

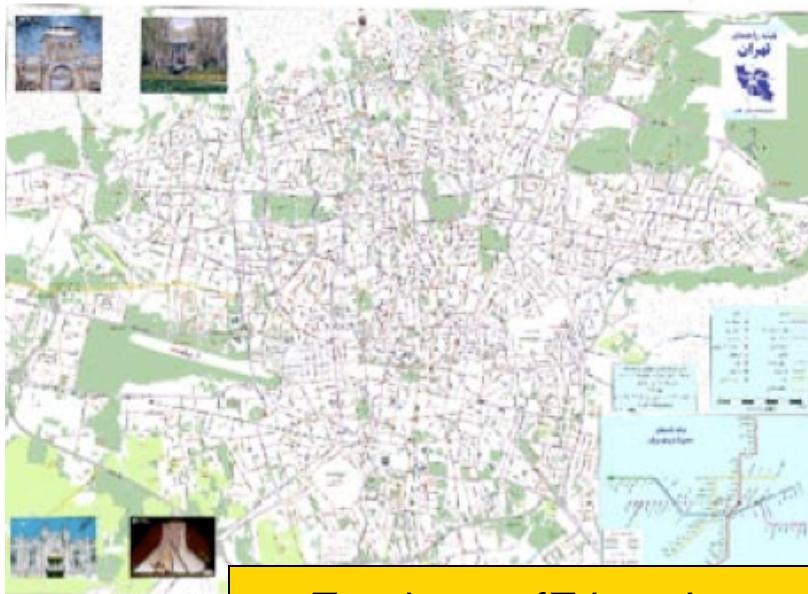
A General Approach to Discovering, Registering, and Extracting Features from Raster Maps

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University of Southern California
&
Geosemble Technologies

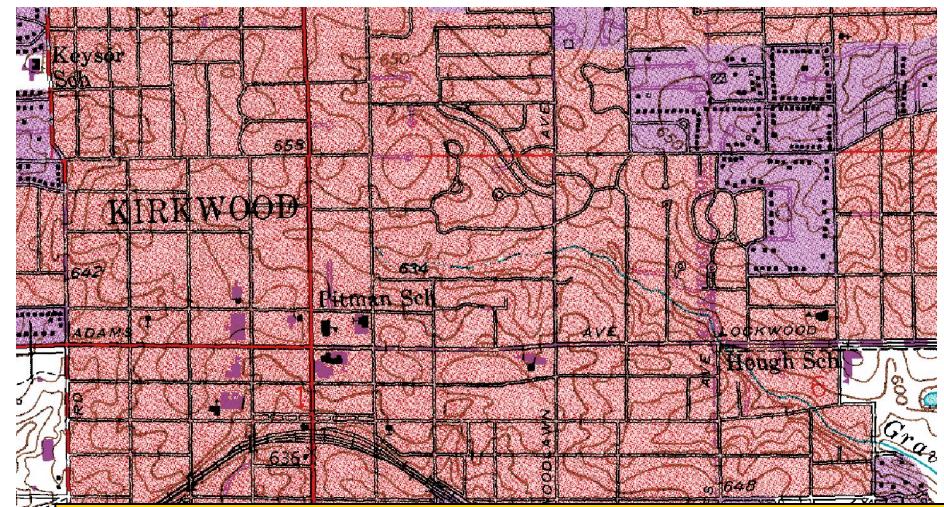
**Joint work with Ching-Chien Chen, Yao-Yi Chiang,
Aman Goel, Matthew Michelson, and Cyrus Shahabi**

Introduction

- **Raster maps are a rich source of geospatial data:**
 - Easily accessible
 - Many different types of information
 - Often contains information that cannot be found elsewhere



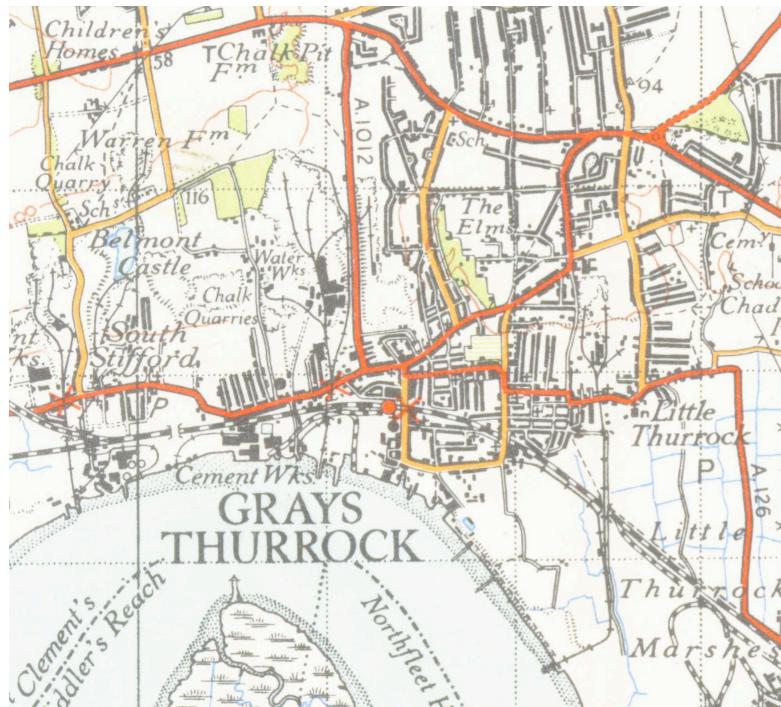
Travel map of Tehran, Iran



USGS topographic map of St. Louis, MO

Challenges

- **Maps have lots of useful information, but...**
 - They have overlapping features
 - There is limited access to the meta-data
 - Often only available in raster format
- **How do we find, register, and extract and recognize the features in a raster map**



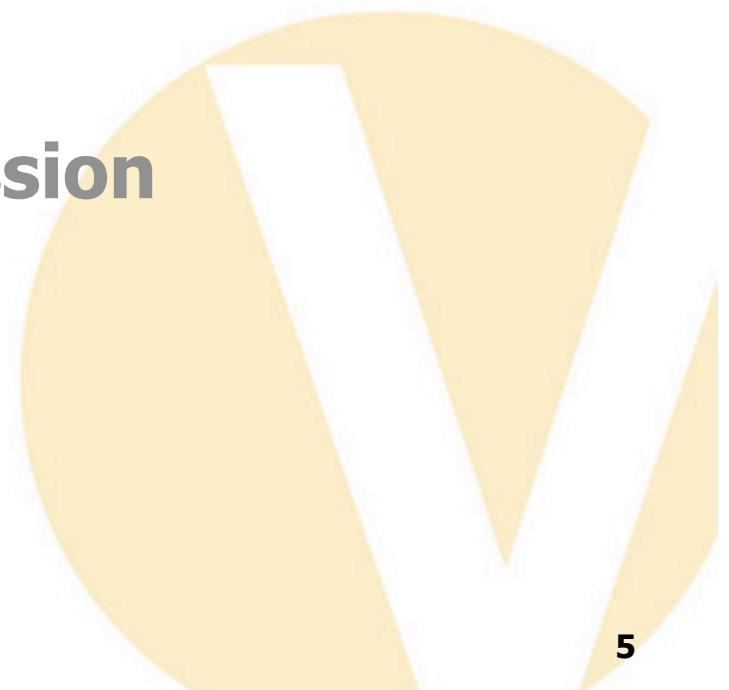
Outline

- **Map Discovery**
- **Automatic Extraction of Features**
- **Feature Extraction from Noisy Maps**
- **Automatic Registration of Maps**
- **Feature Recognition**
- **Related Work and Discussion**

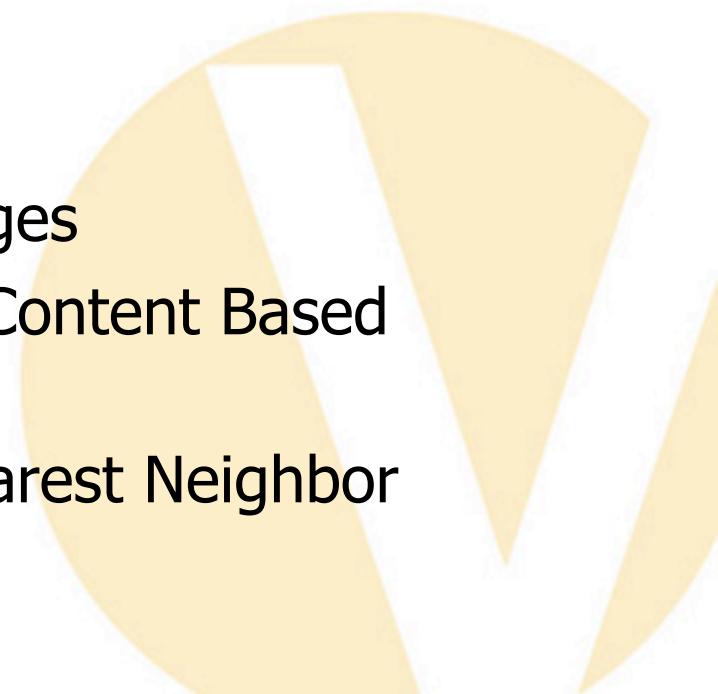


Outline

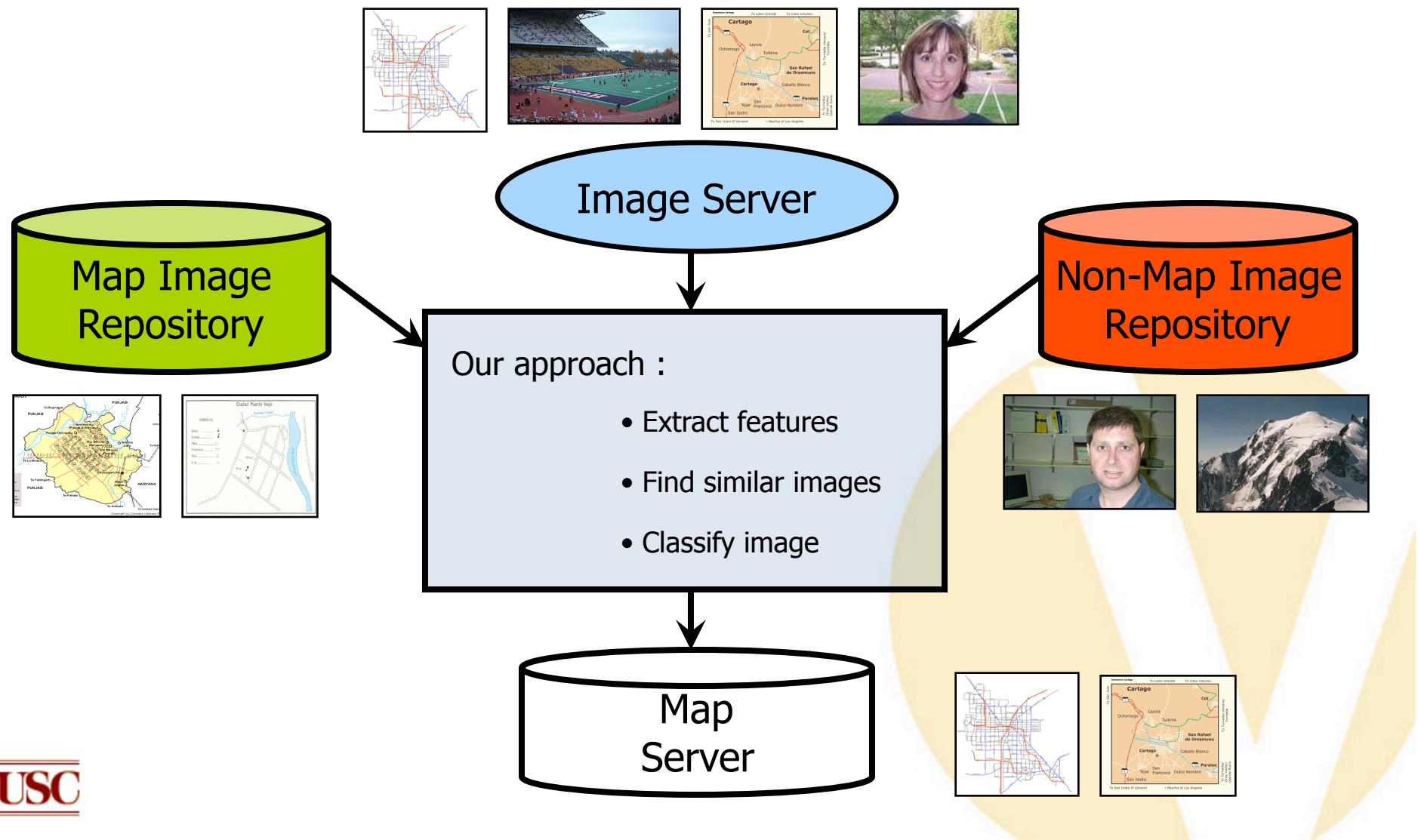
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- **Collect candidate maps from the Web**
 - Standalone maps
 - *Found using an image search engine*
 - Maps embedded in PDF documents
 - *Found using a general search engine and then extracting the images*
- **Classify the images**
 - Extract features from the images
 - Identify similar images using Content Based Image Retrieval (CBIR)
 - Classify the image using k-Nearest Neighbor



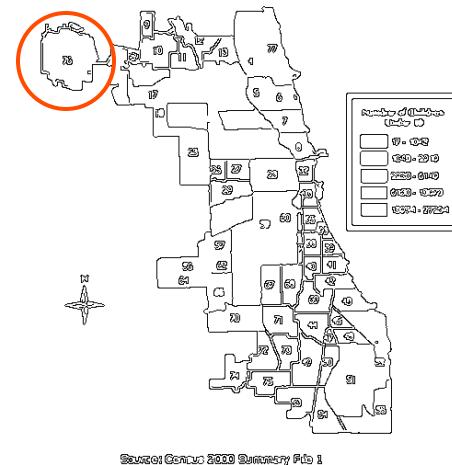
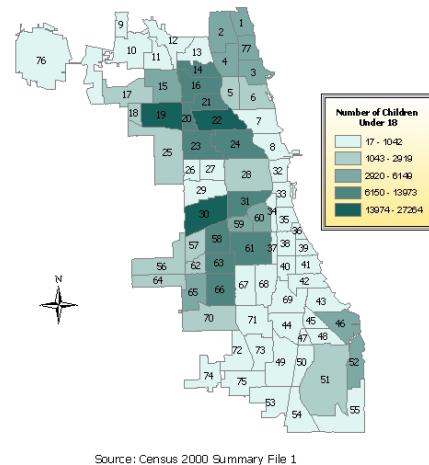
Identifying Maps



Extract Features

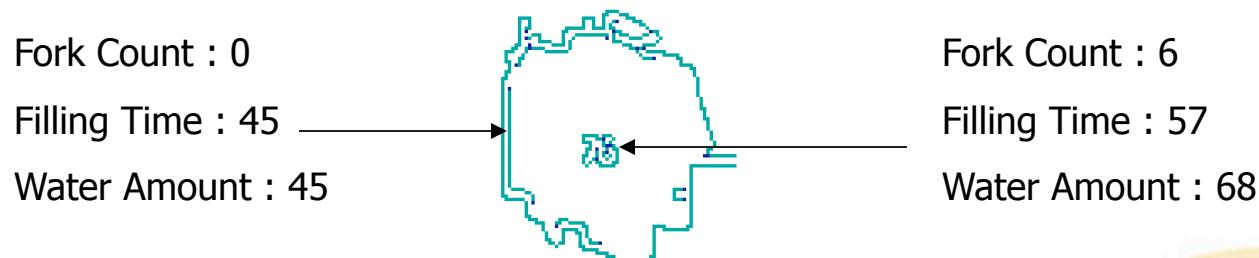
• Water-filling features

- Zhou, X.S. et al. - Water-filling: A novel way for image structure feature extraction, 1999, Intl. conference on Image Processing
- Works well on images with strong edges

