Harvesting Geographic Features from Heterogeneous Raster Maps

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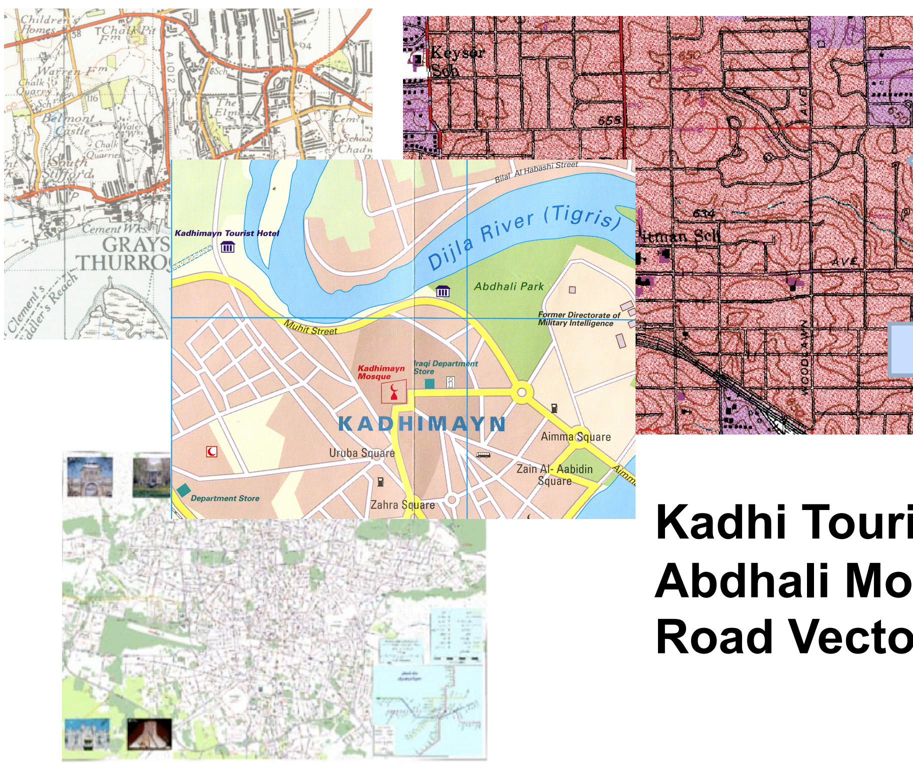
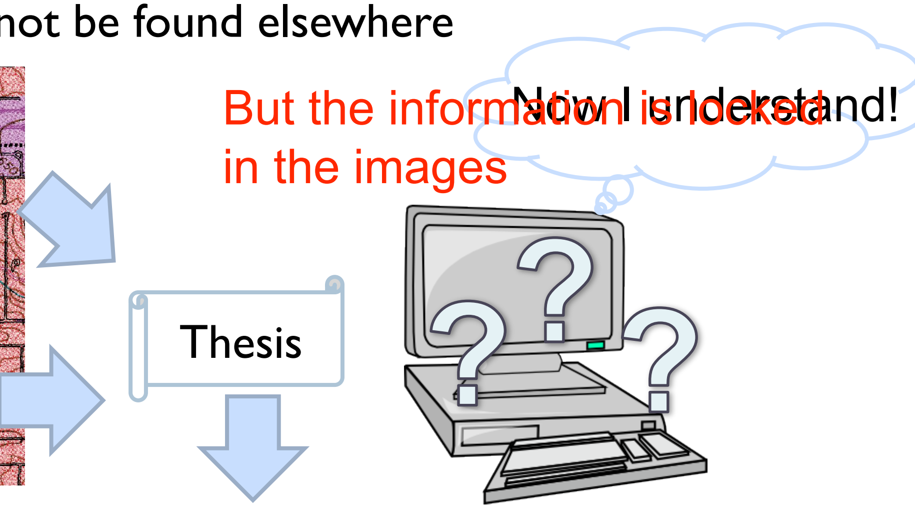
Motivation

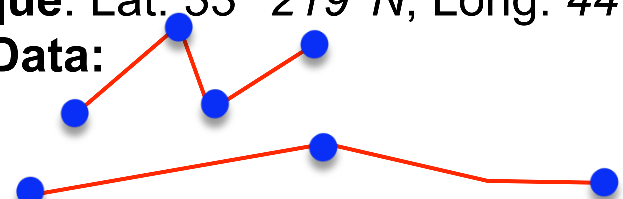
- Raster maps are a rich source of geospatial information:
  - Easily accessible
  - Many different types of information
  - Often contains information that cannot be found elsewhere



But the information is locked in the images

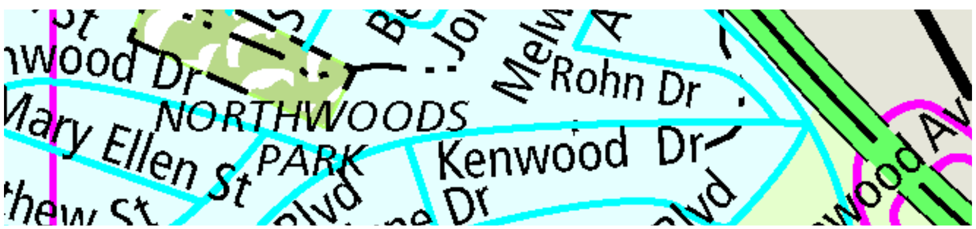


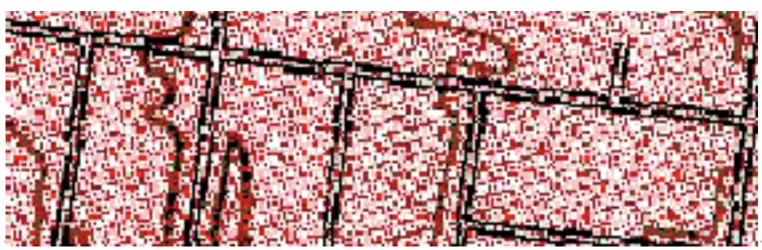
Kadhi Tourist Hotel: Lat: *33° 2012' N*, Long: *44° 263' E*
Abdhali Mosque: Lat: *33° 219' N*, Long: *44° 228' E*
Road Vector Data:



