to break out. Akasha – a new restaurant, bar and lounge with an earthy, rustic-sophisticated feel – is quickly becoming the talk of Culver City, too, it’s seemed.

Akasha is the namesake of a Hindu deity of wisdom, learning, music and self-control, and with 20 years of experience in the food and service business, who had a vision of “terracotta” menu served in bright, bold tones surrounding a white-walled seafood bar.

The restaurant serves lunch and dinner while the bakery opens its doors early morning to serve breakfast and coffee and tea throughout the day. The bar – a sleek lounge space, is open later than the restaurant.

# Talk Outline

- **Fusing open source maps with Imagery**
- **Linking news articles to imagery**
- **Exploiting open-source data to Identify buildings in imagery**

# Building Identification (BID) Problem

## Traditional Sources



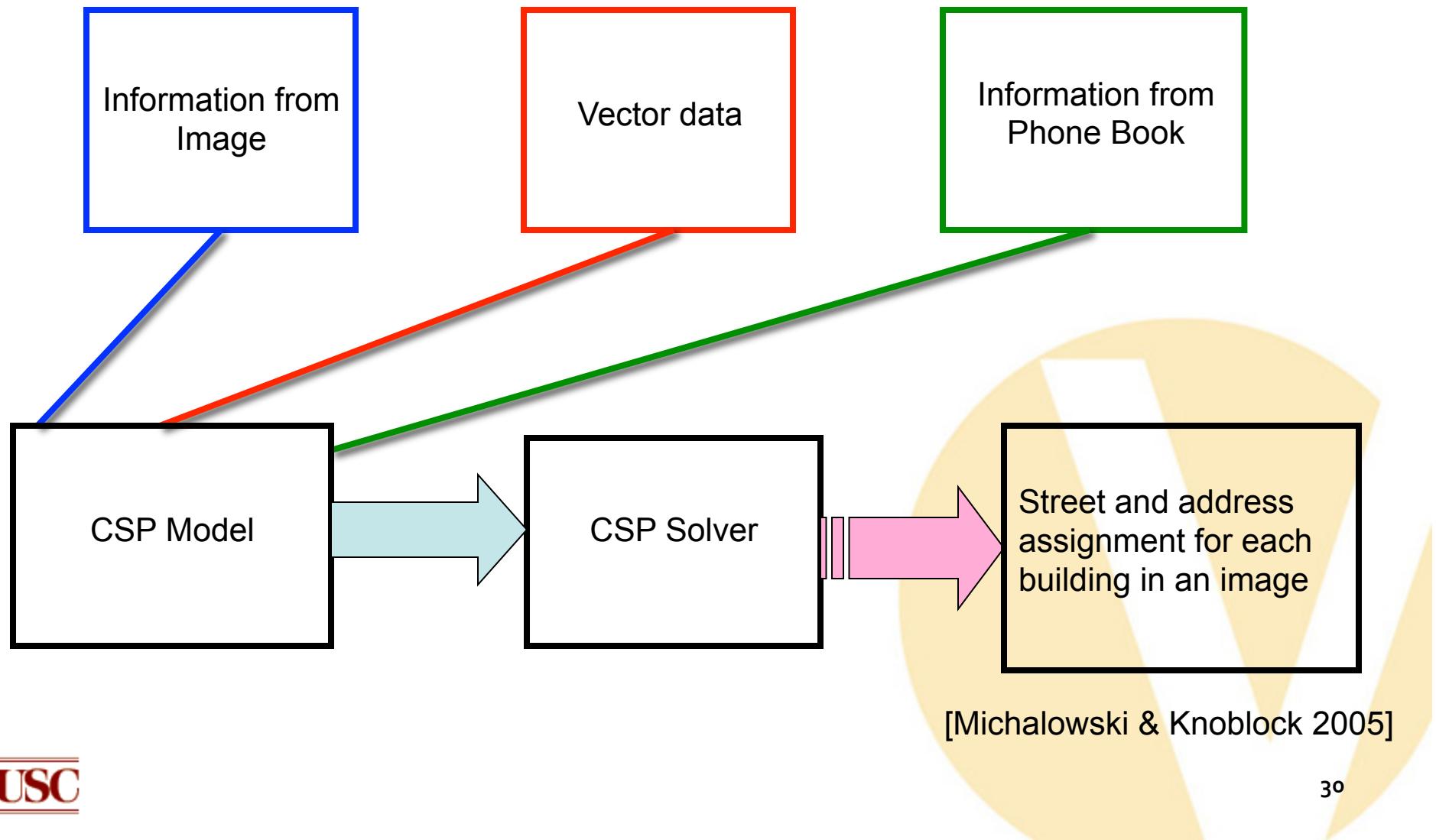
## Non-traditional Sources



After

[www.ncbi.nlm.nih.gov](http://www.ncbi.nlm.nih.gov)