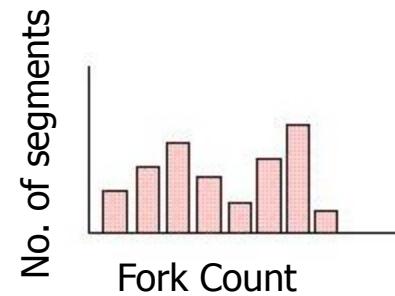


- Works on standard Canny edge maps of original images
 - Color invariant

- Features computed for each segment

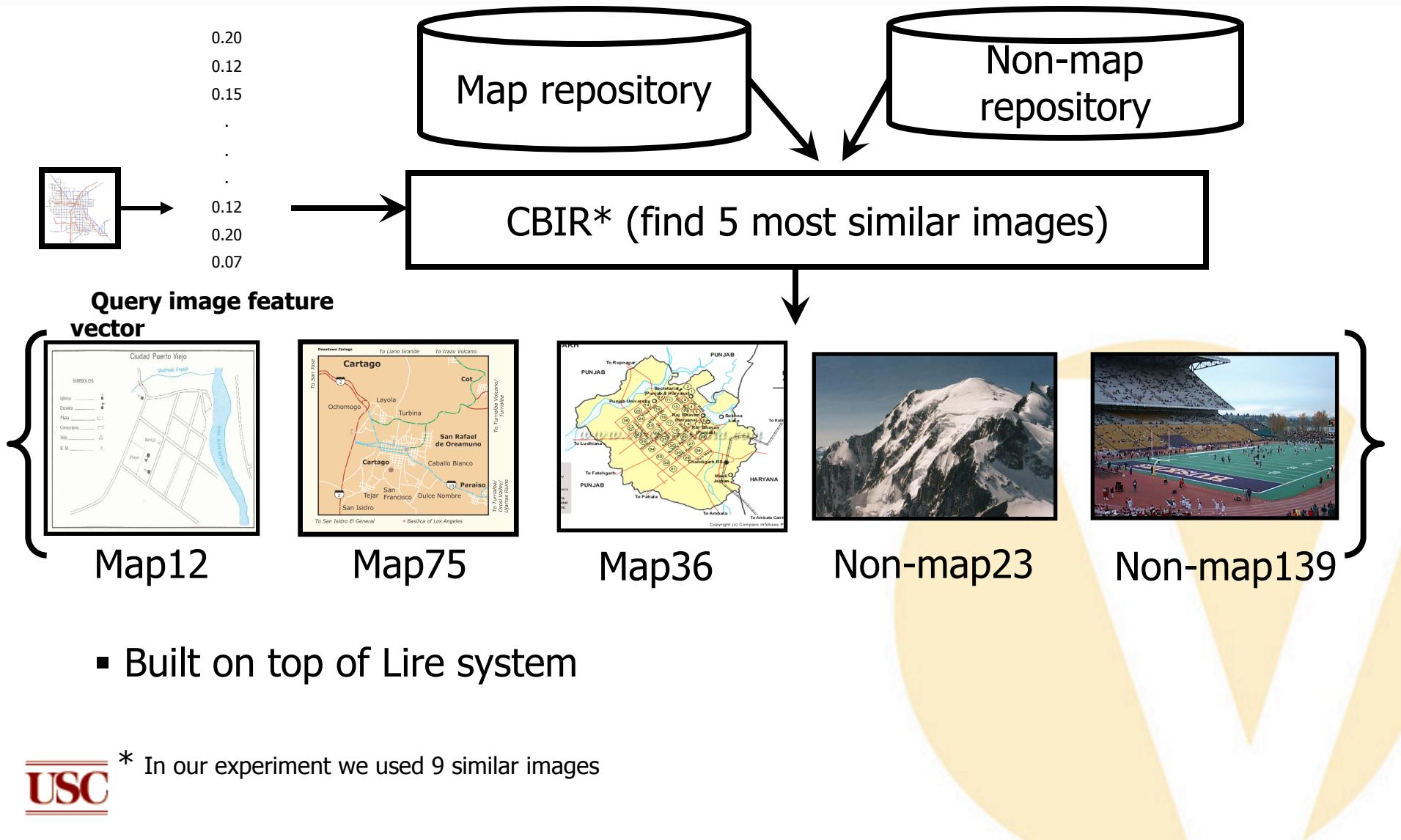


- Normalized histogram - size invariant



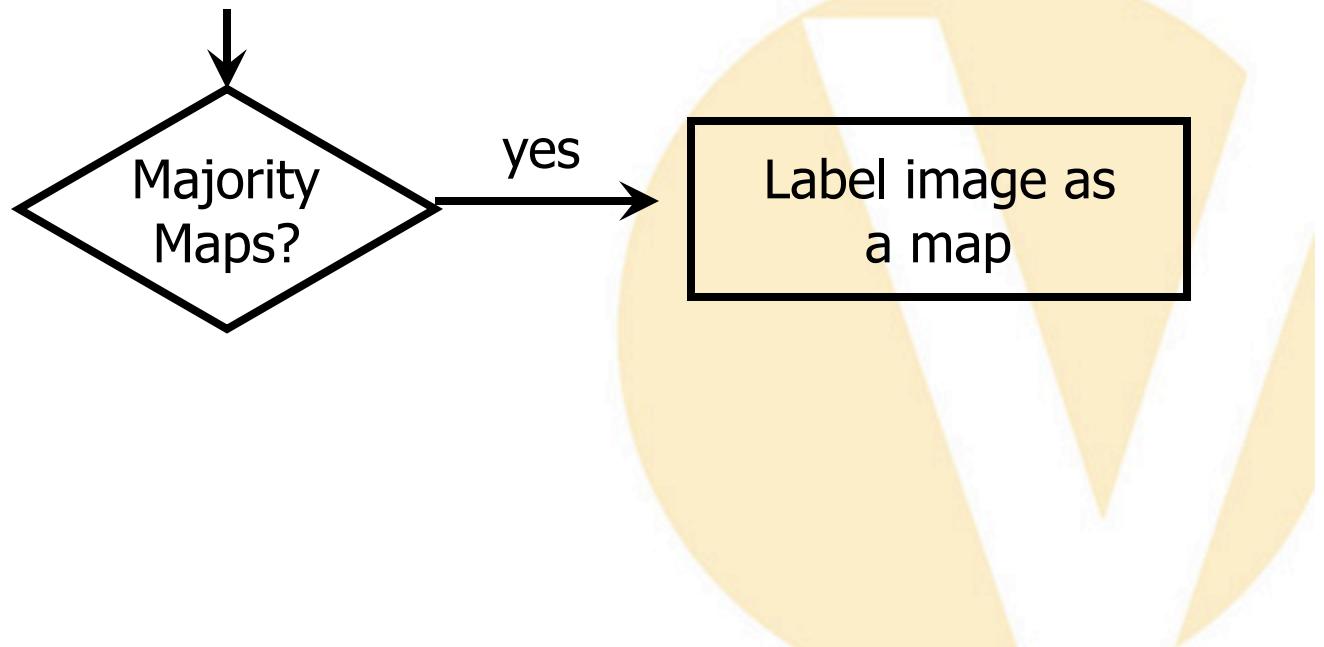
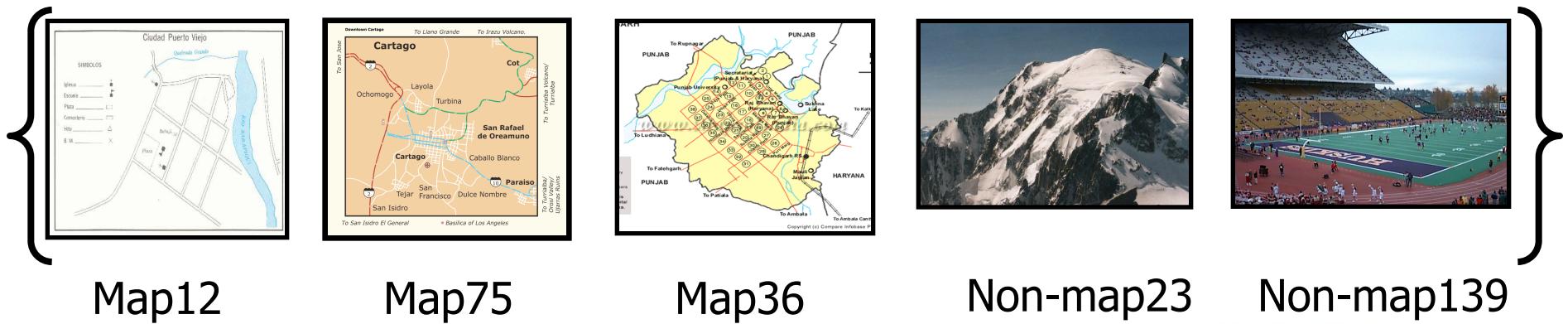
- 3 features x 8 buckets = 24 element feature vector

Content-Based Image Retrieval (CBIR)