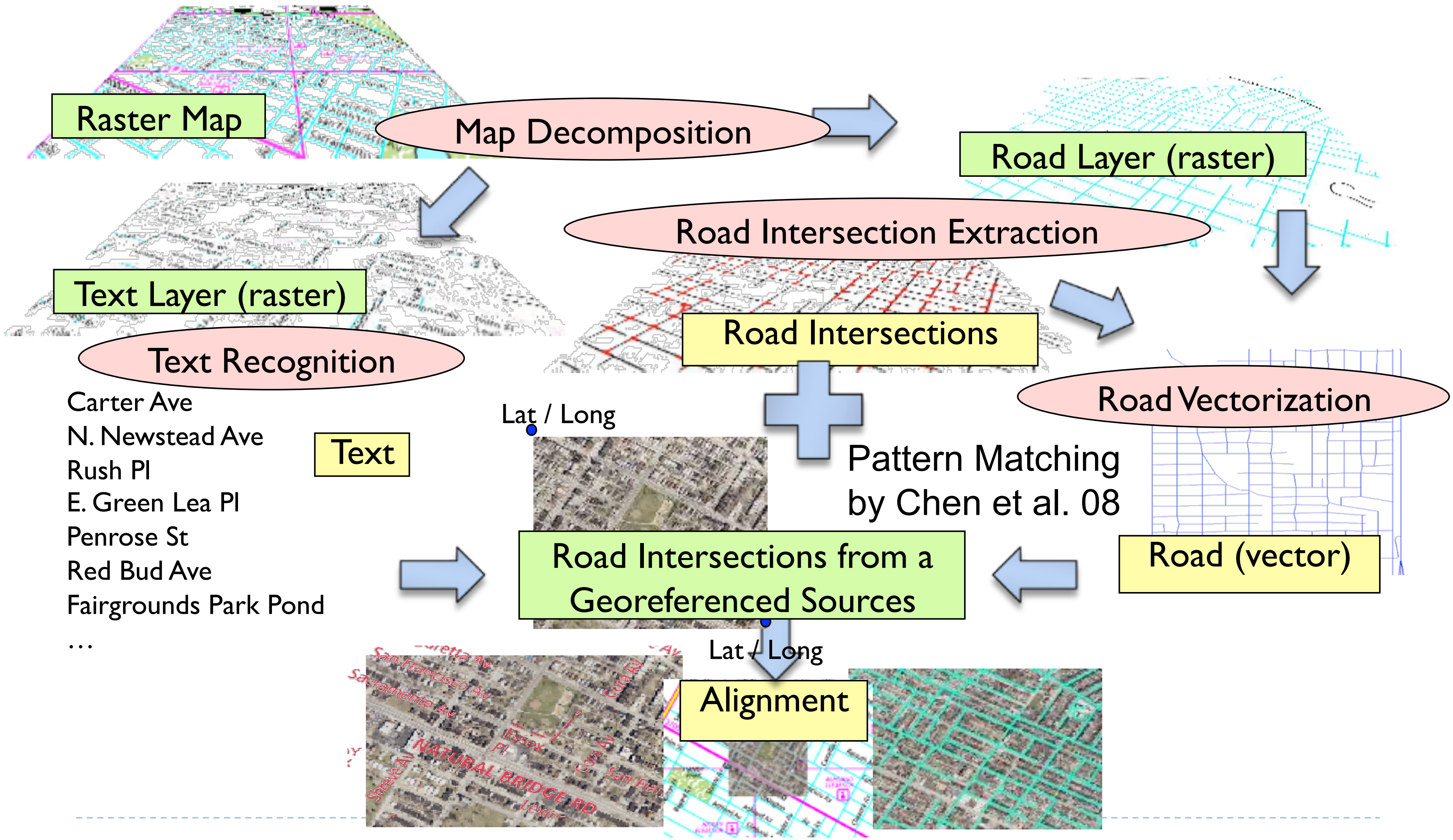
Challenges

- It is difficult to unlock the geospatial information in raster maps:
  - There is limited access to the meta-data
  - They have overlapping features
  - They often have poor image quality
- Previous work is typically limited to a specific type of map and often relies on intensive manual work





Harvesting Geographic Features From Heterogeneous Raster Maps



Contributions

Techniques	Summary
Automatic Map Decomposition	▪ Automatically extract road and text layers
Automatic Road-Intersection Detection for Map Alignment	▪ Automatically extract road intersections, connectivity, and road orientations
Road Vectorization	▪ Extract road layers from poor quality maps ▪ Automatically generate and vectorize road geometry from road layer
Text Recognition	▪ Extract text layers from poor quality maps ▪ Automatically recognize text labels in text layers

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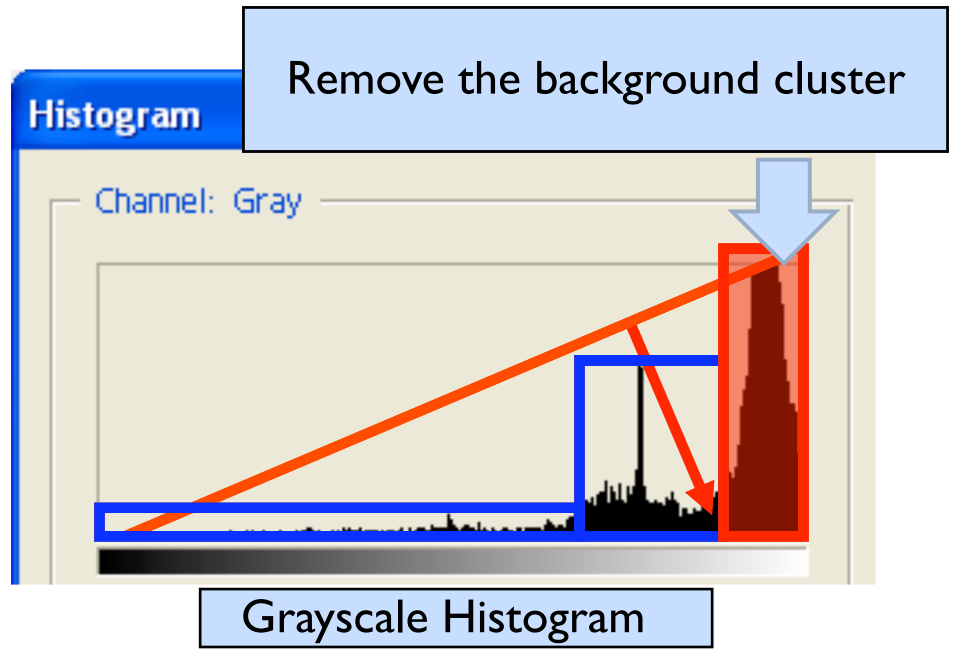
First Contribution

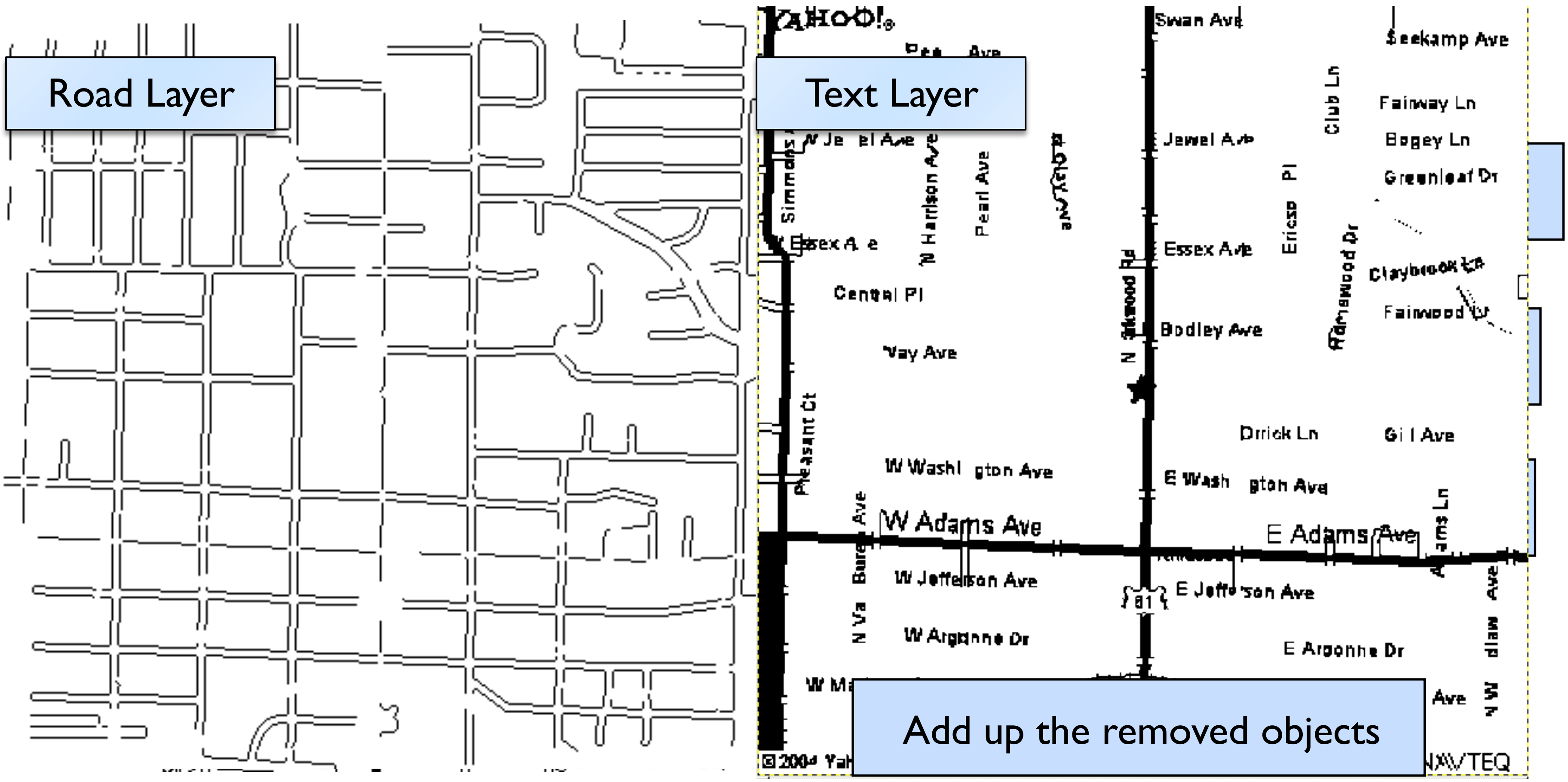
Remove Raster Map Background

- Locate individual luminosity clusters (the triangle method, Zack et al., 77)
- Identify background clusters
  - Background has a dominant number of pixels
  - Foreground has high contrast against the background