# BID Problem as a CSP



- **Definition of a CSP**

- Given  $P = (V, D, C)$

- $V$  is a set of variables,  $V = \{V1, V2, \dots, Vn\}$
    - $D$  is a set of variable domains (domain values)
    - $D = \{DV1, DV2, \dots, DVn\}$
    - $C$  is a set of constraints,  $C = \{C1, C2, \dots, Cl\}$
    - $CVa, Vb, \dots, Vi = \{(x, y, \dots, z)\} \subseteq DVa \times DVb \times \dots \times DVi$

- Query: can we find a value for each variable such that all constraints are satisfied?

- **Useful for modeling & solving combinatorial problems**

# Example Constraints

## Parity Constraint

Assures all these buildings will  
be even or odd, not a mix



# Example Constraints

## Ascending Constraint

Assures that **address > address** because we know numbers ascend in south direction on N/S running streets



# Key Ideas

- **Use both explicit and implicit information in publicly available data sources.**

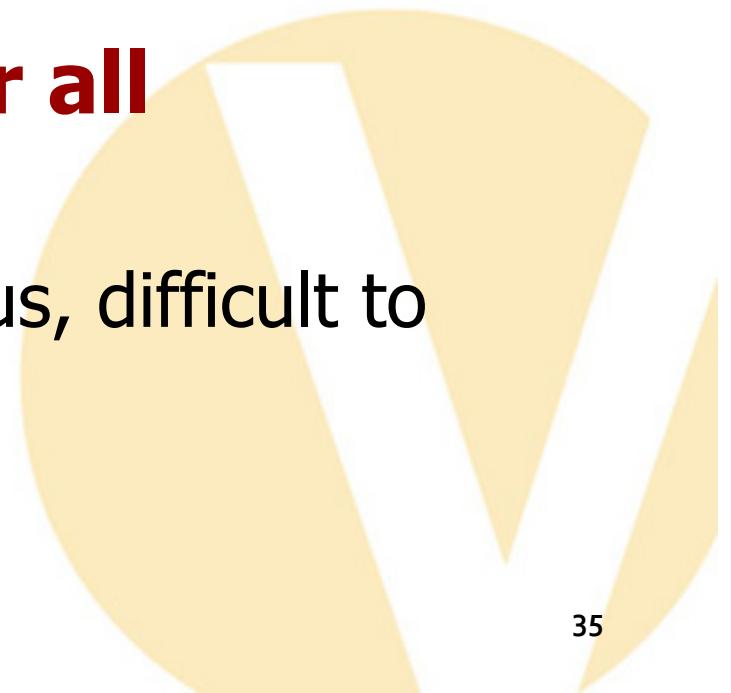
- Challenge: combining this information
- Solution: use a constraint satisfaction framework