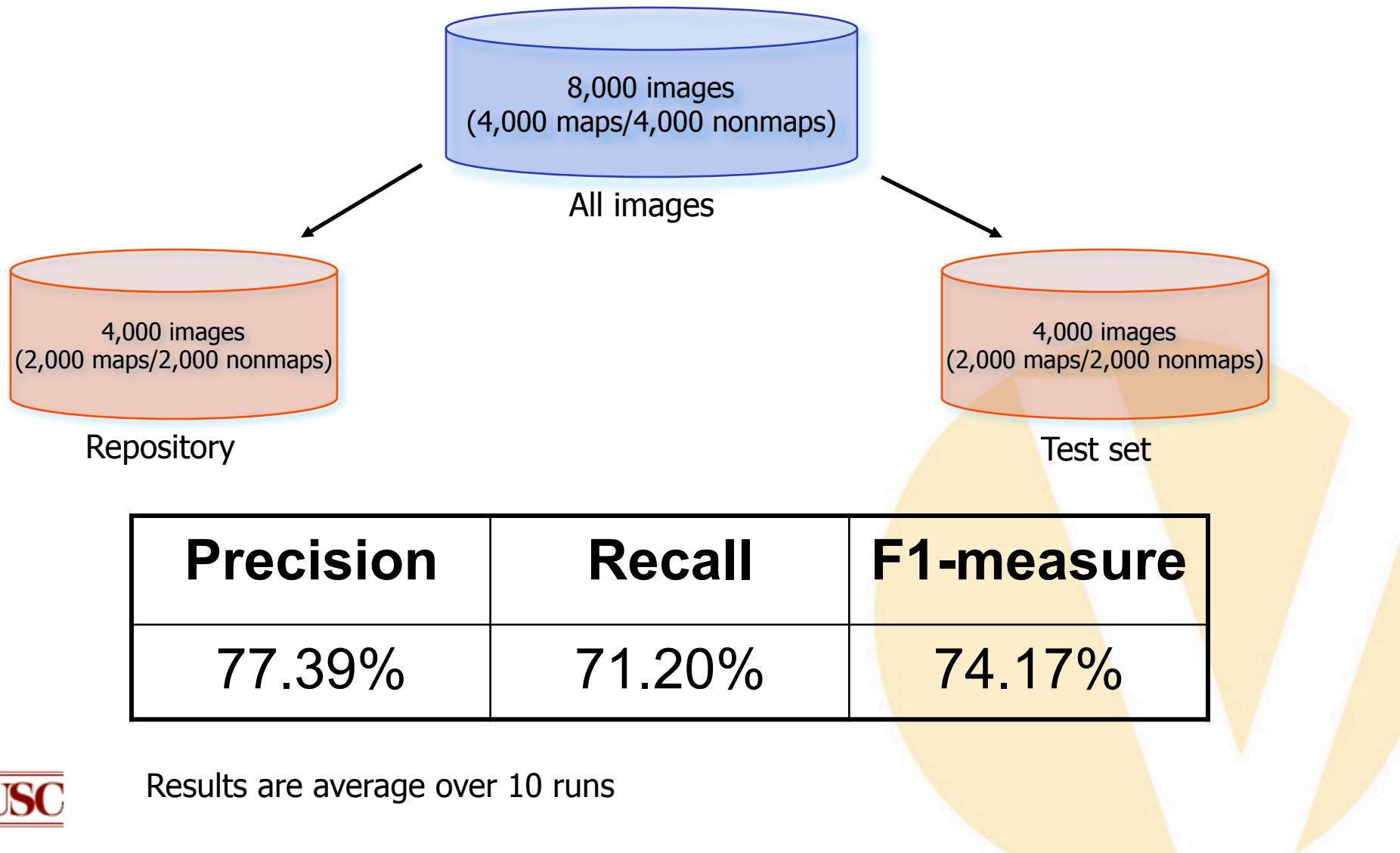


- Built on top of Lire system

k - Nearest neighbor classification

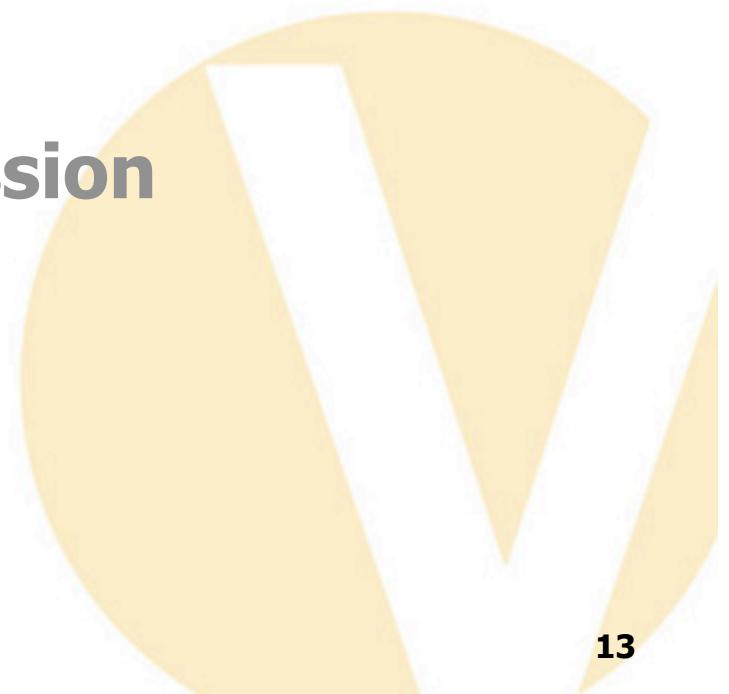


Results



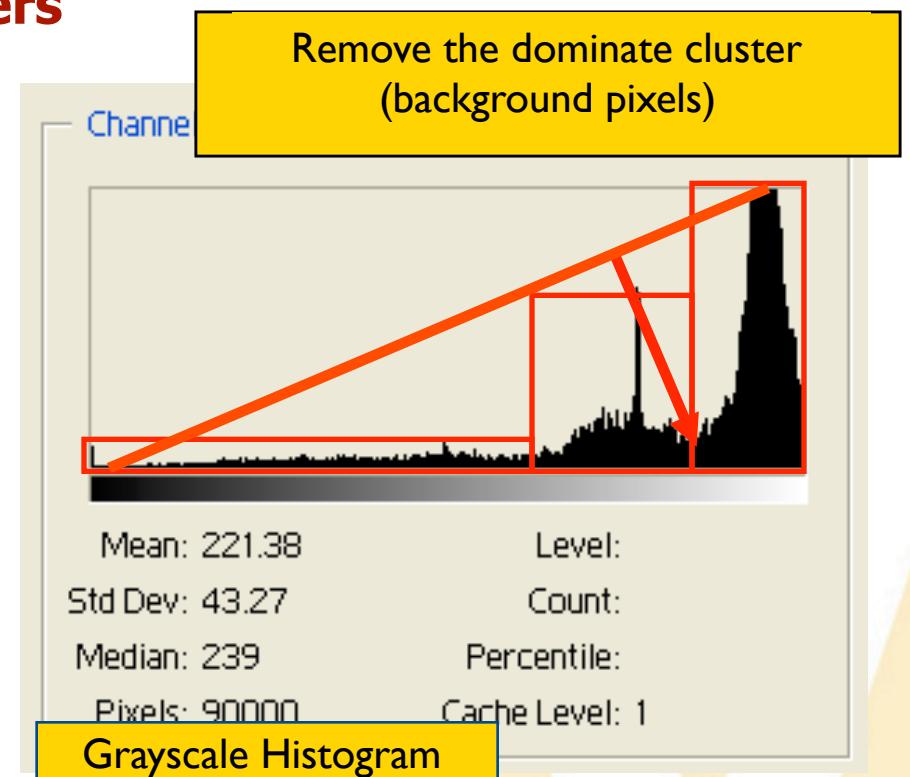
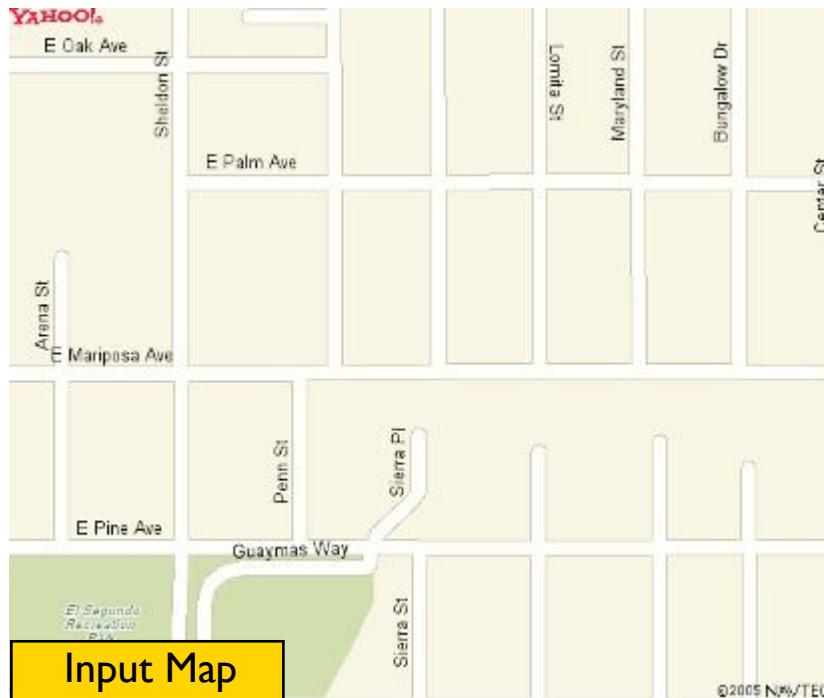
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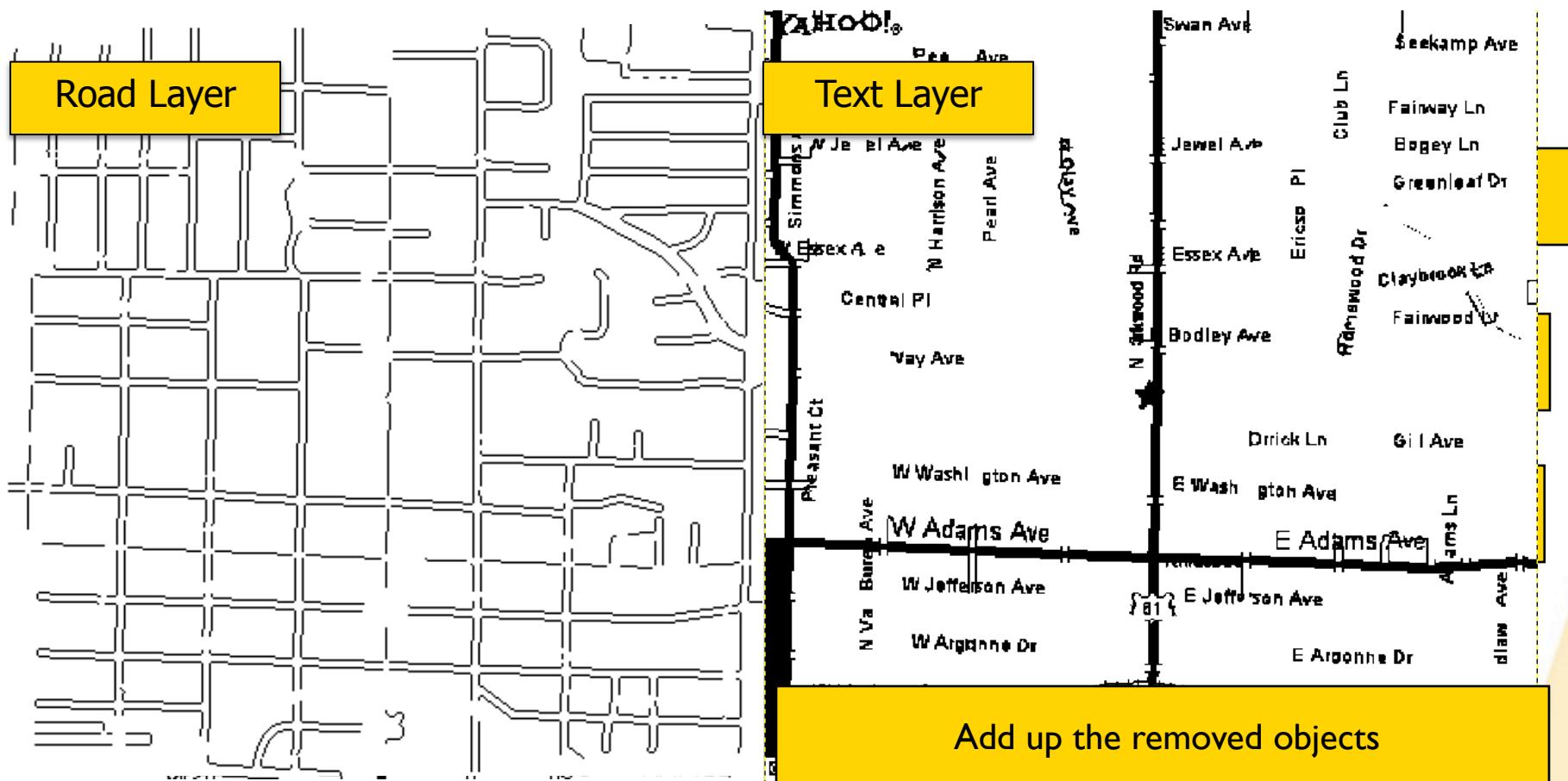
Background Removal

- Use the Triangle method (Zack, 1977) to locate clusters in the grayscale histogram
- Remove the background clusters



Text/Graphics Separation

- Separate linear structures from text (Cao and Tan, 02)



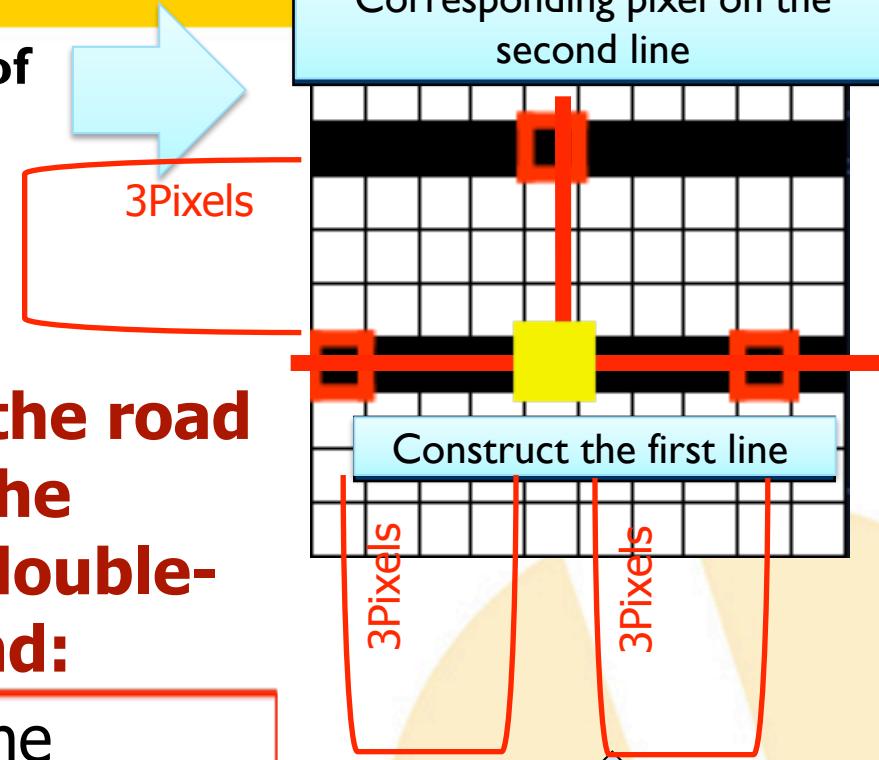
Pixilated view of a segment of double-line streets

Black cells: Road pixels

White cells: Backgrounds

- **Assuming we know the road width is 3 pixels, if the yellow pixel is on a double-line layer, we can find:**

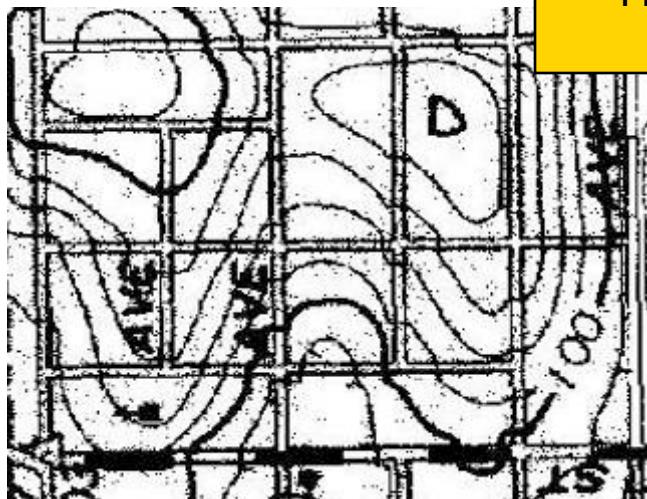
- At least 1 pixel on the original road line
- At least 1 corresponding pixel on the other road line



The parallel pattern@3-pixel road width!

Road Format and Road Width Detection

- ▶ **Apply parallel-pattern tracing (PPT) iteratively on different sizes of road width**
- ▶ **If it is a double-line road layer, the actual road width**
 - Has the maximum percentage of parallel pattern pixels
 - The percentage is larger than a threshold

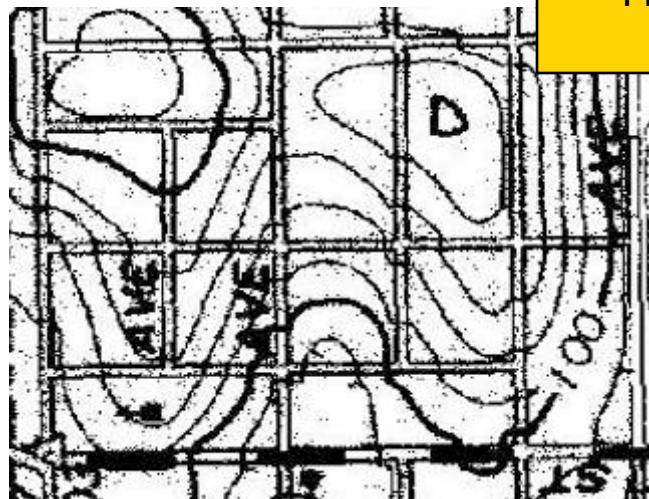


Apply PPT using the detected road width to remove non-parallel lines



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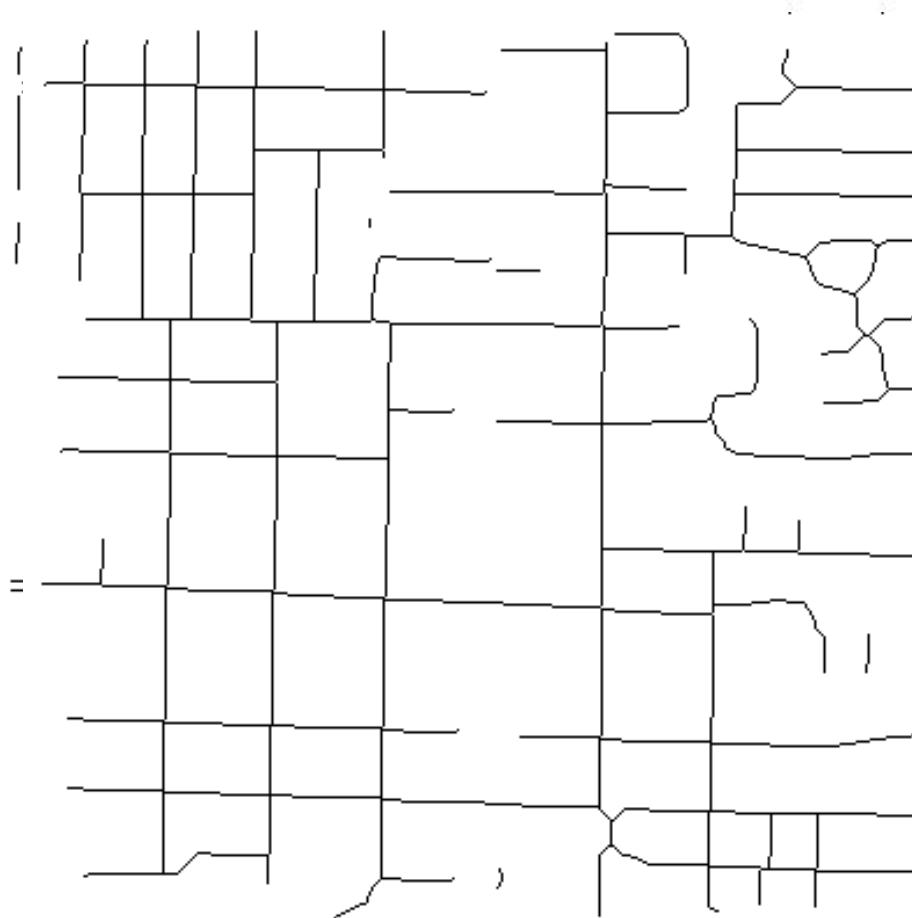


Apply PPT using the detected road width to remove non-parallel lines



Road Topology Extraction

- Use morphological operations to reconnect broken lines and generate one-pixel width roads



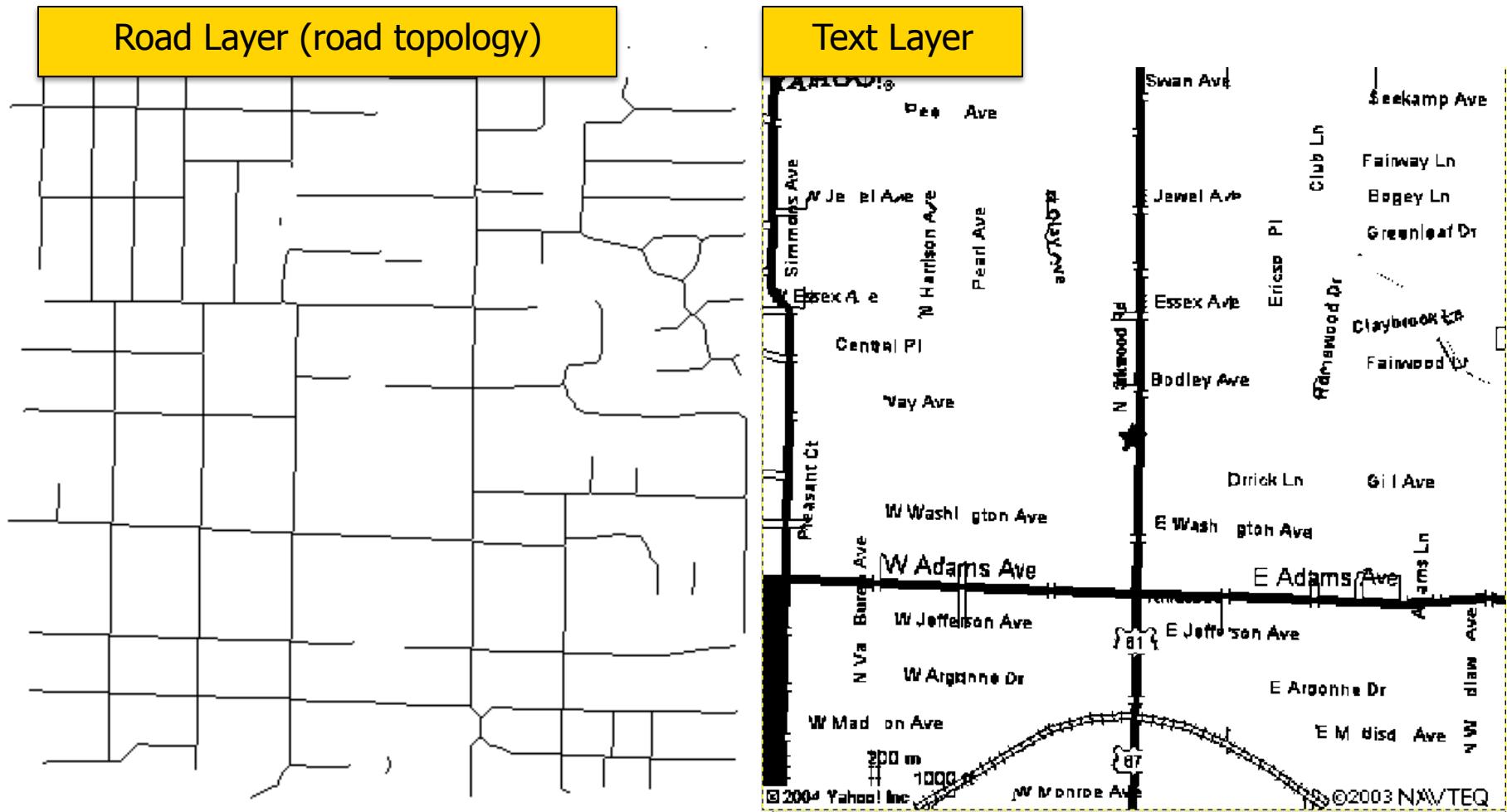
Morphological Operations:
Use the detected road format and road width to determine the number of iterations