Text/Graphics Separation

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



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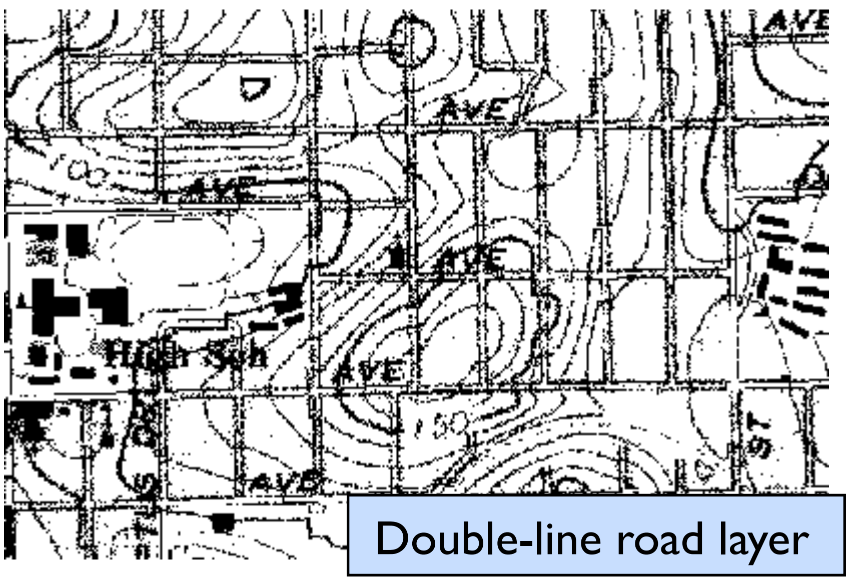
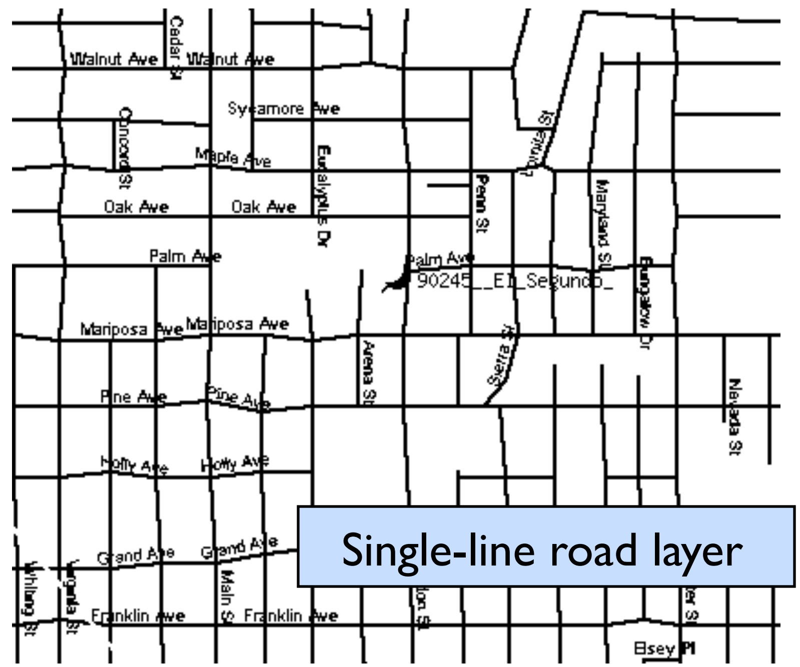
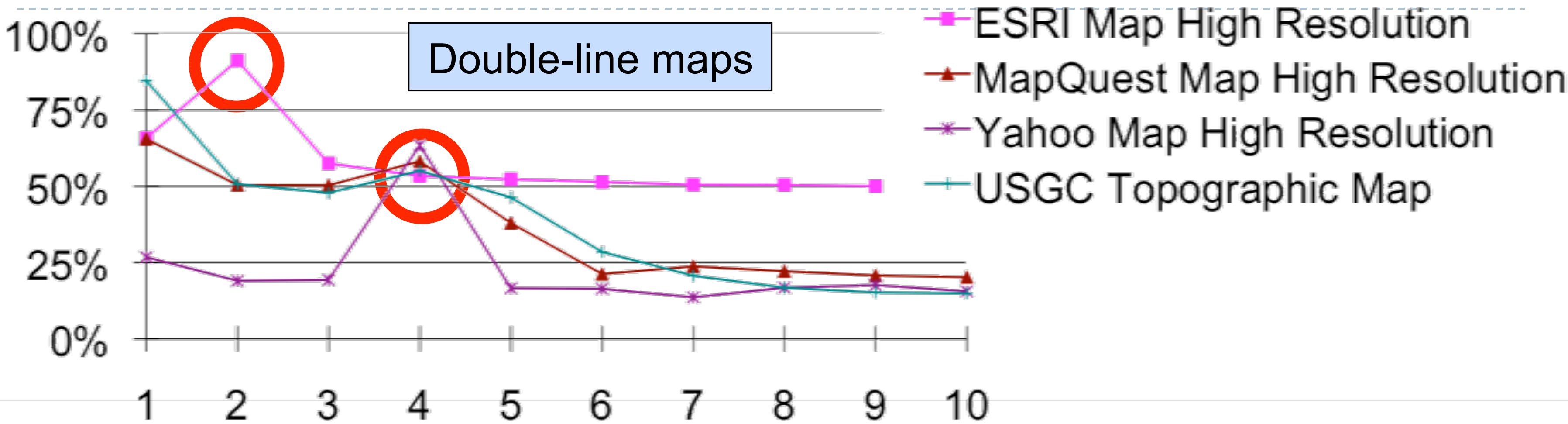
Road-Layer Format