- **Leverage common properties of streets and addresses**

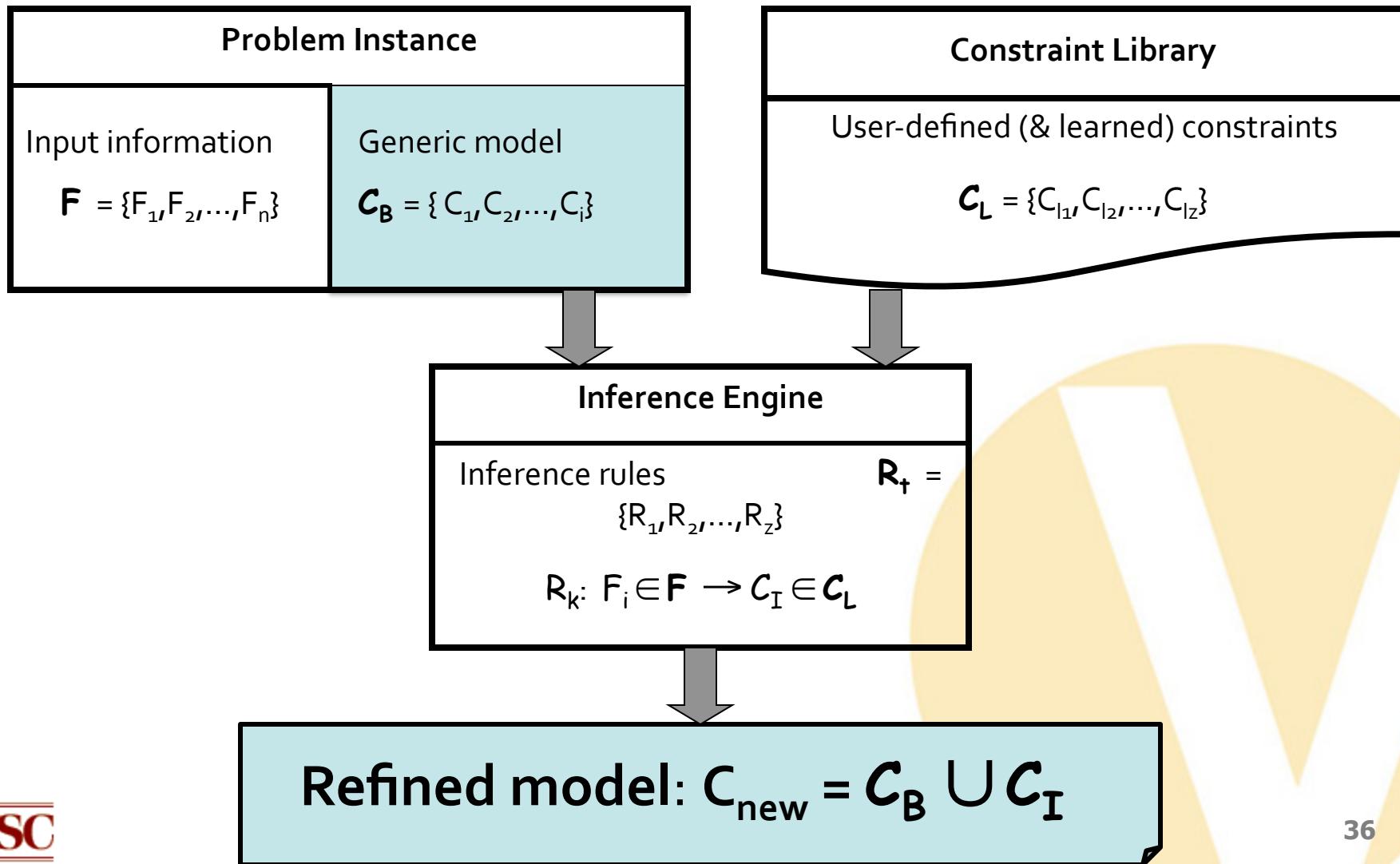
- Cannot be deduced from any individual source but require the combination of data from multiple sources.
- Represent as constraints

# Challenges

- **Varying addressing schemes exist**
  - Static models don't work
- **Single areas are non-homogeneous**
  - Further complicates the problem
- **Generating models for all possible scenarios**
  - BAD! Lots of work, tedious, difficult to account for everything,...

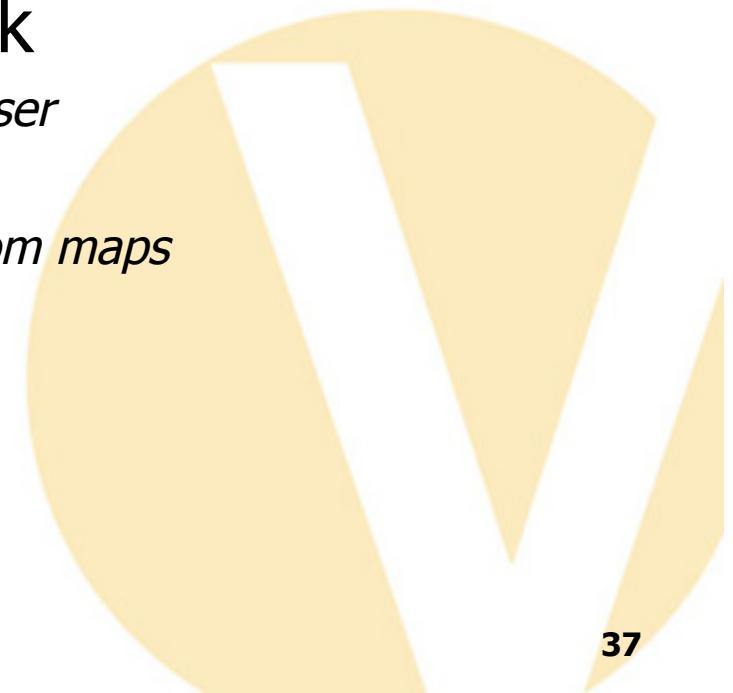


# Constraint-Inference Framework



# Geospatial Fusion Framework

- **Challenge: How to put technologies together into a framework that can be applied in the real world**
- **Approach**
  - Mixed-initiative framework
    - *Provides the available data to the user*
    - *Supports the automated reasoning*
    - *Integrates information extracted from maps*