Dilation

Erosion

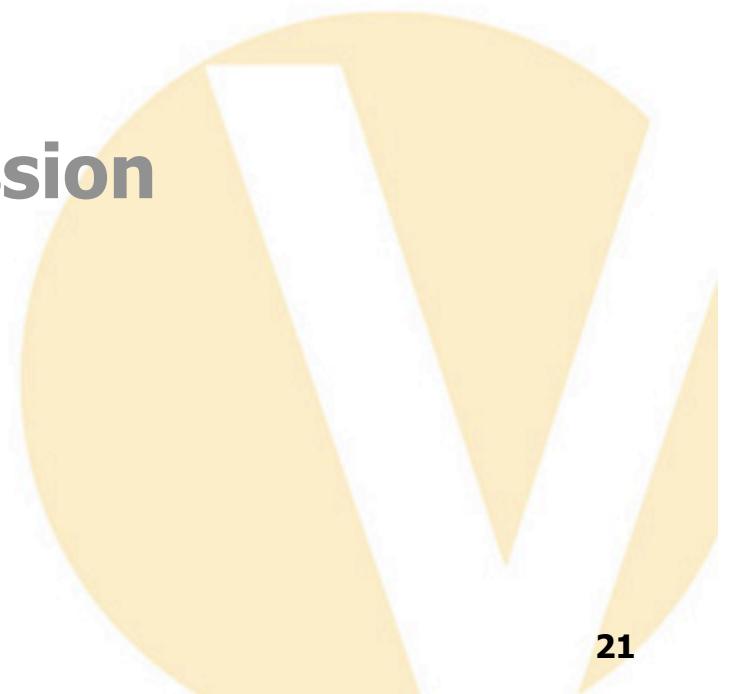
Thinning

Extracted Road and Text Layers



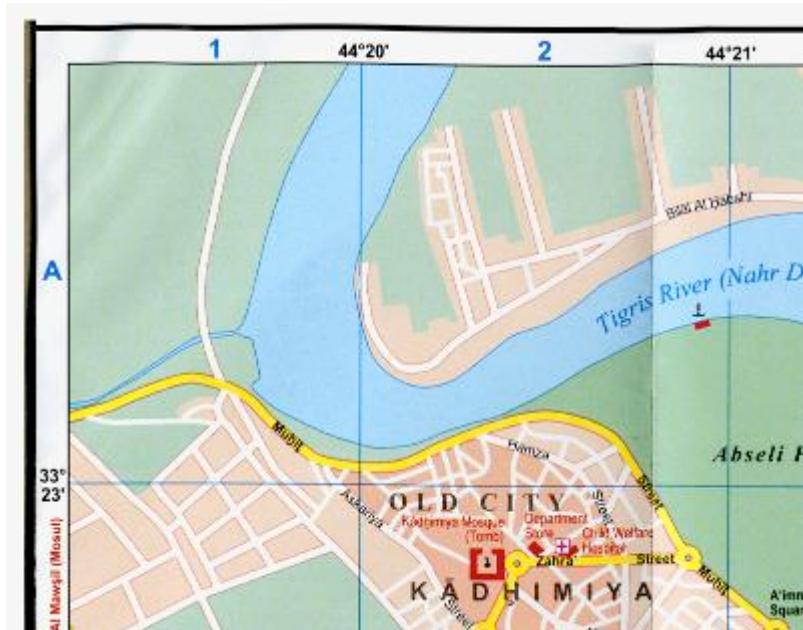
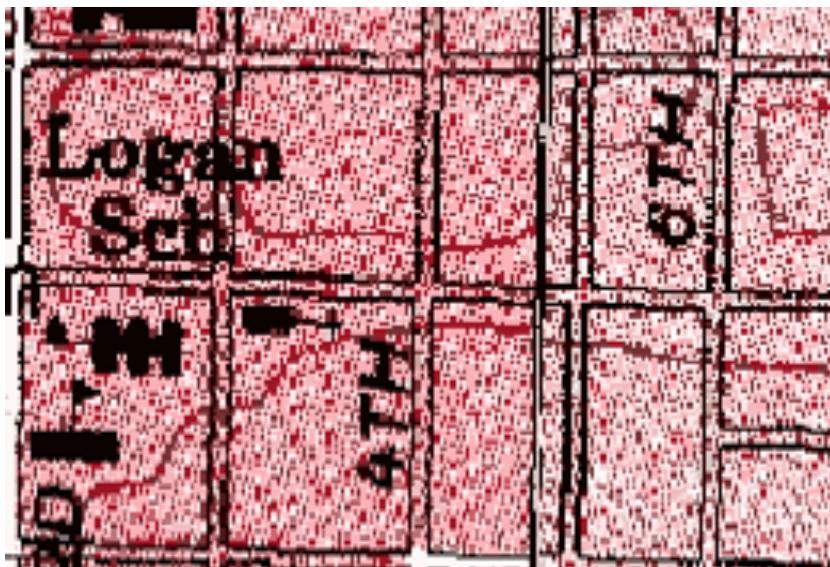
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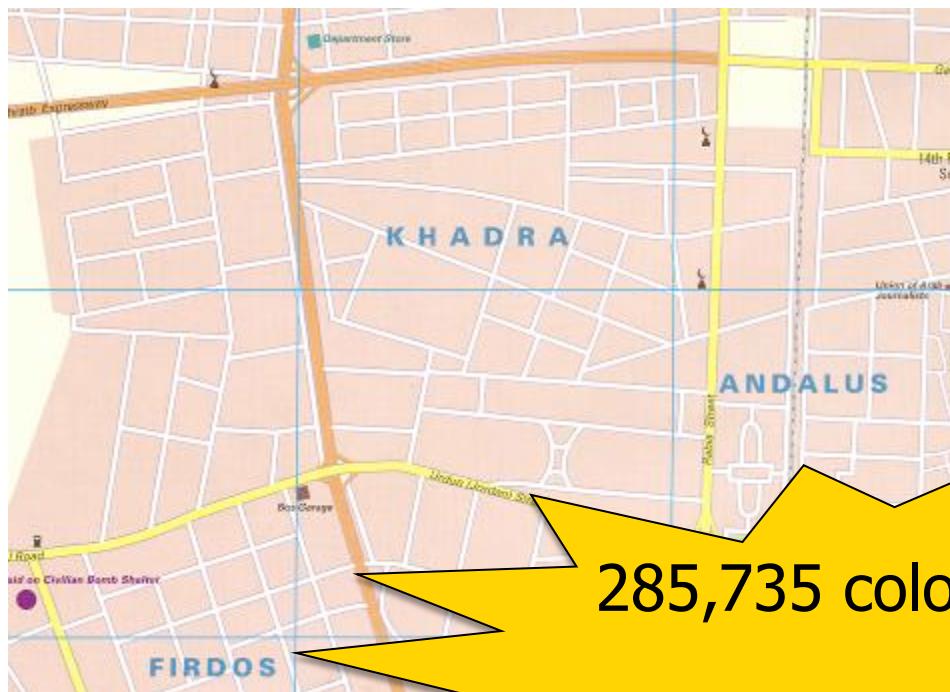
Supervised Map Decomposition

- **What if we cannot automatically remove the background from raster maps?**
 - Raster maps usually contain noise from scanning and compression process



Difficulties

- **Raster maps contain numerous colors**
 - Manually examining each color for extracting features is laborious



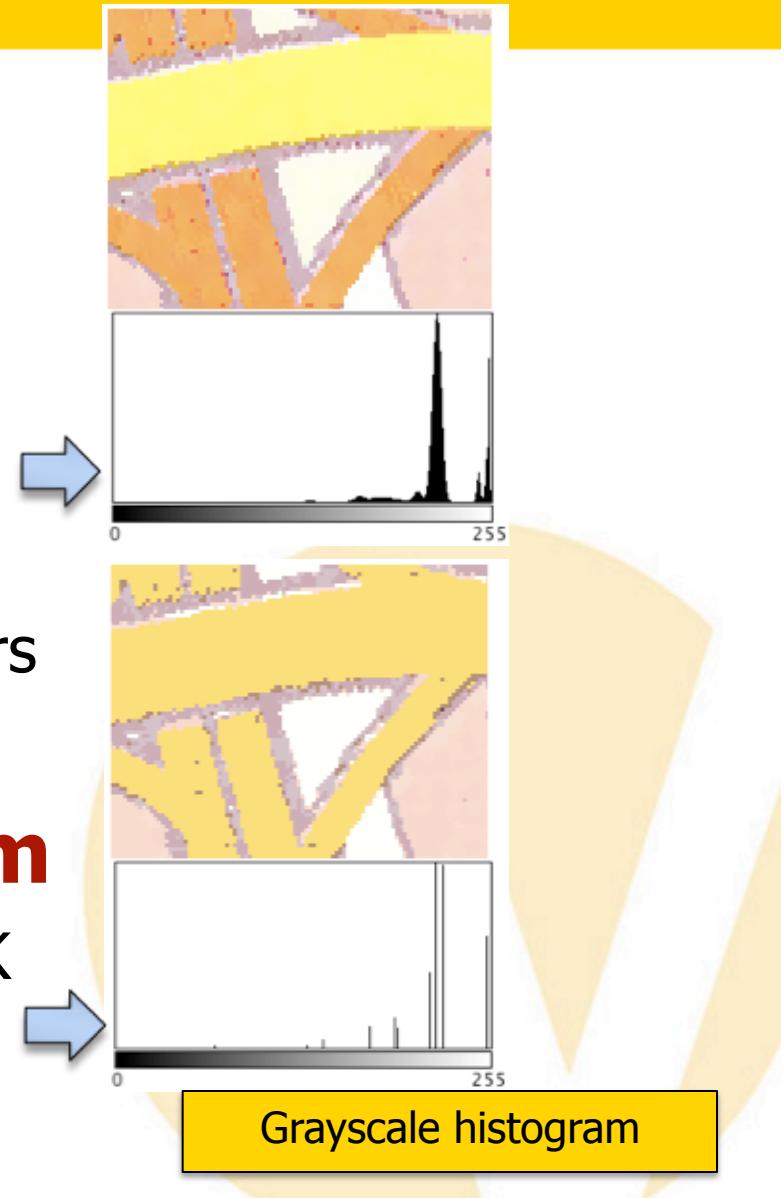
285,735 colors



Grayscale histogram

- **The Mean-shift algorithm**

- Consider distance in the RGB color space and in the image space
- Preserve object edges
- From 285,735 to 155,299 colors

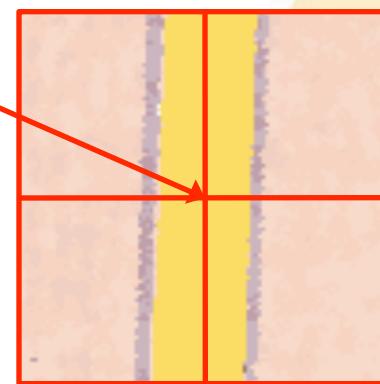
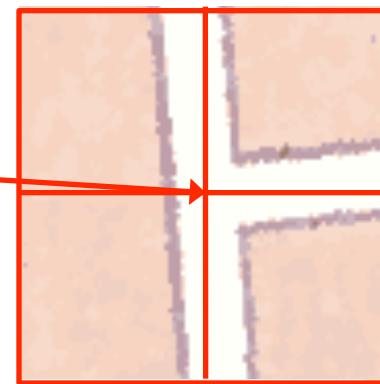


- **The K-means algorithm**

- Limit the number of colors to K
- From 155,299 to 10 colors
(K=10)

User Labeling

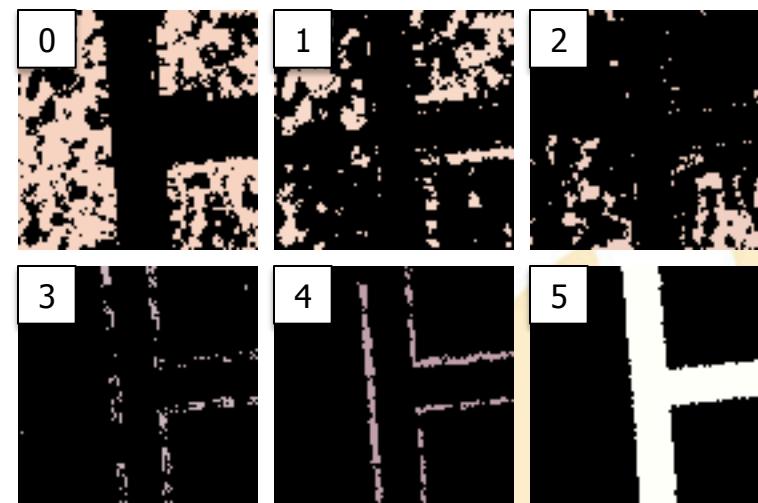
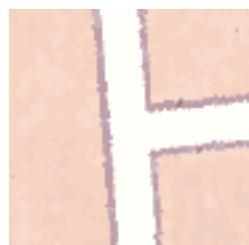
- To extract the road layer, the user needs to provide a user label for each road color (at most K colors)



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

Label Decomposition

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

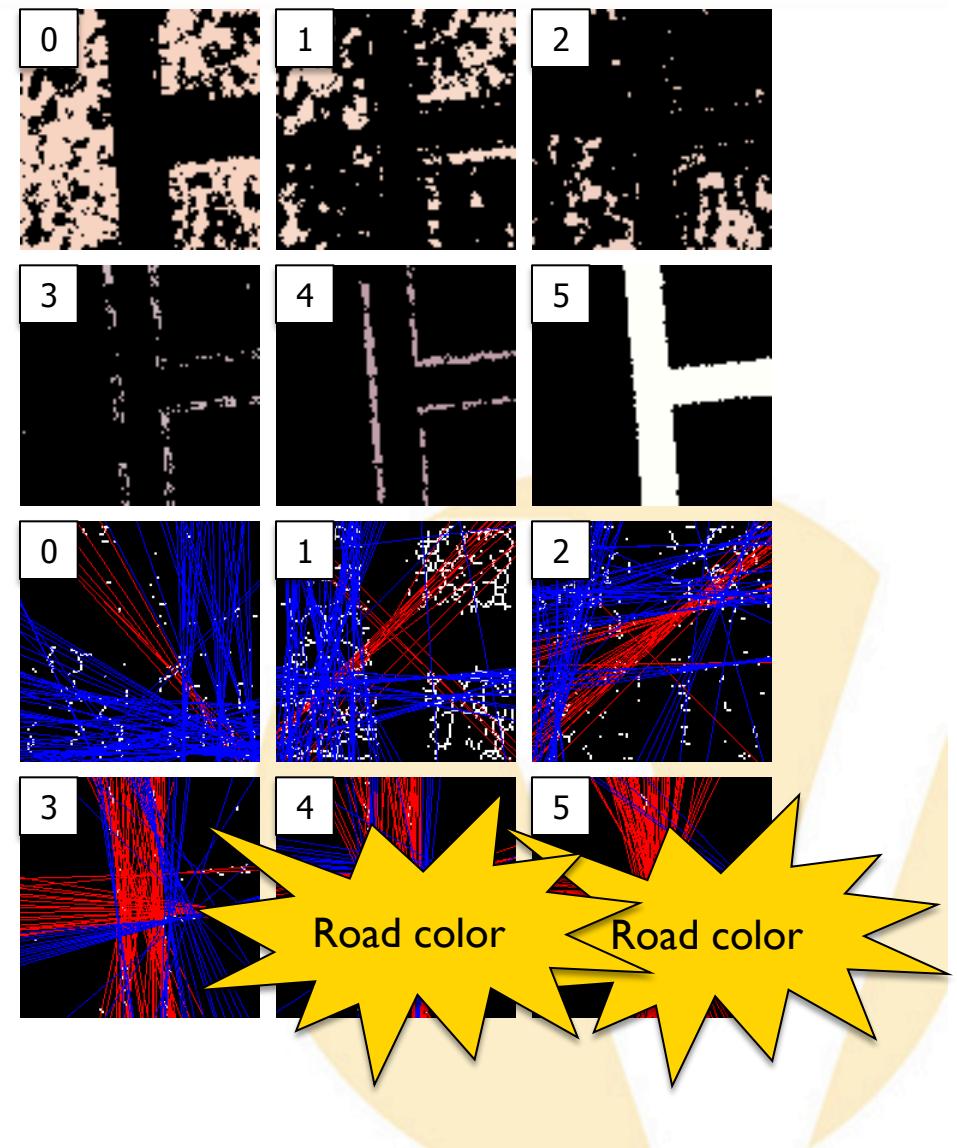


(background is shown in black)

Hough-Line Approach to Identify Road Color

- ▶ Detect Hough lines
- ▶ The center of the user label is the center of a road line
 - ▶ The Hough lines that are far away from the image center are NOT constructed by road pixels
- ▶ Identify road colors using
 - ▶ The average distance between the Hough lines to the image center