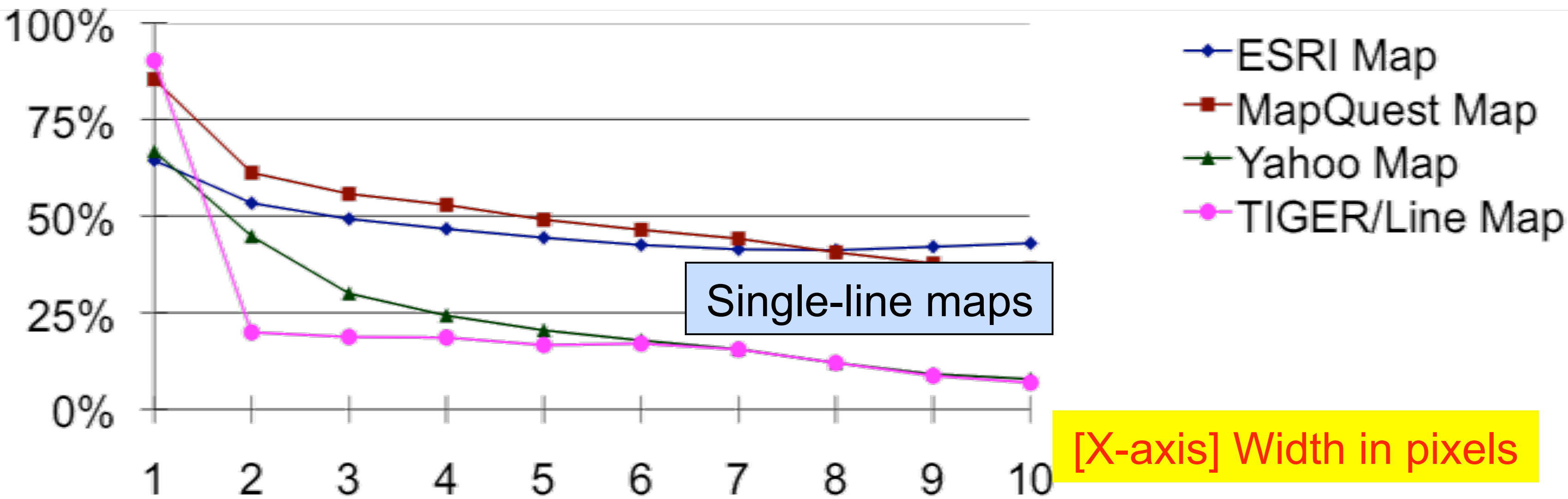
- Detect the road format for generating road geometry
  - The double-line roads usually used in the maps where linear objects that are not roads exist, such as the contour lines
  - Merge the parallel lines in a double-line map and remove single-line objects





Applying Parallel-Pattern Detection Varying Road Width

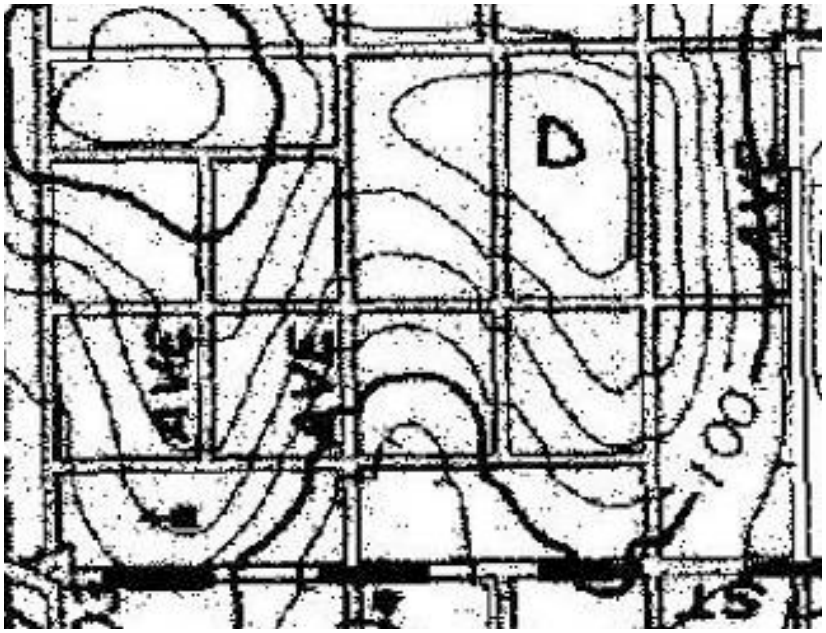




[X-axis] Width in pixels

[Y-axis] Parallel Pixel Ratio (Identified parallel-line pixels / Foreground pixels)

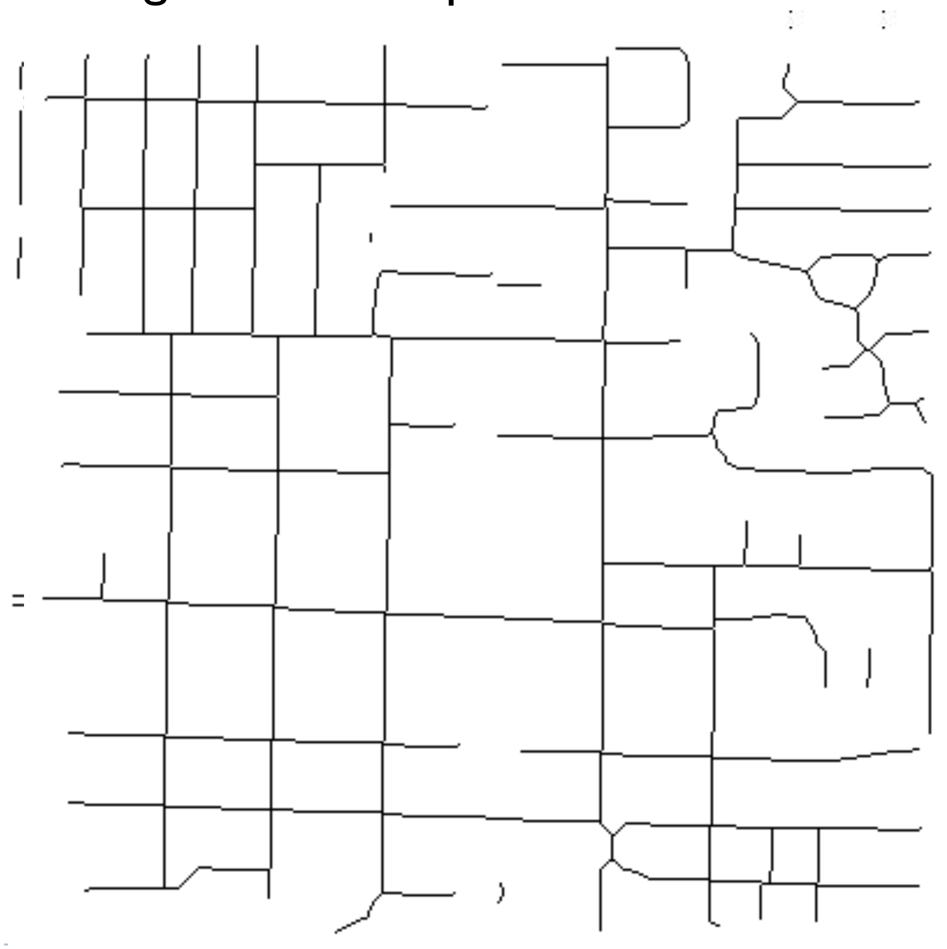
Remove Single-line Linear Objects

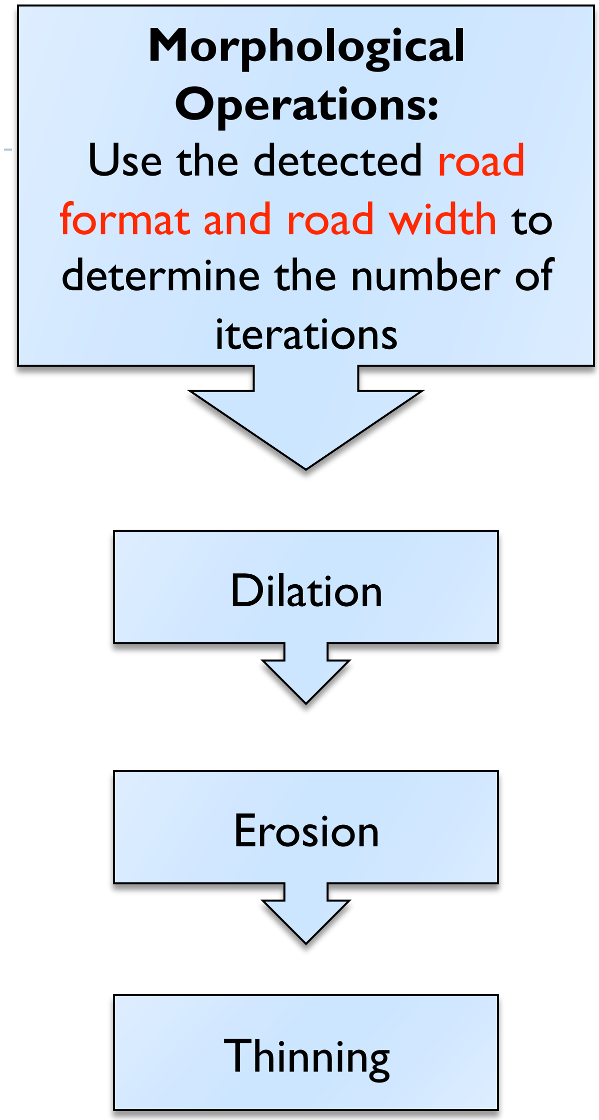


- Apply PPT using the detected road width
- Remove pixels without a parallel-pattern detected