# Exploiting Open Source Data to Identify Structures

IDENTIFY STREETS → IDENTIFY BUILDING LOCATIONS → IDENTIFY BUILDING ADDRESSES

POSSIBLE VALUES:

- [Svetozara Miletića 12](#)
- [Mihizova 15](#)

ENTER VALUE FOR BUILDING:

SAVE CANCEL

PHONE DATA

PLOIT TRAINTS

LABEL DINGS

Click on a street or building to view information

:Mapped

:Unmapped

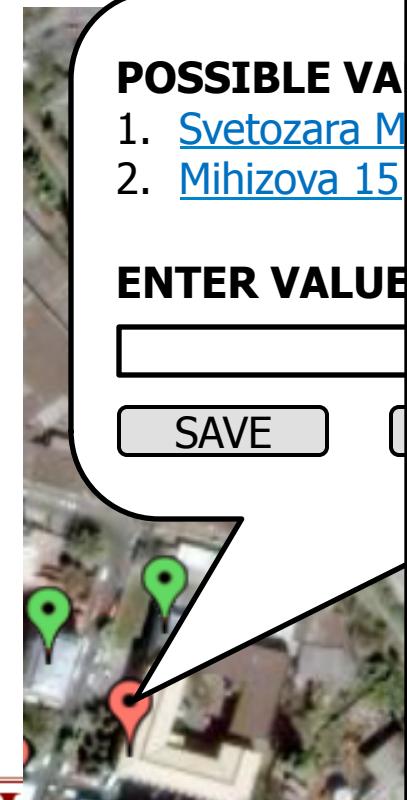
Each link opens a popup (shown in next slide) with respective Information.

IDENTIFY  
STREETS

**POSSIBLE VA**  
1. [Svetozara M](#)  
2. [Mihizova 15](#)

**ENTER VALUE**

**SAVE**



**ADDRESS: Svetozara Miletića 12**

**YELLOW PAGES/ WHITE PAGES  
INFORMATION:**

**White Pages**

N/A

**Yellow Pages**

Name: CORUN AD UŽICE  
Phone No.: +381 11 3392 058  
Category: Tools and Cutting  
Tools  
Map Link: <http://mape.nadlanu.com/Mapa.aspx?x=7458690&y=4964220>

**GOOGLE SEARCH RESULTS:**

(for Svetozara Miletića 12, BEE TELECOM DOO, CORUN AD UŽICE )

1. [E kapija](#)
2. [Bee Telecom d.o.o.](#)
3. [CORUN ad UŽICE - Imenik KoŠtaGde](#)

**www.wikimapia.org suggestion**

**LINK TO RELATED IMAGES/ MAPS DUG FROM INTERNET:**



**CLICKING ON A  
RED BALLOON**

Link can be opened  
in browser to view  
location on map

## ADDRESS: Svetozara Miletića 12

IDENTIFY  
STREETS

### POSSIBLE VA

1. [Svetozara M](#)
2. [Mihizova 15](#)

### ENTER VALUE

SAVE



USU

### YELLOW INFORM

Wh

N/A

### GOOGL

(for Svetozar  
UŽICE )

1. [E kapi](#)
2. [Bee To](#)
3. [CORU](#)

[TNK T

]