Red Hough lines are within 5 pixels to the image center



Initial Road Template

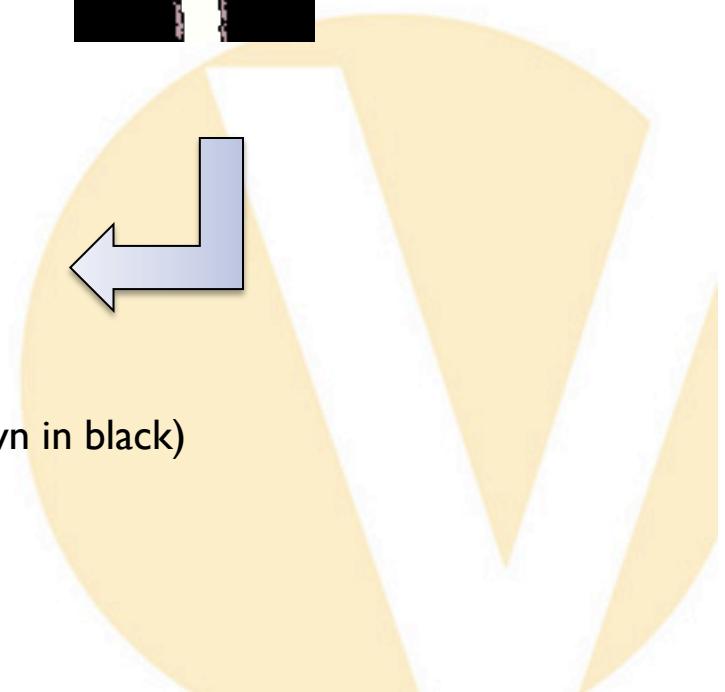
- Generate an initial road template using the images of identified road colors from the Hough line approach



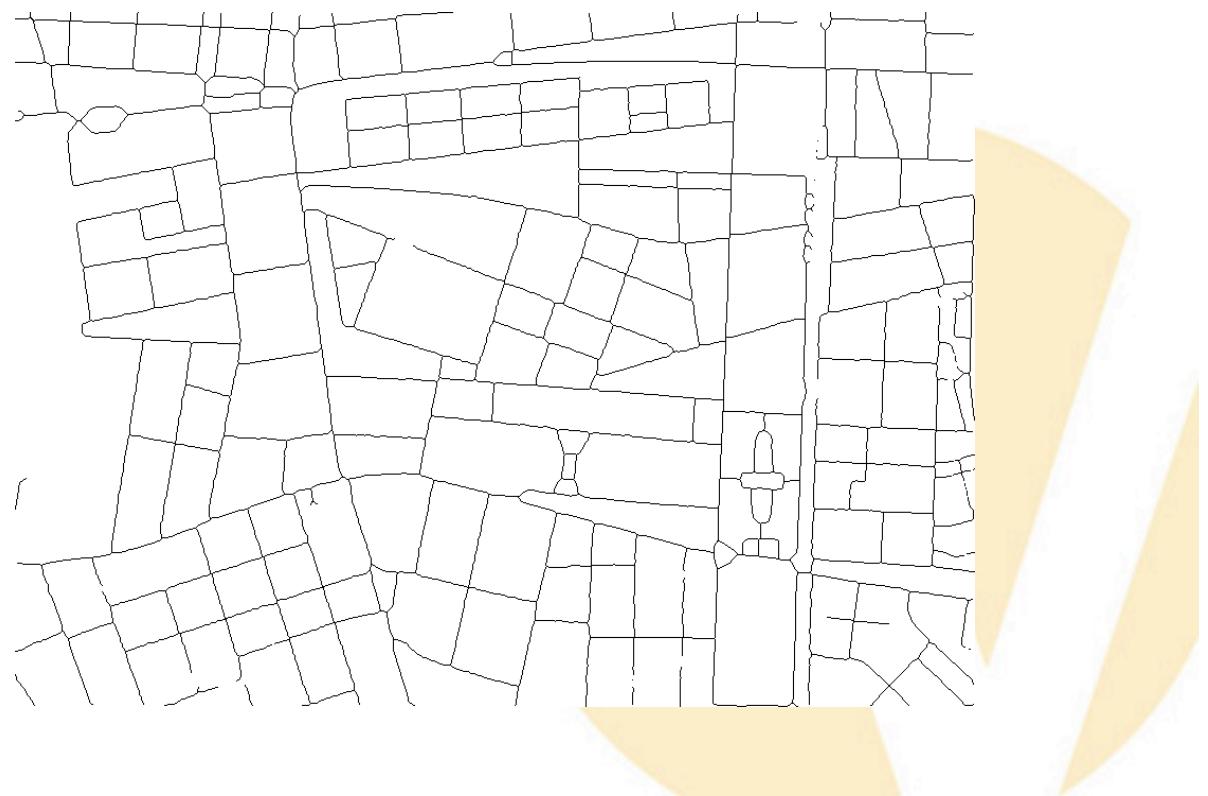
(background is shown in black)



(road pixels are shown in red, background is shown in black)

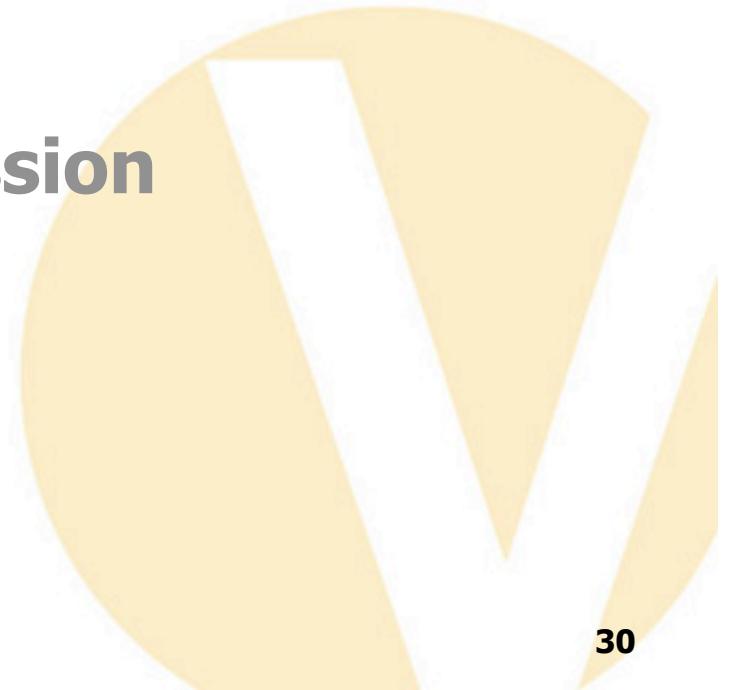


- Identify a set of road colors from each user label
- Use the identified road colors to extract road pixels
- Apply morphological operations to remove solid areas and reconnect lines



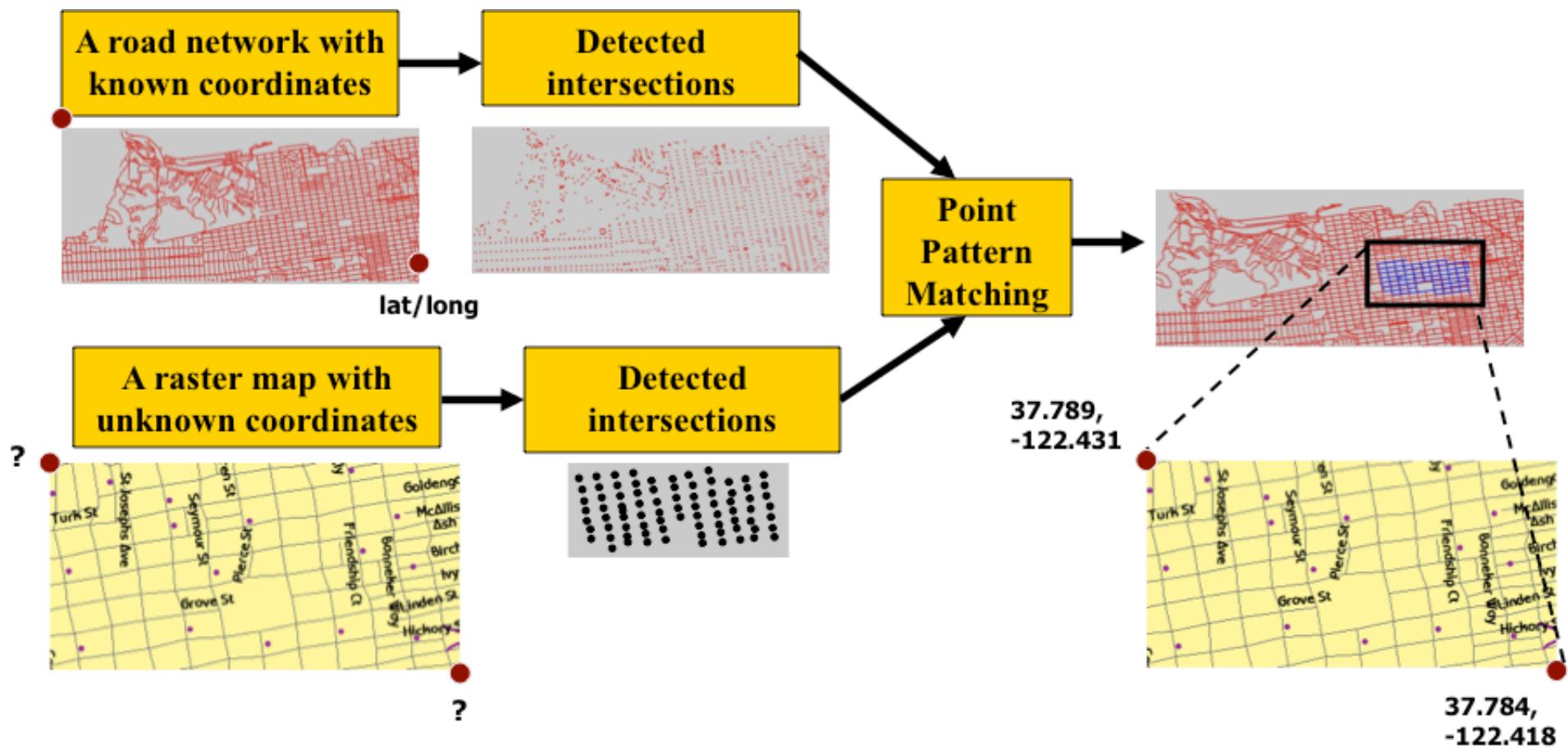
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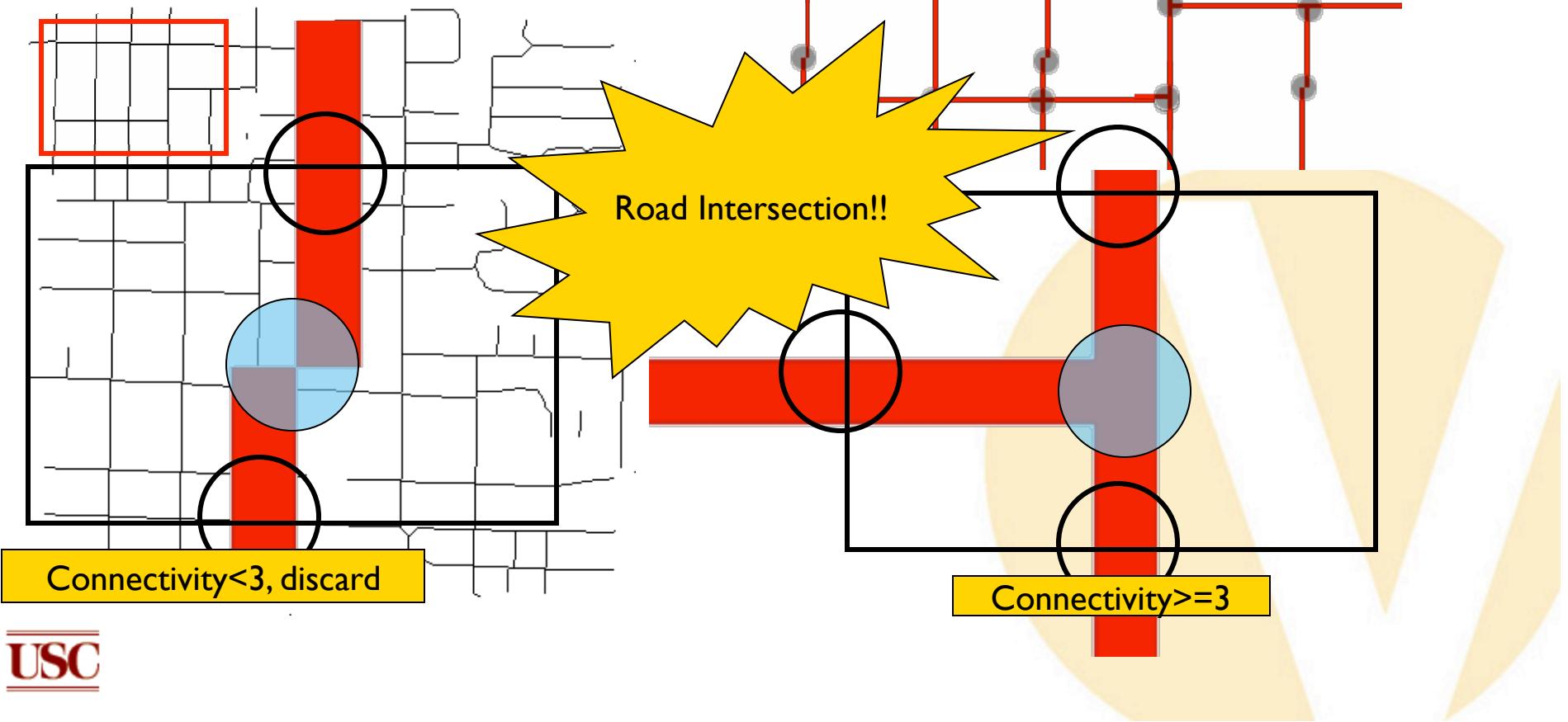
Automatic Map Registration

- Exploit the pattern of intersections found on a map and compare to a road vector dataset



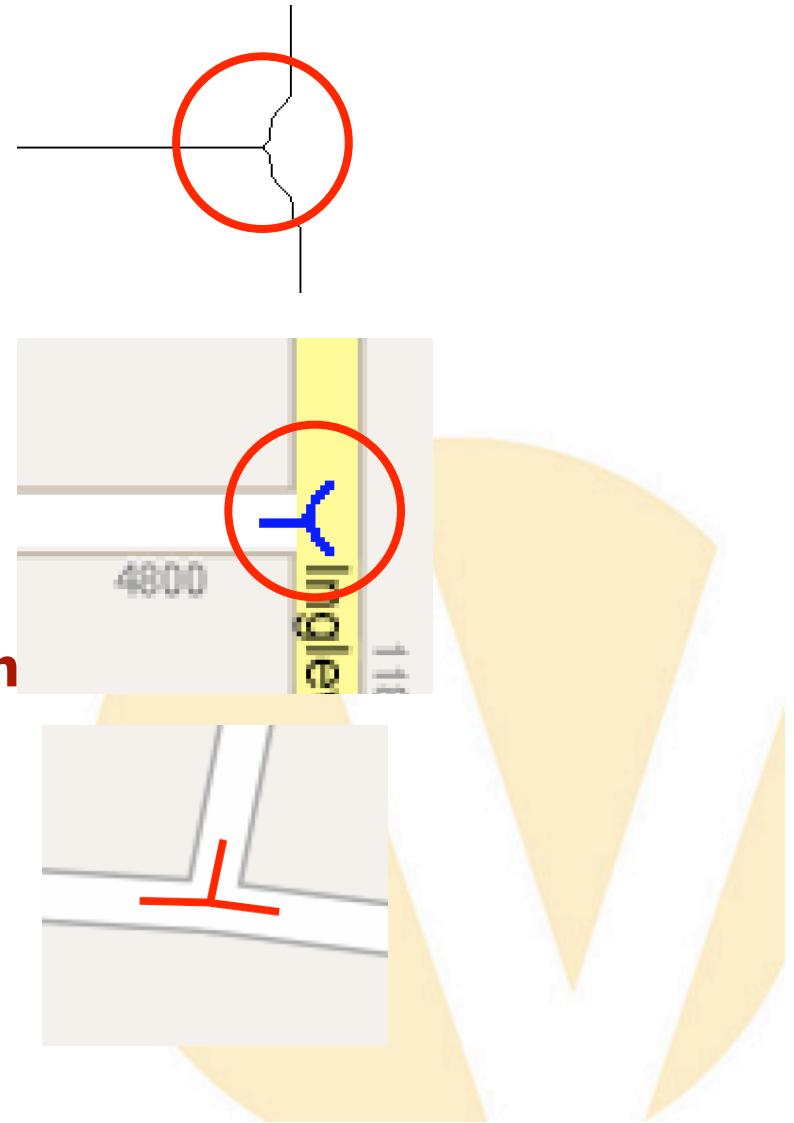
Road-Intersection Position Detection

- **Corner detector (OpenCV)**
 - Find intersection candidates
- **Compute the connectivity to determine real intersections**