Extract Road Geometry

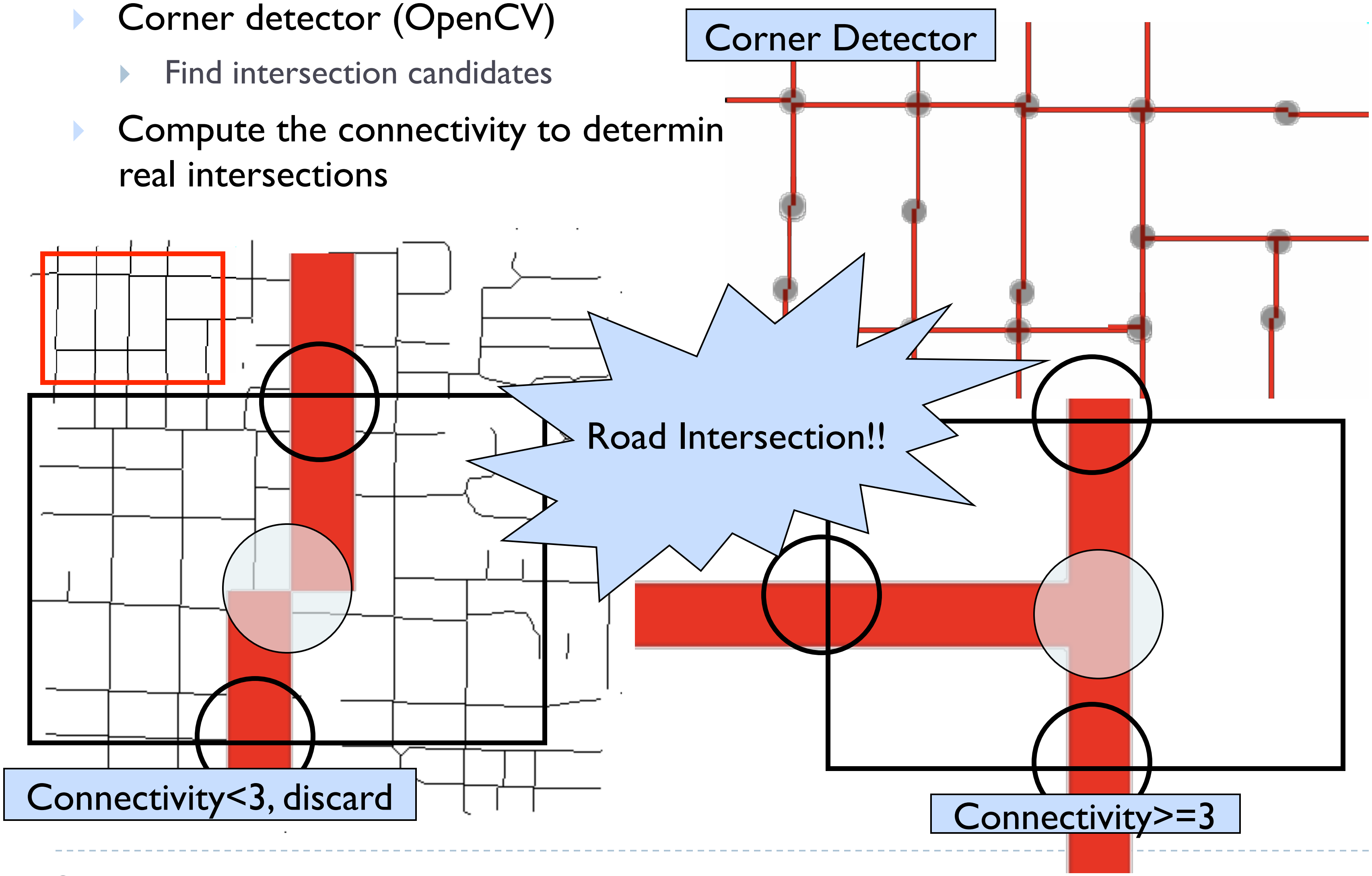
- Use morphological operations to reconnect broken lines and generate one-pixel width roads





Detect Road-Intersection Positions

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



Experimental Results

- Tested 87 maps from 12 sources
- Successfully decomposed the test maps automatically
- For intersection detection, **average precision: 95% recall: 75%**
  - Support the map alignment for a conflation system by Chen et al. 2008

Map Source	Map Count	Precision	Recall	F-Measure
ESRI Maps	10	93%	71%	81%
MapQuest Maps	9	98%	66%	79%
TIGER/Line Maps	9	97%	84%	90%
Yahoo Maps	10	95%	76%	84%
A9 Maps	5	100%	93%	97%
MSN Maps	5	97%	88%	92%
Google Maps	5	98%	86%	91%
Map24 Maps	5	100%	82%	90%
ViaMichelin Maps	5	100%	98%	99%
Multimap Maps	5	98%	85%	91%
USGS topographic maps	10	82%	60%	69%
Thomas-Brothers Maps	2	98%	65%	79%

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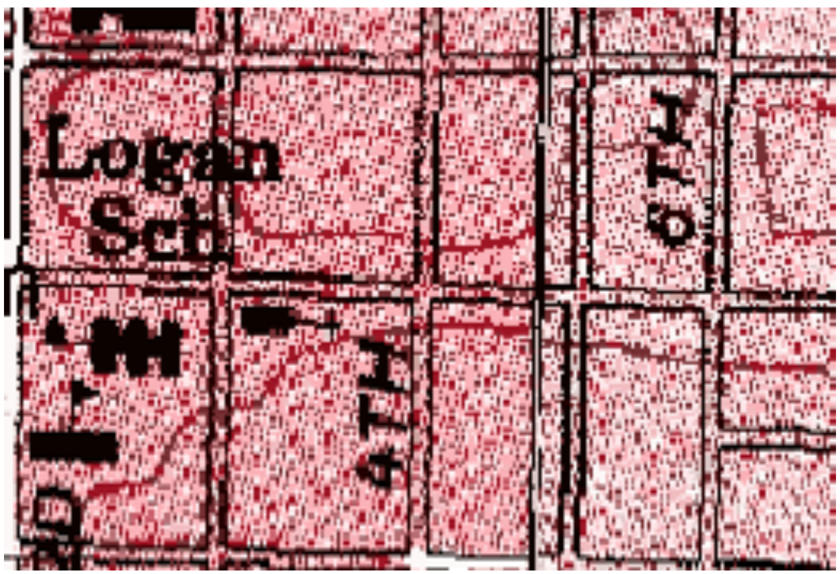
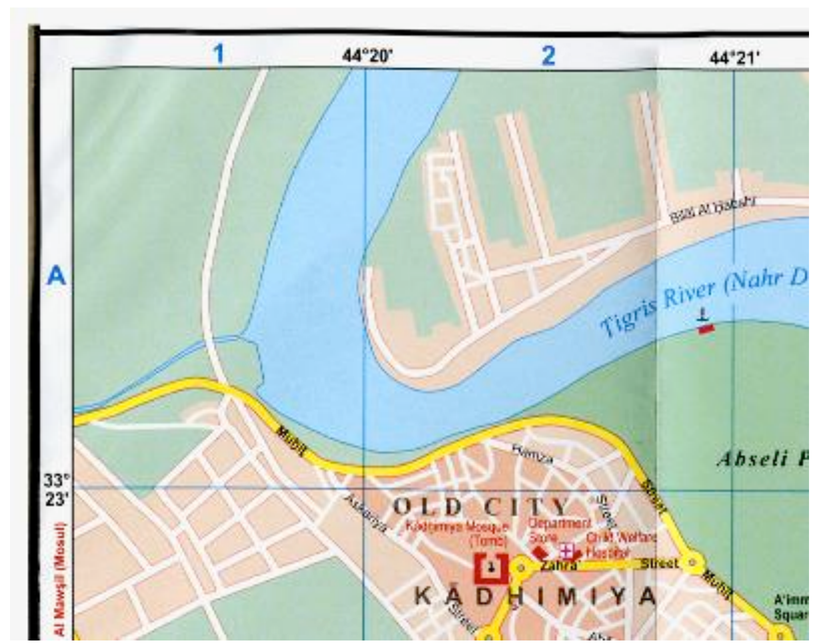
Third Contribution