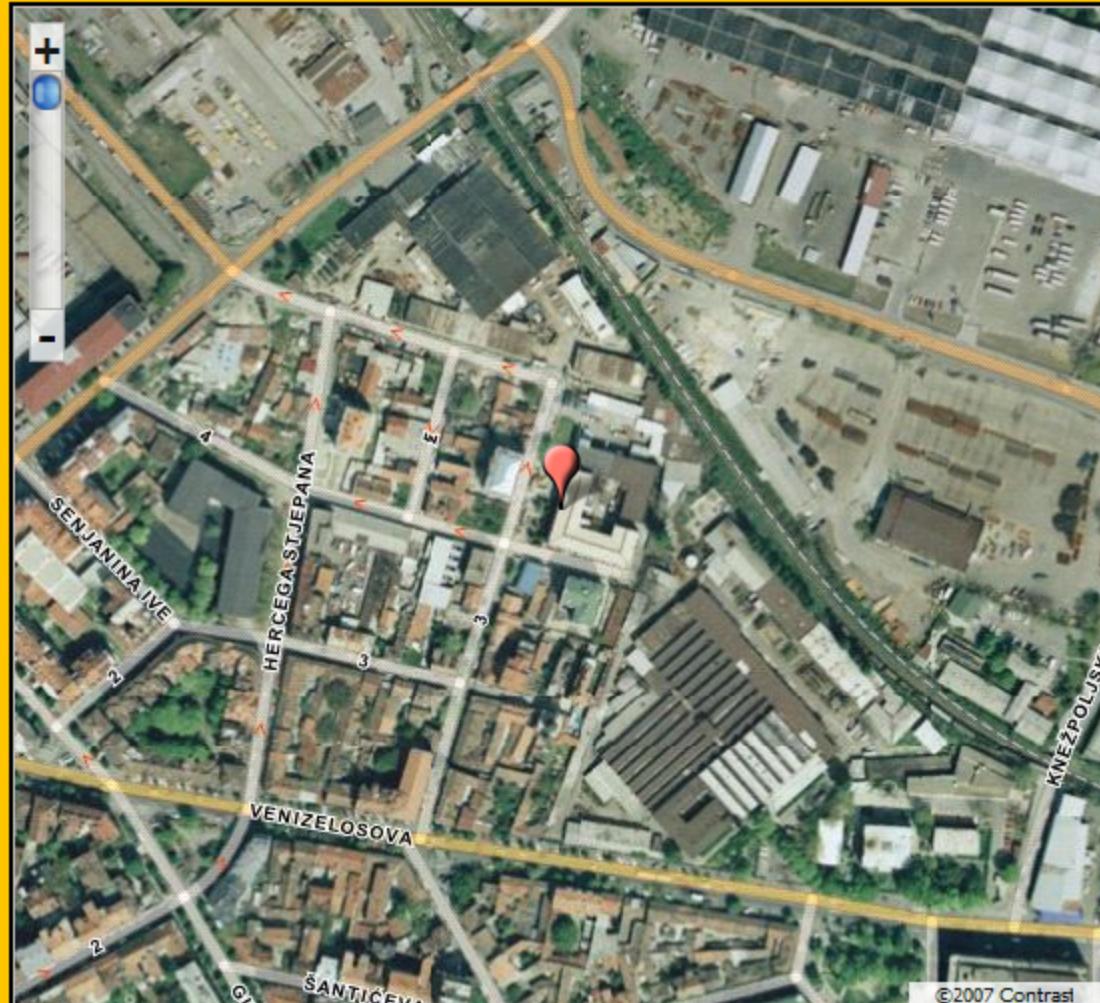


Done

Mapa - Mozilla Firefox

http://mape.nadlanu.com/Mapa.aspx?x=7458690&y=4964220

nadlanu.com



Institute

opened  
view  
ap

# Exploiting Open Source Data to Identify Structures

IDENTIFY STREETS → IDENTIFY BUILDING LOCATIONS → IDENTIFY BUILDING ADDRESSES

CLICKING ON A RED BALLOON

**POSSIBLE VALUES:**

1. [Svetozara Miletića 12](#)
2. [Mihizova 15](#)

**ENTER VALUE FOR BUILDING:**

Svetozara Miletića 12

SAVE

CANCEL

PHONE  
DATA

PLOIT  
TRAINTS

LABEL  
DINGS

Click on a street  
or building to  
view information

- Mapped
- Unmapped

We can assign  
a value to red  
balloon after  
viewing popups  
and other links.



# Exploiting Open Source Data to Identify Structures

IDENTIFY STREETS → IDENTIFY BUILDING LOCATIONS → IDENTIFY BUILDING ADDRESSES



LOAD PHONE BOOK DATA

EXPLOIT CONSTRAINTS

LABEL BUILDINGS

Click on a street or building to view information

- Green marker : Mapped
- Red marker : Unmapped

Run constraint reasoning algorithm again in attempt to map more buildings with addresses.

# Exploiting Open Source Data to Identify Structures

IDENTIFY  
STREETS

IDENTIFY  
BUILDING  
LOCATIONS

IDENTIFY  
BUILDING  
ADDRESSES



LOAD PHONE  
BOOK DATA

EXPLOIT  
CONSTRAINTS

LABEL  
BUILDINGS

Click on a street  
or building to  
view information

- :Mapped
- :Unmapped

New Values are  
mapped (in yellow  
circle) after red balloon  
was assigned value.

- **Fusing open source maps with Imagery**
  - Currently funded jointly at Geosemble and USC under an AFOSR Phase II STTR project
  - Need a customer for Phase III to transition the technology
    - *DOD would provide matching funds*
- **Linking news articles to imagery**
  - Currently funded at USC and Geosemble by DARPA & DHS
  - In-Q-Tel has committed to fund commercialization work at Geosemble
- **Exploiting open-source data to Identify buildings in imagery**
  - Currently funded at USC under a basic research grant from AFOSR
  - Looking for a customer to support both the research and the technology transition