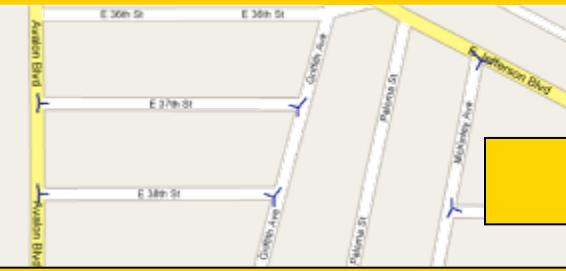


Road-Intersection Template Extraction

- Road lines are distorted by the morphological operators
- The extracted road vector around intersections will not be accurate
- Extract accurate road-intersection template
 - road intersection position
 - road connectivity
 - road orientation



Distortion Correction

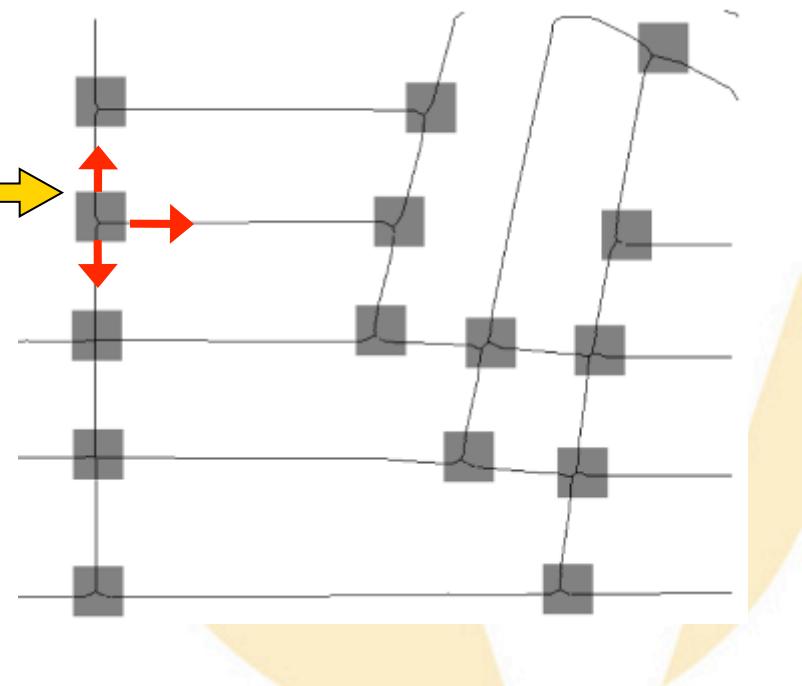


Use the road width to determine the blob size for covering the distorted lines

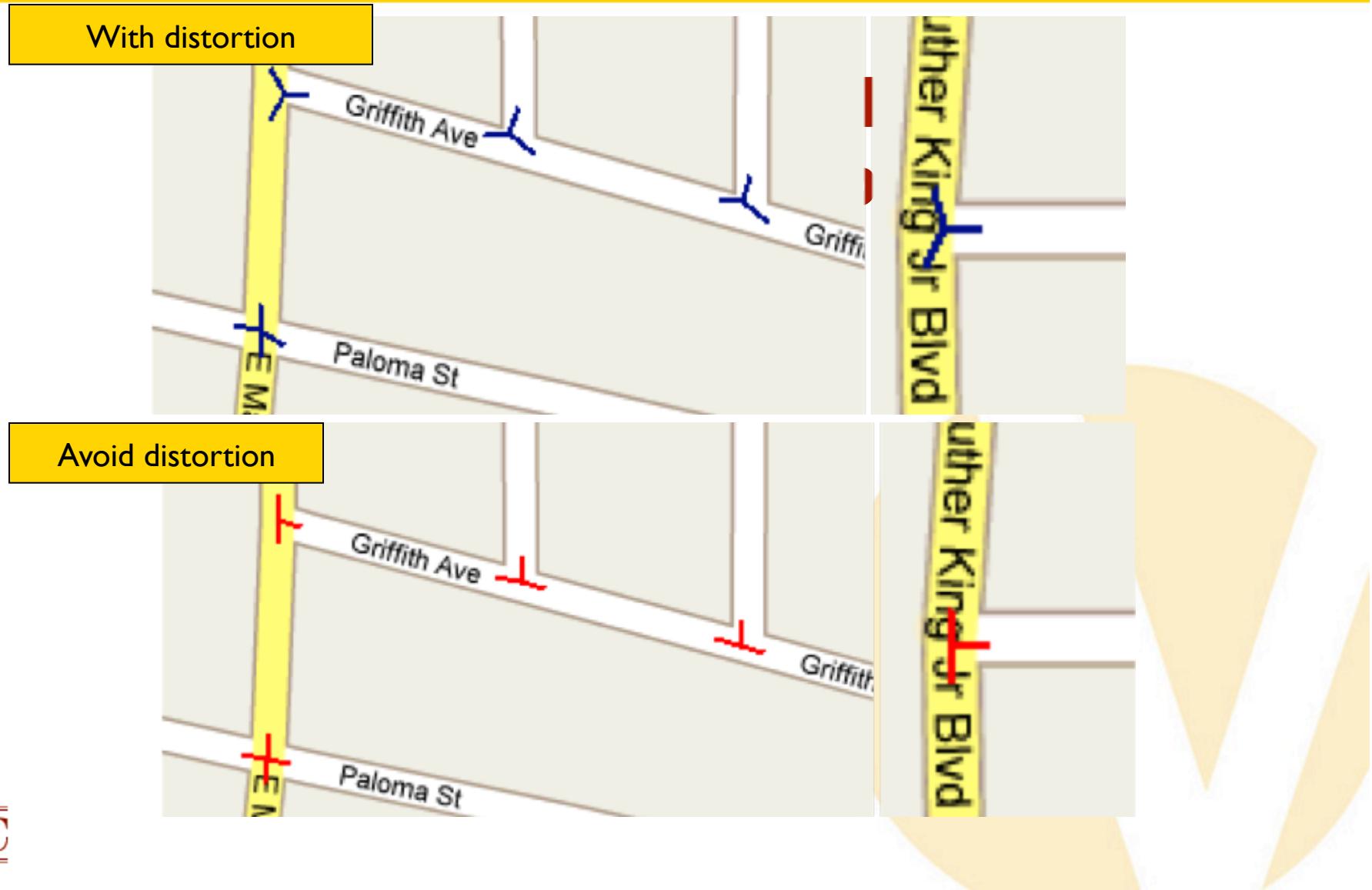
The thinned lines

Intersect the images

Intersection Positions



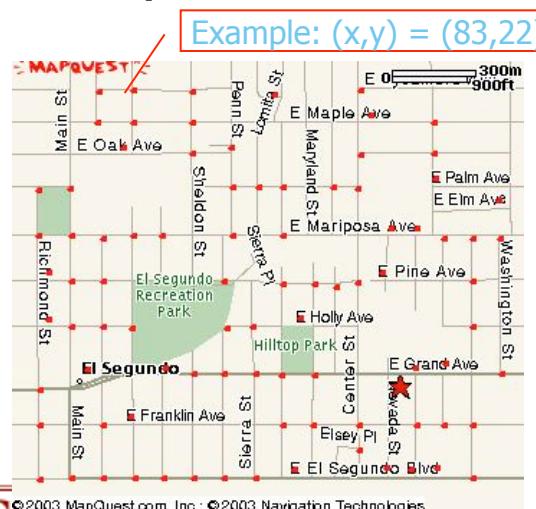
Accurate Road- Intersection Templates



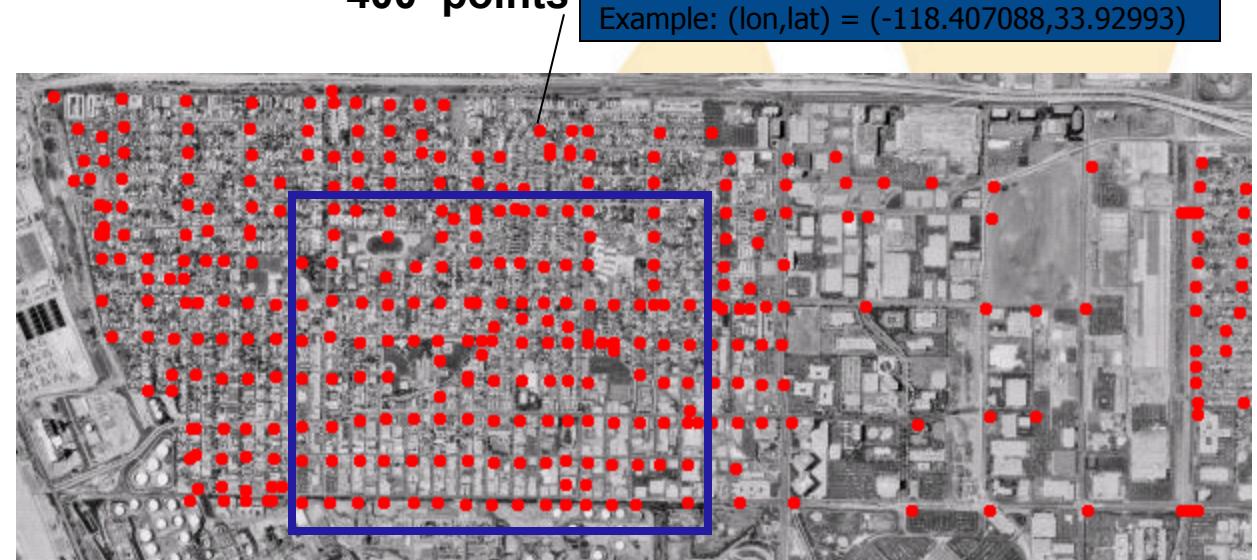
Point Pattern Matching

- Distribution of intersections is used to determine the relationship between a map and an image
- Find the mapping between these points to get a set of control point pairs
 - Find the transformation T between the layout (with relative distances) of the two point sets

80 points

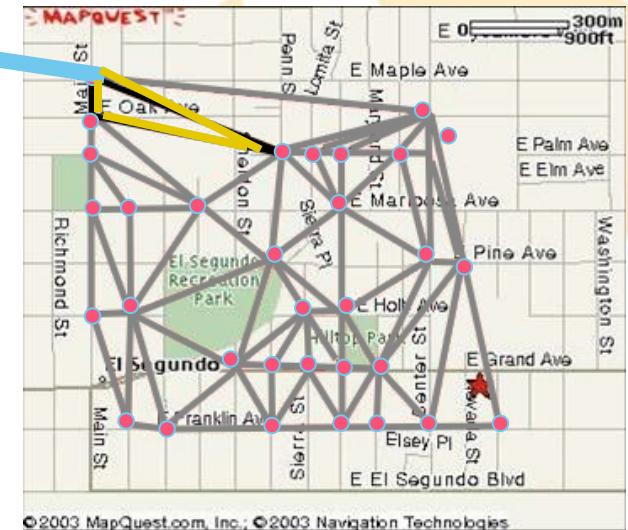
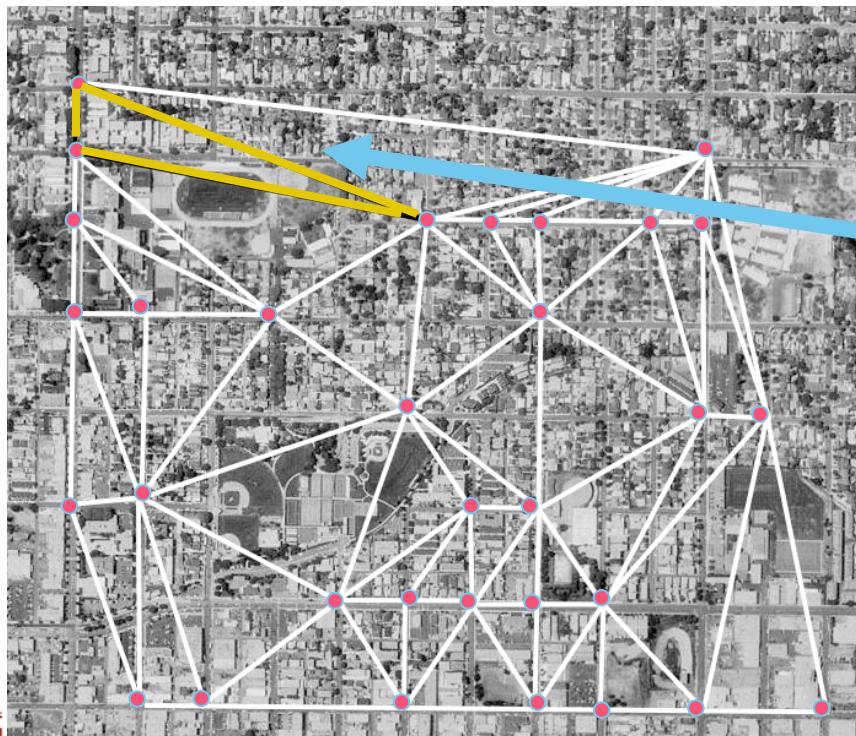


400 points



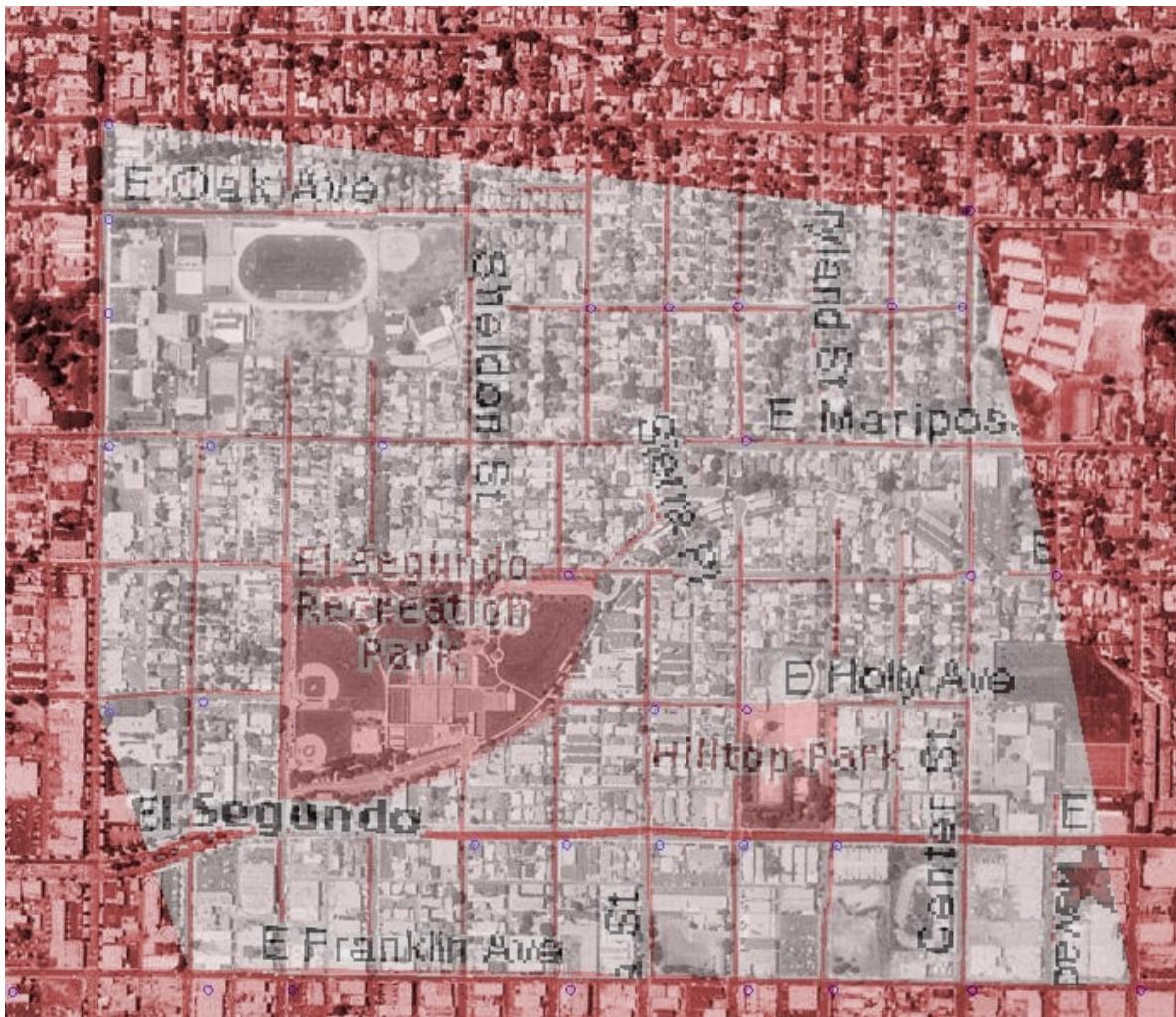
Aligning Maps and Imagery

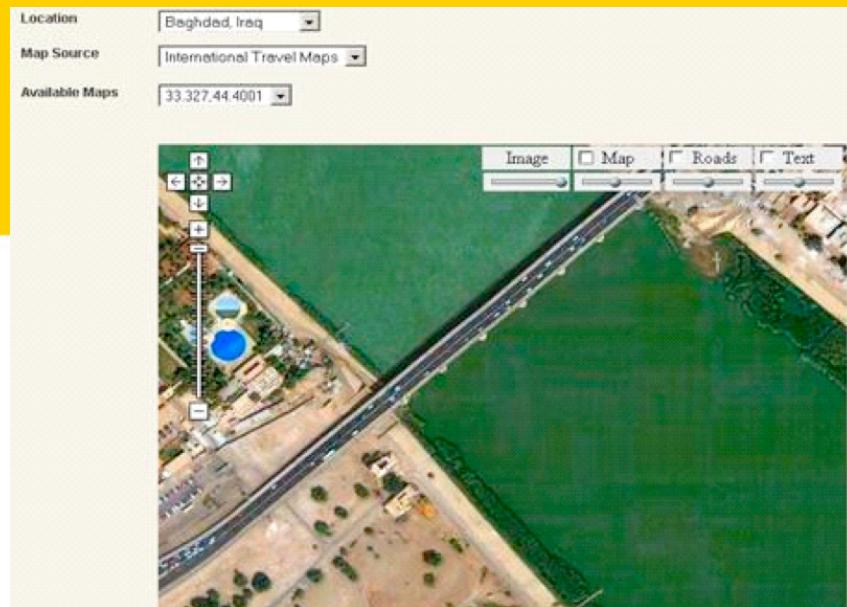
- Using matched point pattern to align maps with imagery by rubber-sheeting