Supervised Extraction of Road Layers

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

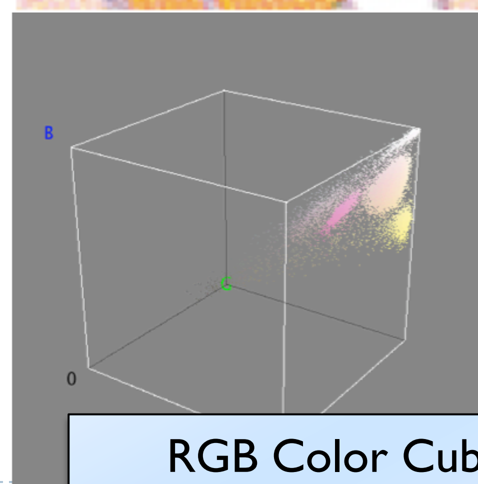




Numerous Colors in Scanned Maps

- Manually examining each color for extracting features is laborious

285,735 colors

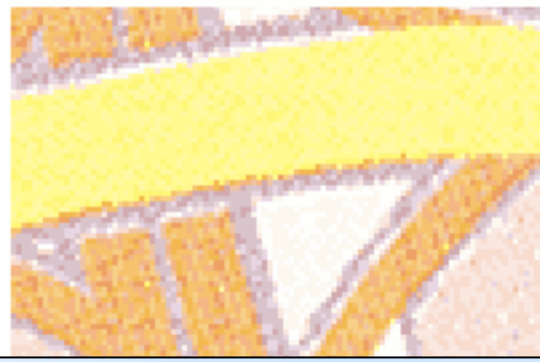


RGB Color Cube

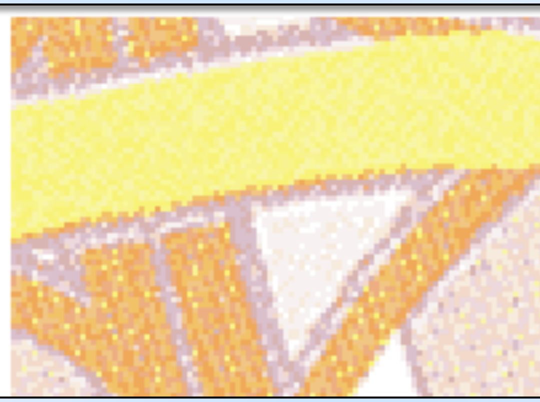
Color Segmentation by Analyzing Color Space

- Analyze only color space for color segmentation does not work for feature extraction purpose
  - Colors of individual features do not merge

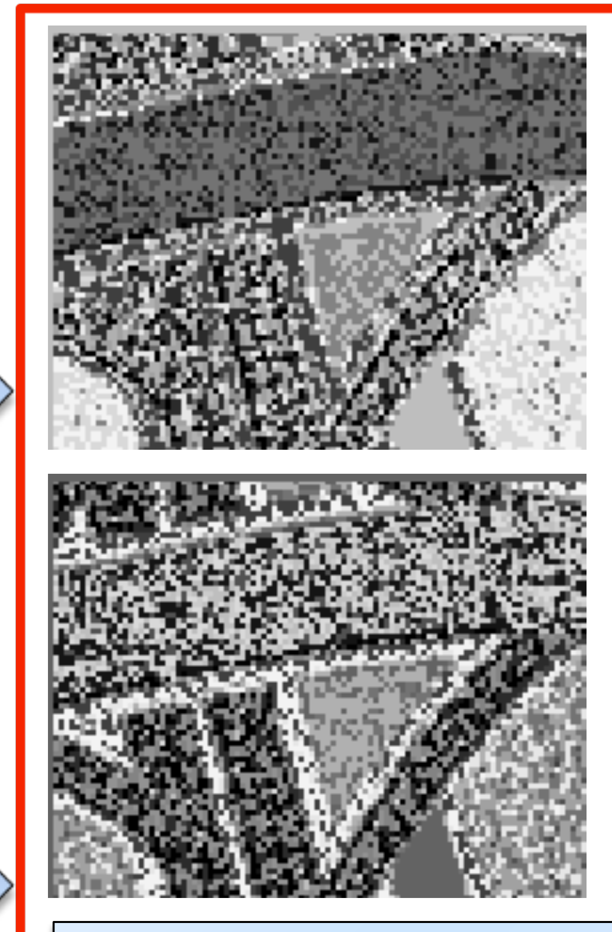
Original image



After K-means (16 colors)



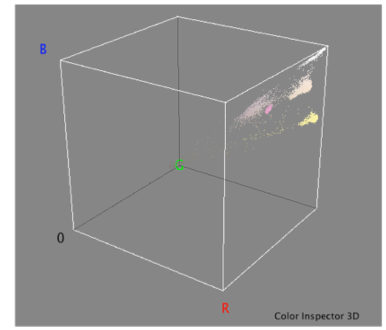
After Median-Cut (16 colors)



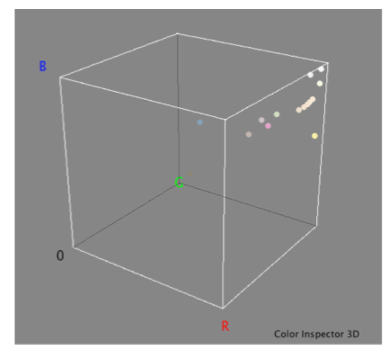
Each color is represented by a grayscale level

Color Segmentation with Spatial Information

- The Mean-shift algorithm
  - Consider distance in the color space and in image space
  - Preserve object edges
  - Reduce the colors by 50%

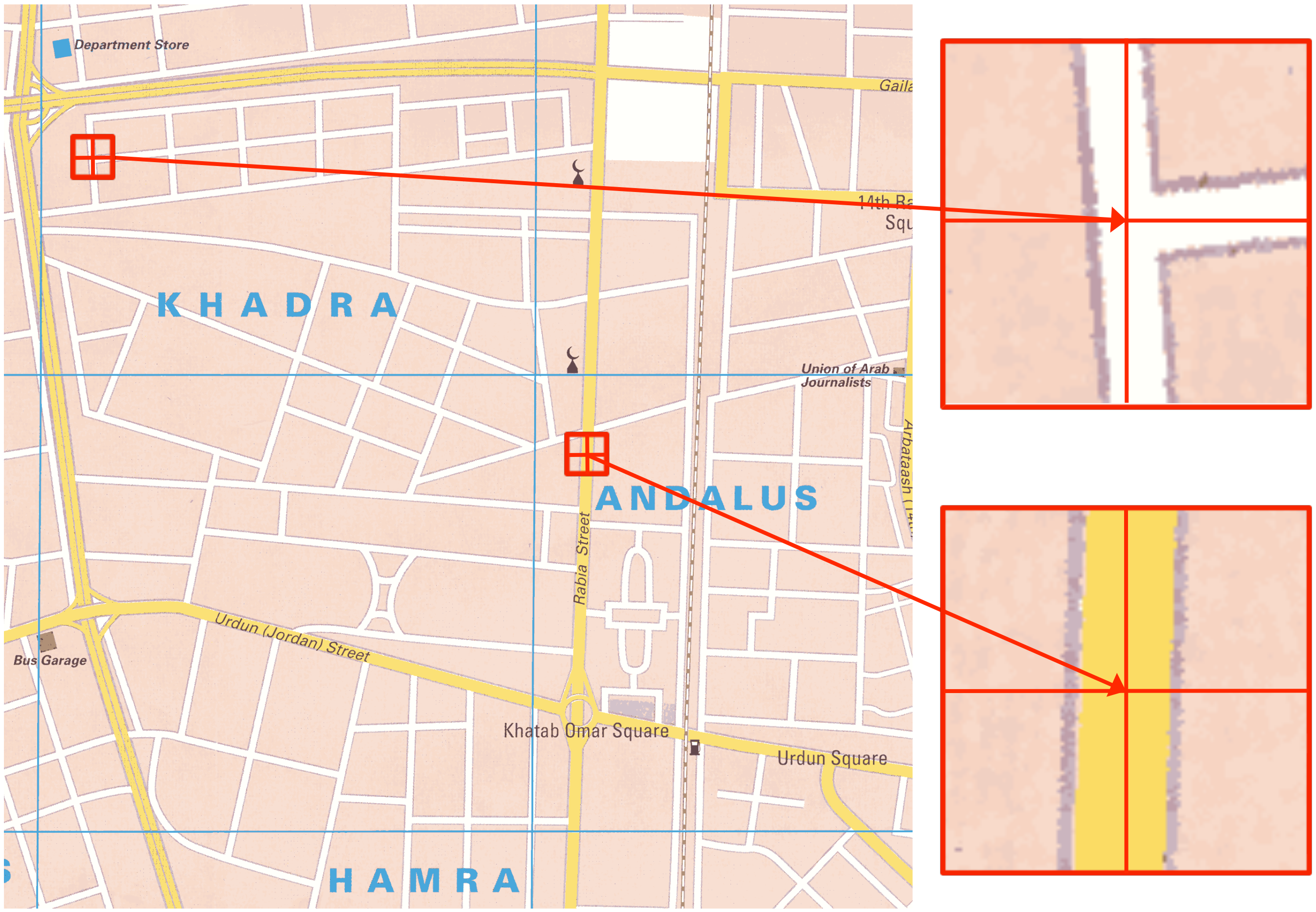


- The K-means algorithm
  - Limit the number of colors to K
  - From 155,299 to 10 colors (K=10)



User Labeling

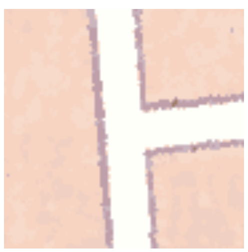
- To extract the road layer, the user needs to provide a user label for each road color (at most K colors)

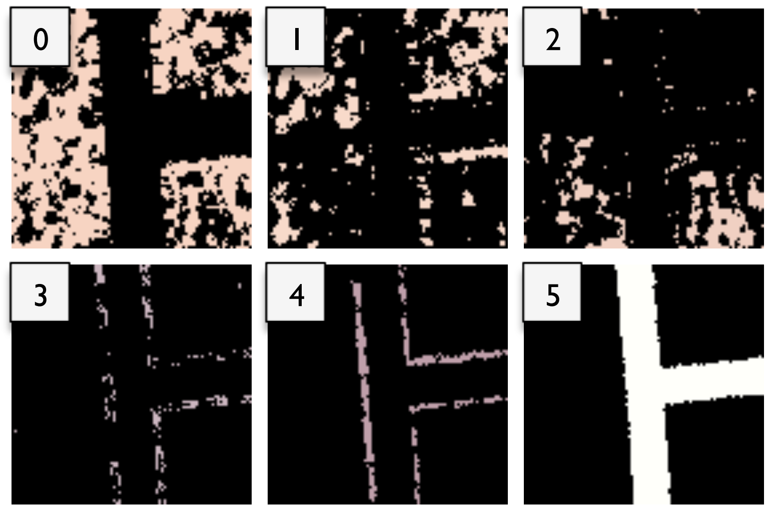


User label should be (approximately) centered at a road intersection or at the center of a road line

Label Decomposition

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

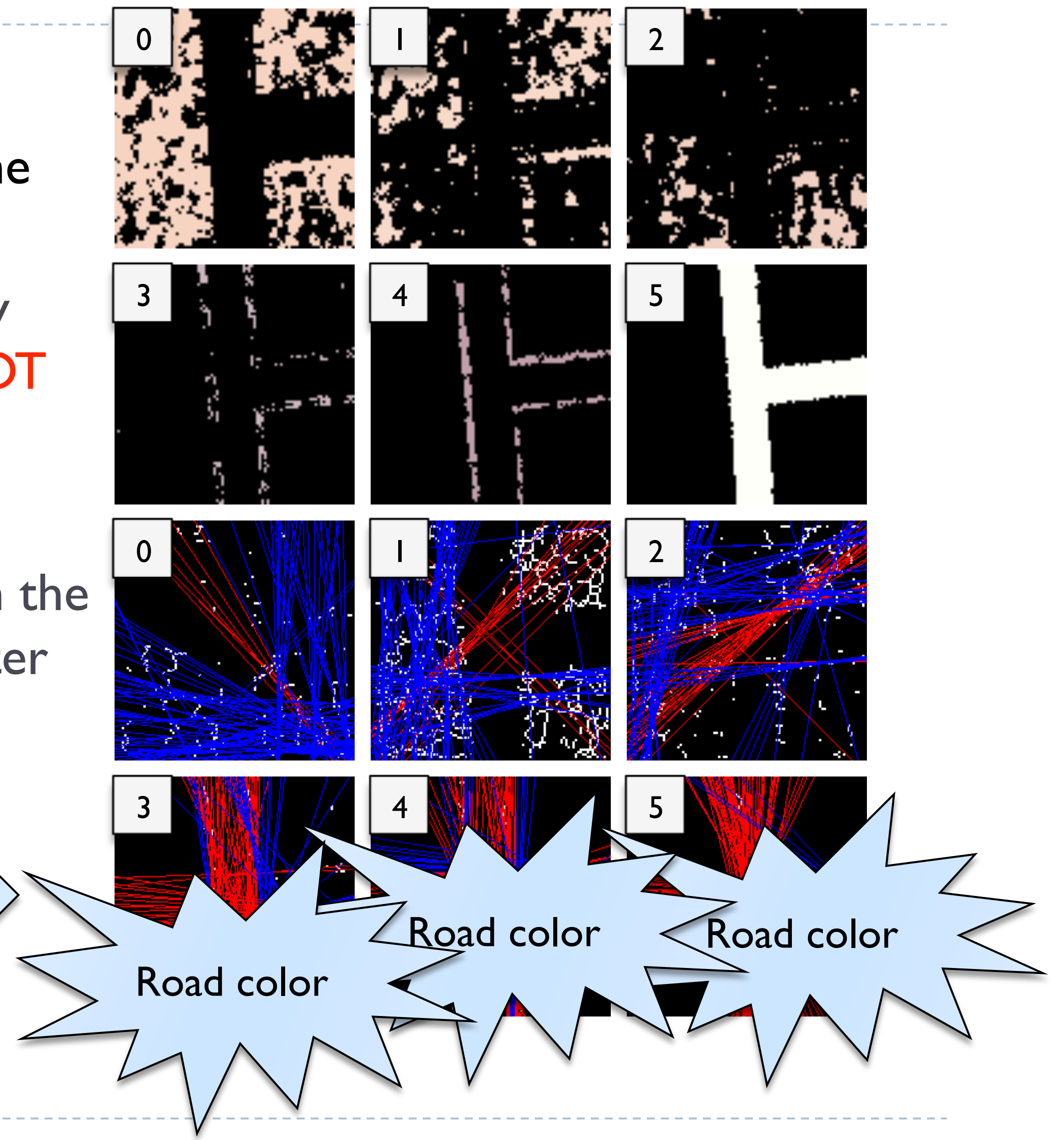




(background is shown in black)