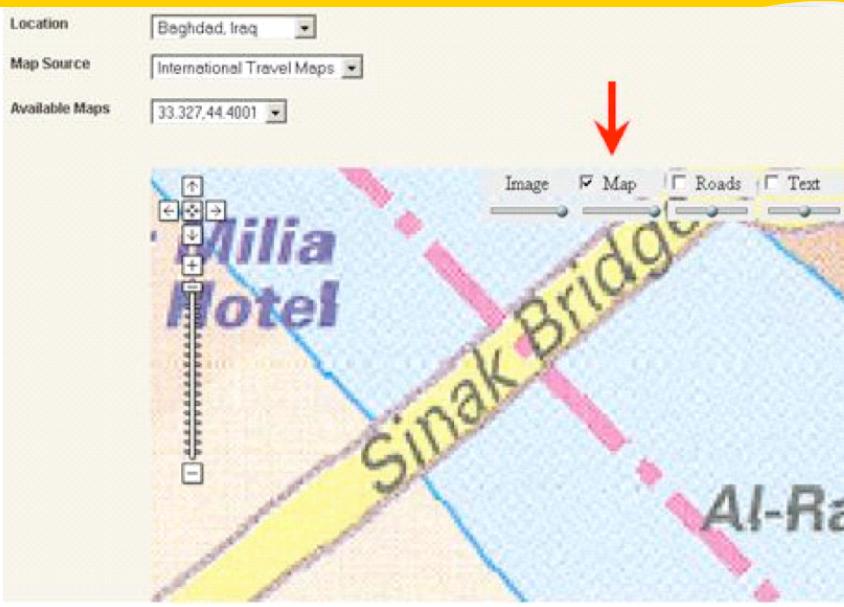
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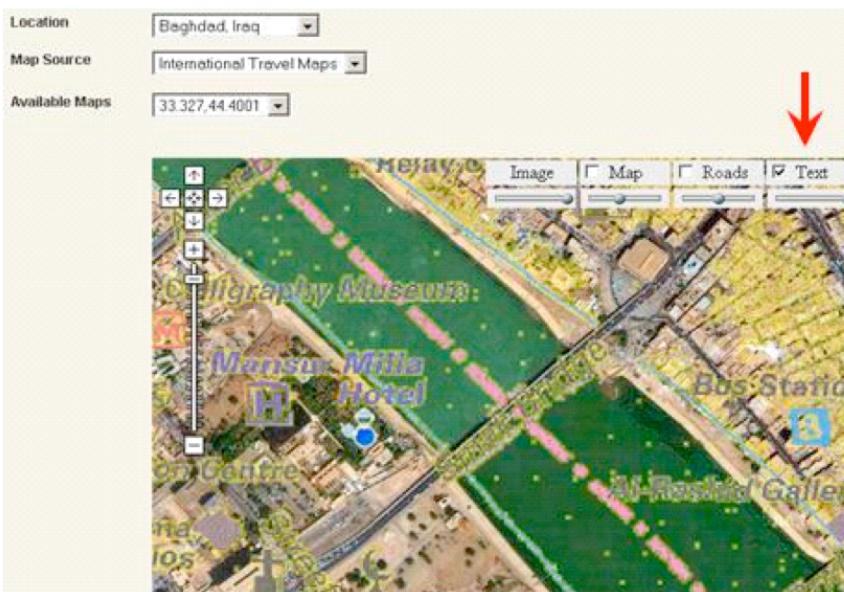
(a)



(b)



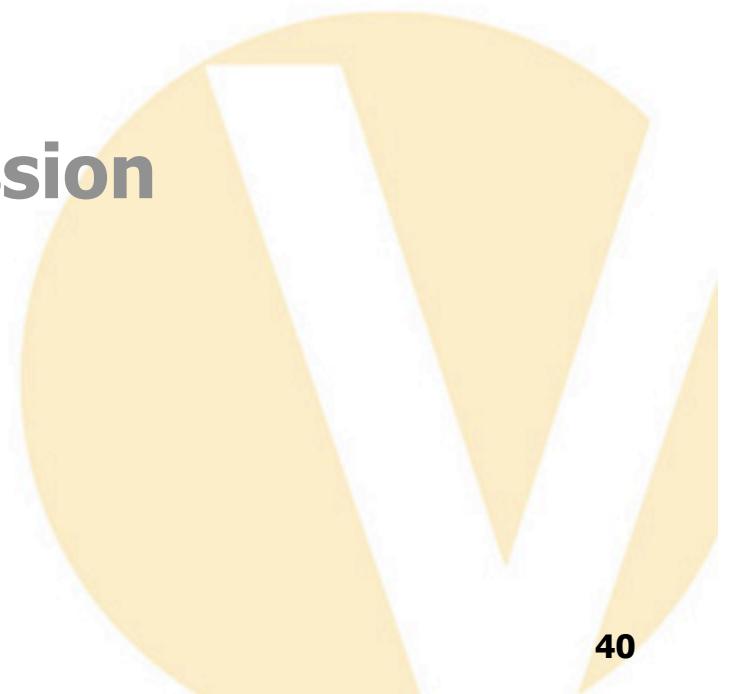
(c)



(d)

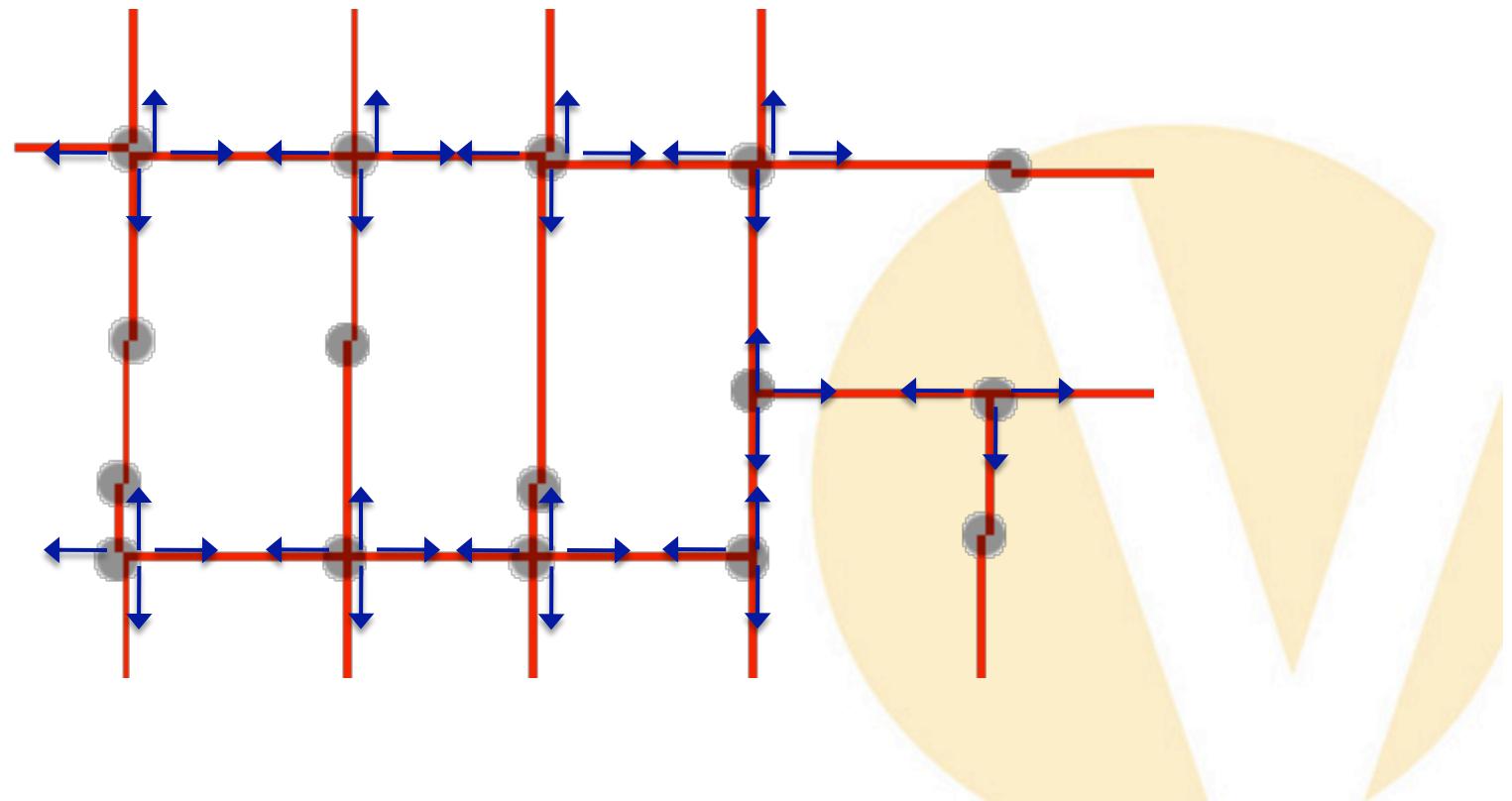
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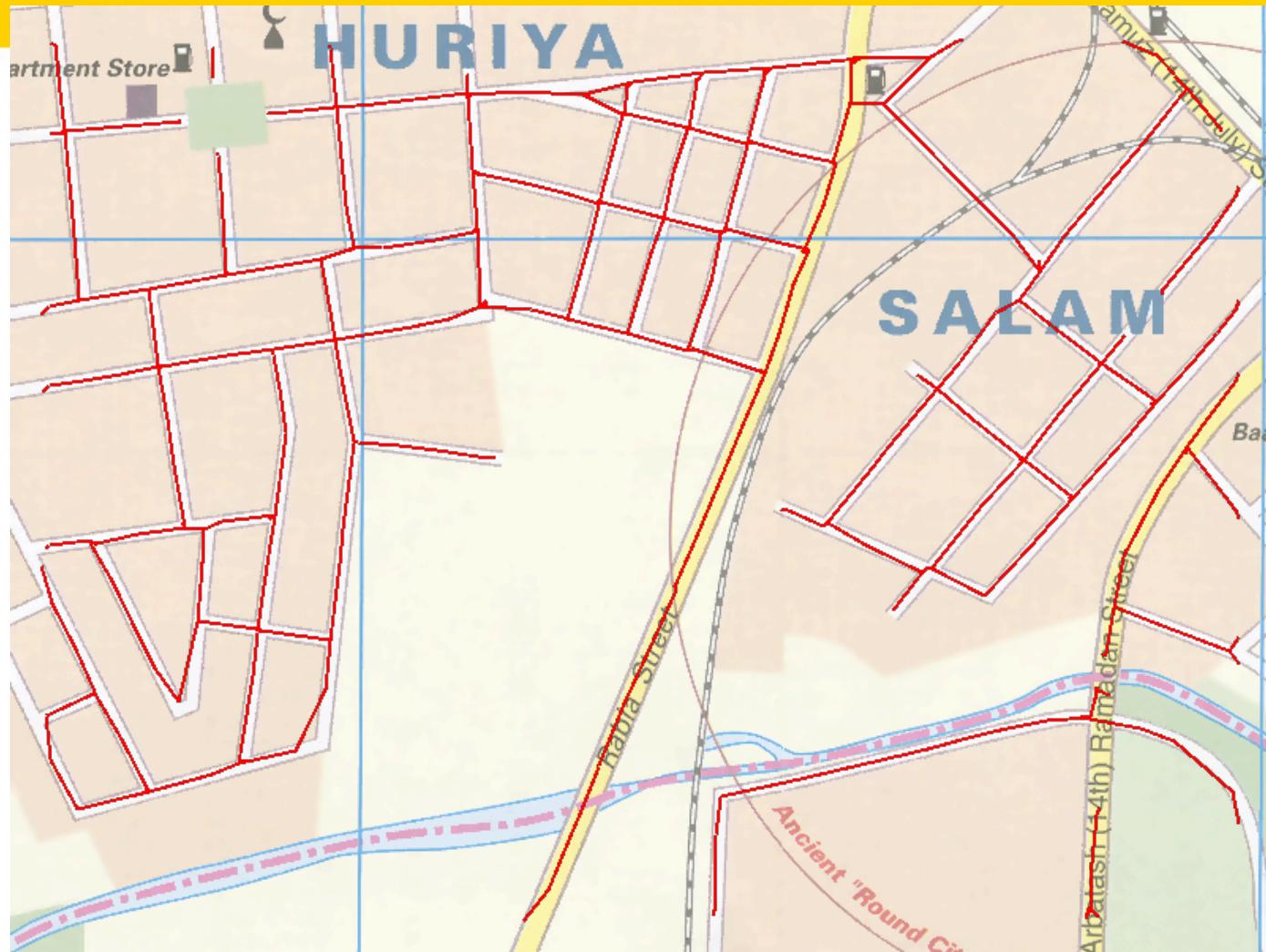


Road Vectorization

- Start from the extracted road intersections to connect the salient points and produce the road vector



Example Result



Experimental Results

- Tested on 16 maps from 11 sources
- Compared with R2V from Able Software
 - an automated raster-to-vector conversion software package specialized for digitizing raster maps
- Average completeness, correctness, quality, redundancy
Strabo: 96.53% 97.61% 94.41% 0.19%
R2V: 94.9% 87.4% 79.73% 42.81%
- R2V could achieve better results if we tuned R2V with manually specified pre-processing and post-processing functions
 - e.g., manually specify the gap size for reconnecting two lines)

Automatic Recognition of Text Labels

Automatically locating text strings

Text Strings

Automatically detecting string orientations

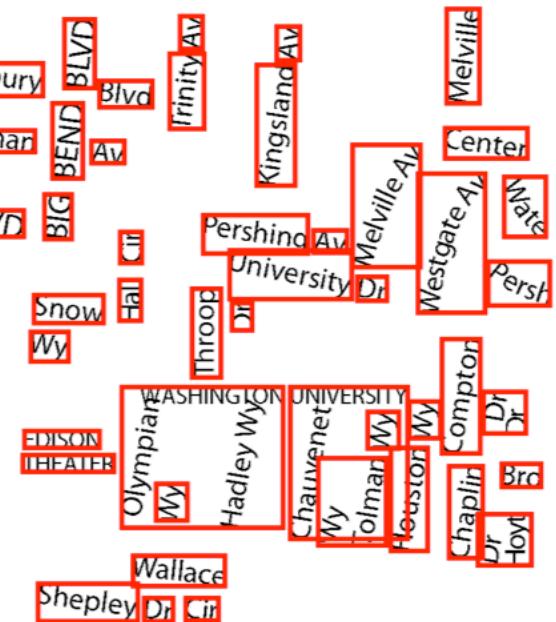
Rotated Horizontal Strings

Optical Character Recognition

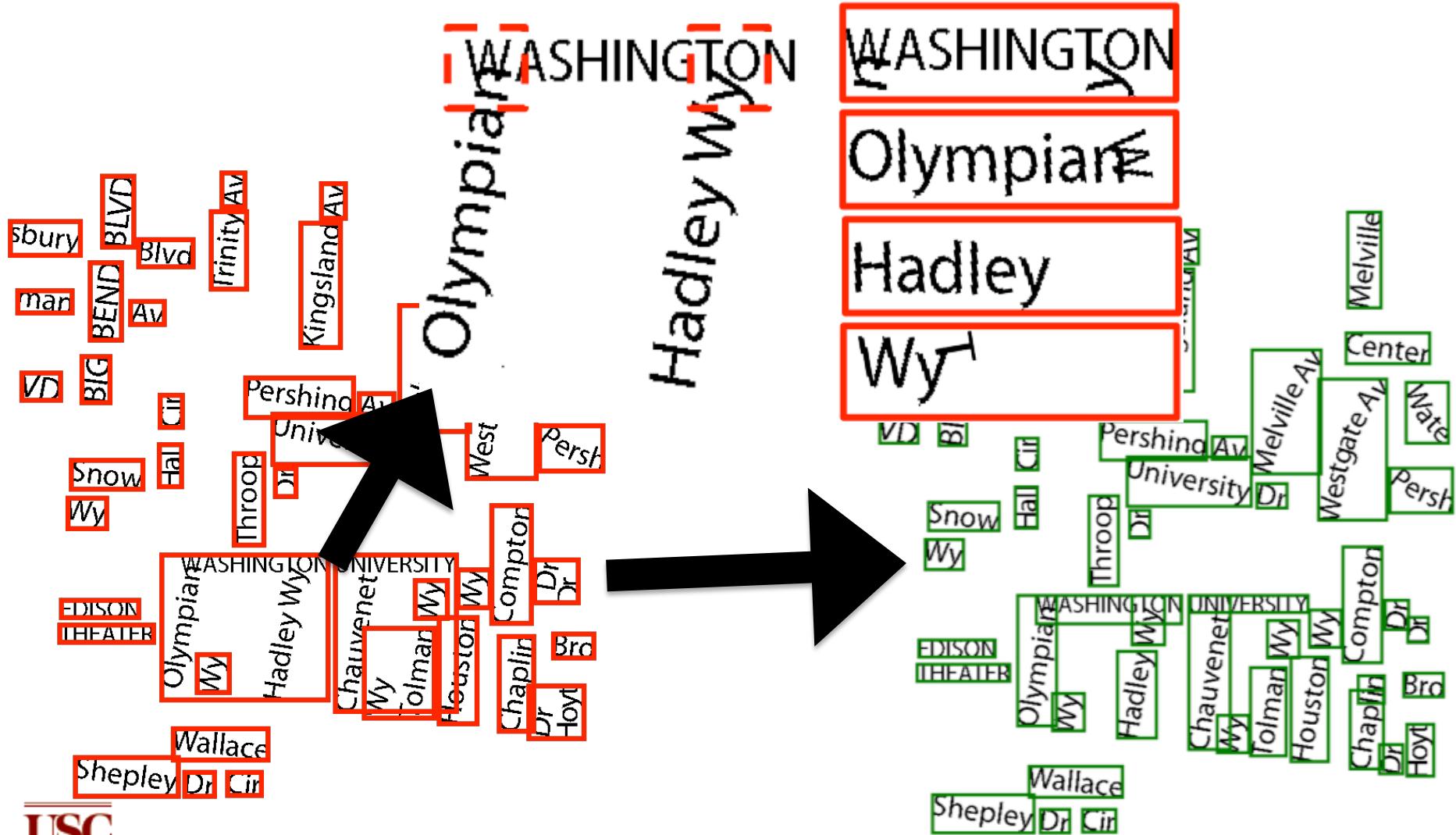
Recognized Text

Group Characters Using the Dilation Operator

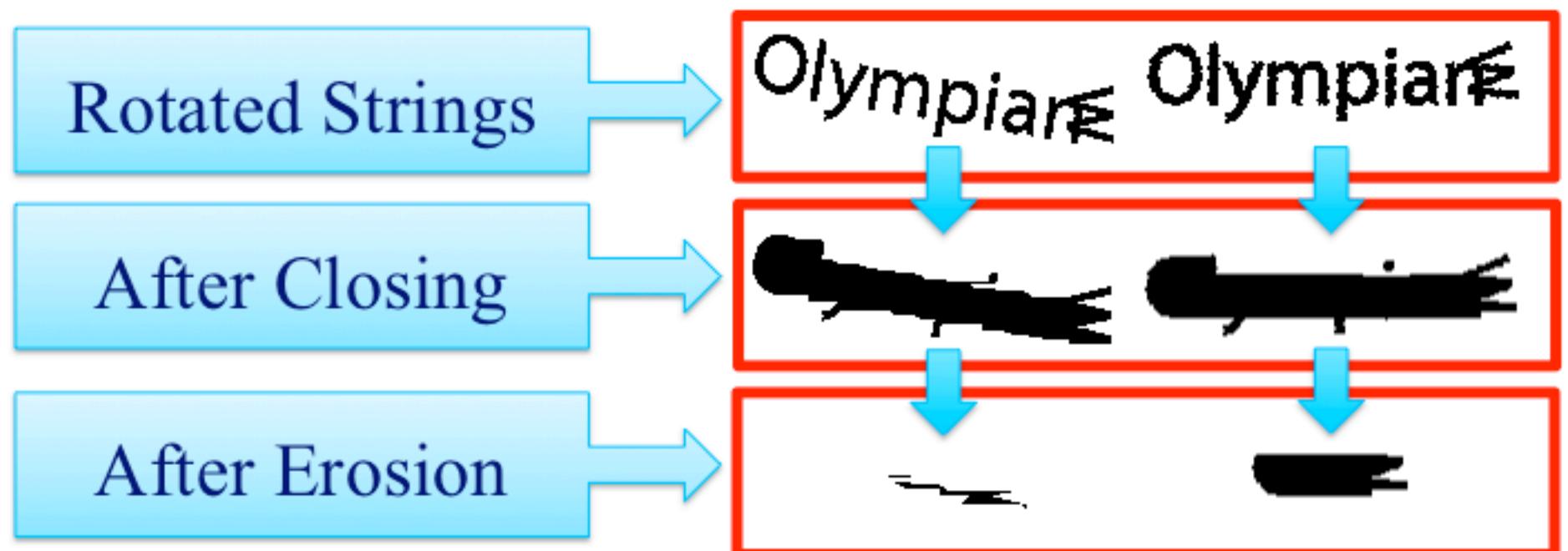
sbury
 man
 VD
 Snow Wy
 EDISON THEATER
 Olympian Wy
 Hadley Wy
 Chauvenet Wy
 Tolman Wy
 Houston Wy
 Chaplin Dr
 Bro Hoyt
 Wallace Shepley Dr Cir



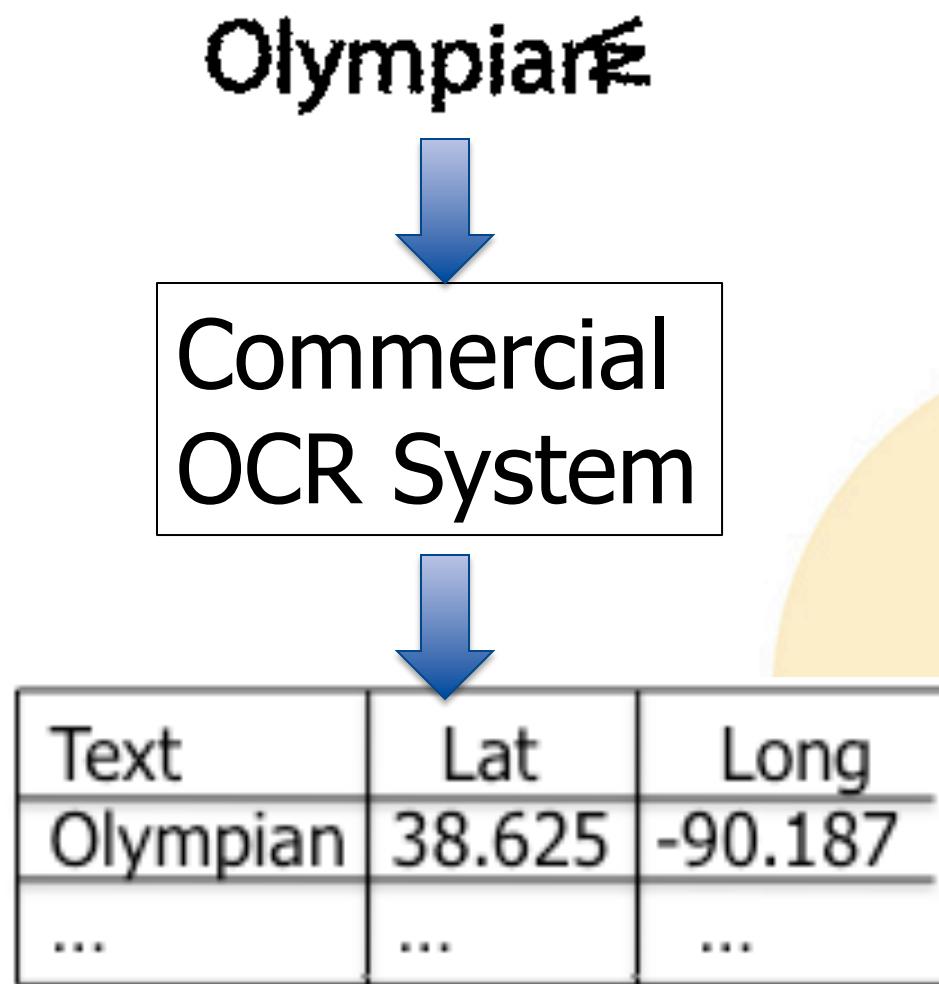
Split Merge Strings



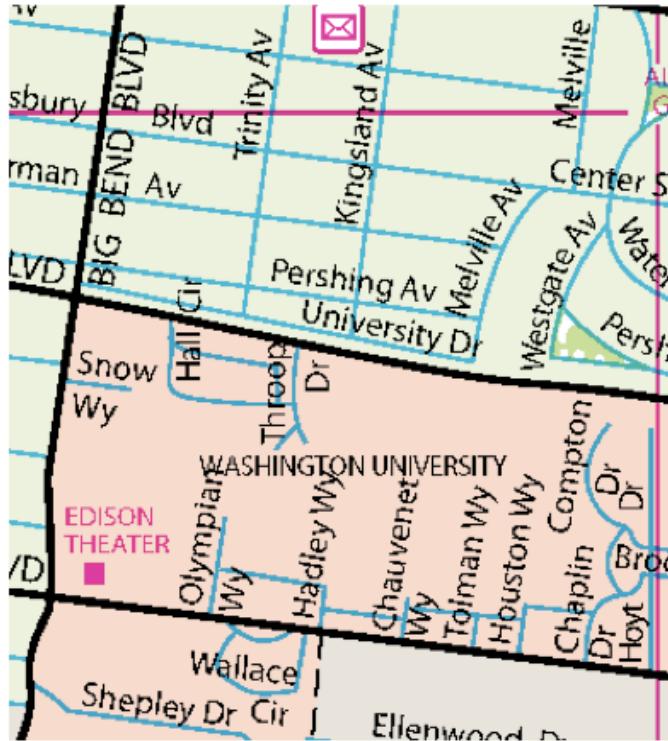
Detect Orientation with Run-Length Smoothing



Run Commercial OCR on Extracted Text



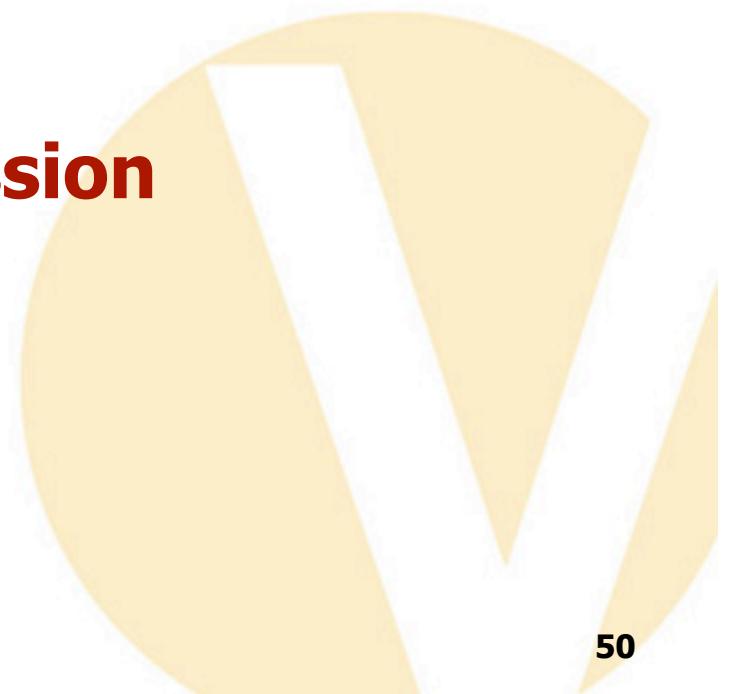
Results



Map	Char. P.	Char. R.	Word P.	Word R.
RM	95.6%	93.1%	76.3%	79.3%
ITM	96.3%	95%	81.5%	85.2%

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Related Work

- **Map Feature Extraction Using Map Specification (Samet and Soffer, 94, 96; Myers et al., 96)**
 - Require huge amount of prior information and training
- **Text/Graphics Separation and Text Recognition (Bixler, 00; Li et al., 00; Cao and Tan 02; Vela, 03; Pouderoux, 07)**
 - Require fixed pre-processing steps, e.g., binarization with fixed threshold
- **Supervised Graphics Extraction (Khotanzad and Zink, 03; Salvatore and Guitton, 04; Chen et al. 06)**
 - Laborious training tasks, e.g., labeling all combination of line and background pixels
- **Road Extraction and Vectorization (Bin, 98; Habib et al., 99; Itonaga et al., 03)**
 - Require lots of parameter tunings, e.g., road width
- **Map, Vectors, and Imagery Conflation (Chen et al., 06; Chen et al., 08; Wu et al., 07)**
 - Exploit for determining feature locations

Conclusion

- **Presented a general approach to discovering, registering, extracting features from maps**
- **Contributions**
 - Ability to identify maps
 - Techniques to extract road and text layers from poor quality maps
 - Algorithms to automatically determine the geocoordinates
 - Automatic feature recognition
 - Intersection templates, road vector data, and text labels
- **Applications**
 - Annotating imagery
 - Creating and updating maps
 - Constructing gazetteers

Publications

- Available from: <http://www.isi.edu/~knoblock>
- **A General Approach to Discovering, Registering, and Extracting Features from Raster Maps.** Knoblock, C. A.; Chen, C.; Chiang, Y.; Goel, A.; Michelson, M.; and Shahabi, C., In Proceedings DRR, 2010.
- **An Approach for Recognizing Text Labels in Raster Maps.** Chiang, Y., and Knoblock, C. A., In Proceedings of ICPR, 2010.
- **A Method for Automatically Extracting Road Layers from Raster Maps.** Chiang, Y., and Knoblock, C. A., In Proceedings ICDAR, 2009.
- **Automatic and Accurate Extraction of Road Intersections from Raster Maps.** Chiang, Y.; Knoblock, C. A.; Shahabi, C.; and Chen, C., Geoinformatica, 13(2):121-157, 2008.
- **Automatically and Accurately Conflating Raster Maps with Orthoimagery.** Chen, C.; Knoblock, C. A.; and Shahabi, C., Geoinformatica, 12(3):377—410, 2008.
- **Automatic Extraction of Road Intersection Position, Connectivity, and Orientation from Raster Maps.** Chiang, Y., and Knoblock, C. A., In Proceedings of ACM GIS, 2008.
- **Automatic Extraction of Road Intersections From Raster Maps.** Chiang, Y.; Knoblock, C. A.; and Chen, C., In Proceedings of ACM GIS, 2005.
- **Automatically and Accurately Conflating Orthoimagery and Street Maps.** Chen, C.; Knoblock, C. A.; Shahabi, C.; Thakkar, S.; and Chiang, Y., In Proceedings of ACM GIS, 2004.