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 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

Extract the Road Layer

- Identify a set of road colors from each user label
- Use the identified road colors to extract road pixels

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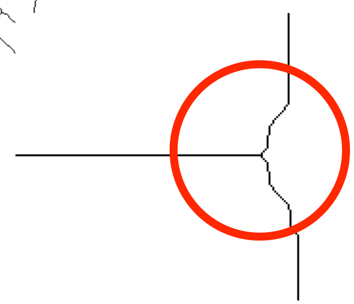
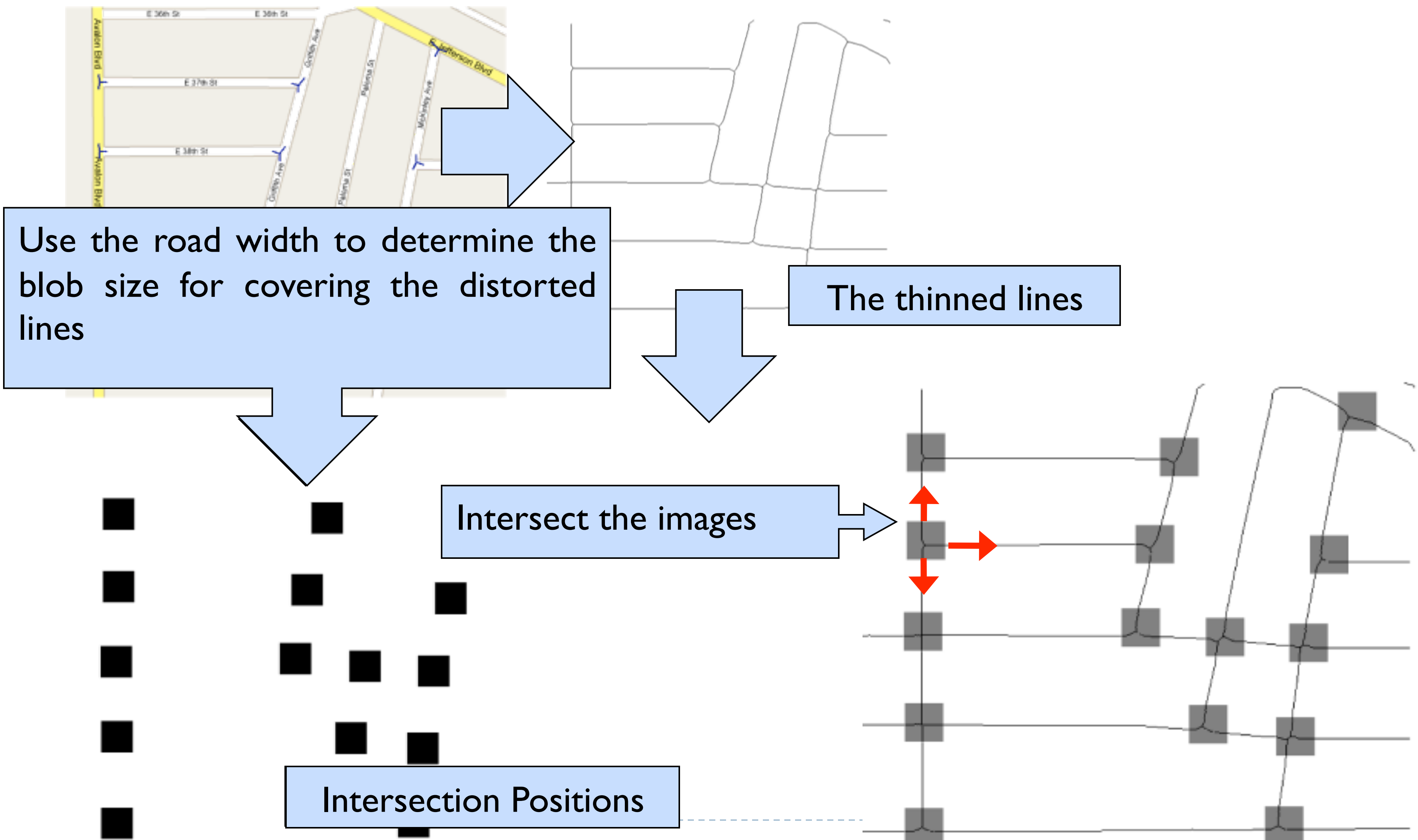
Extract Road Geometry

- Use the morphological operators as in the automatic map decomposition technique to generate road geometry

- The morphological operators can cause distorted lines near intersections



Distortion Correction



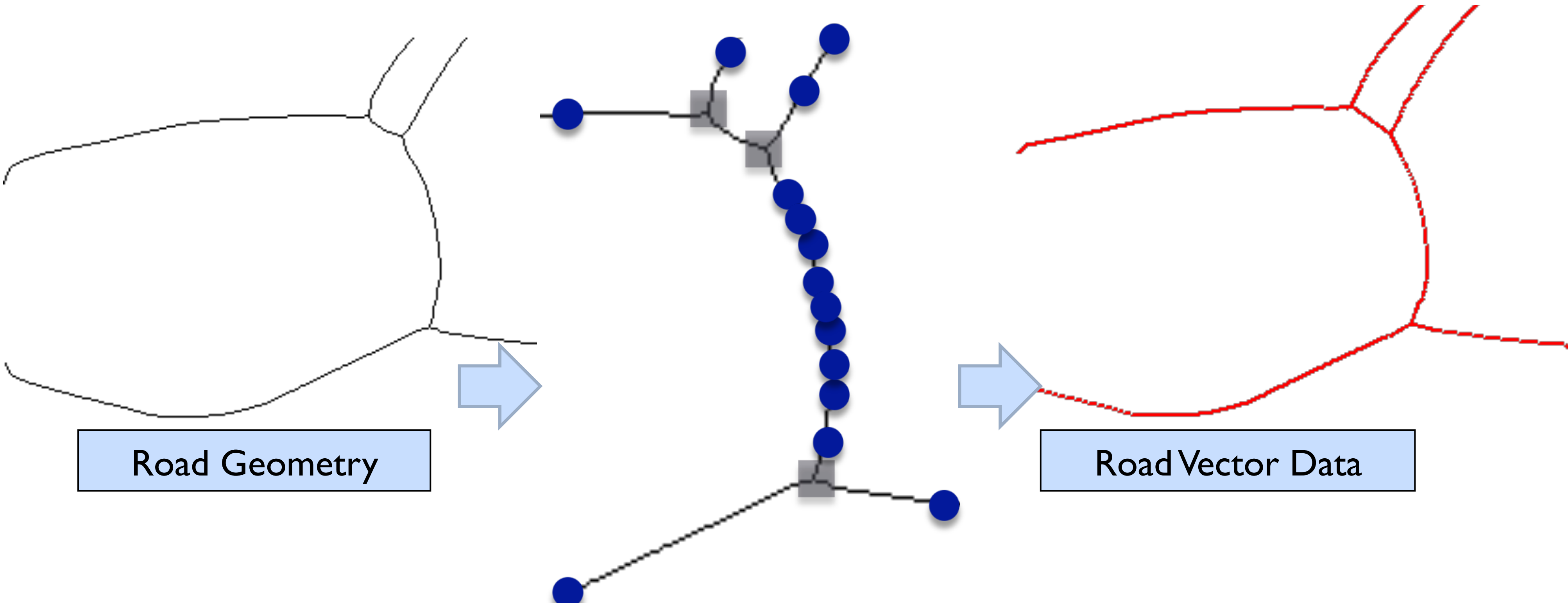
Accurate Road-Intersection Templates

With distortion

Avoid distortion

Road Vectorization

- Trace road geometry outside the distortion areas (gray boxes)
- Use the accurate road-intersection template to replace the road geometry inside the distortion areas



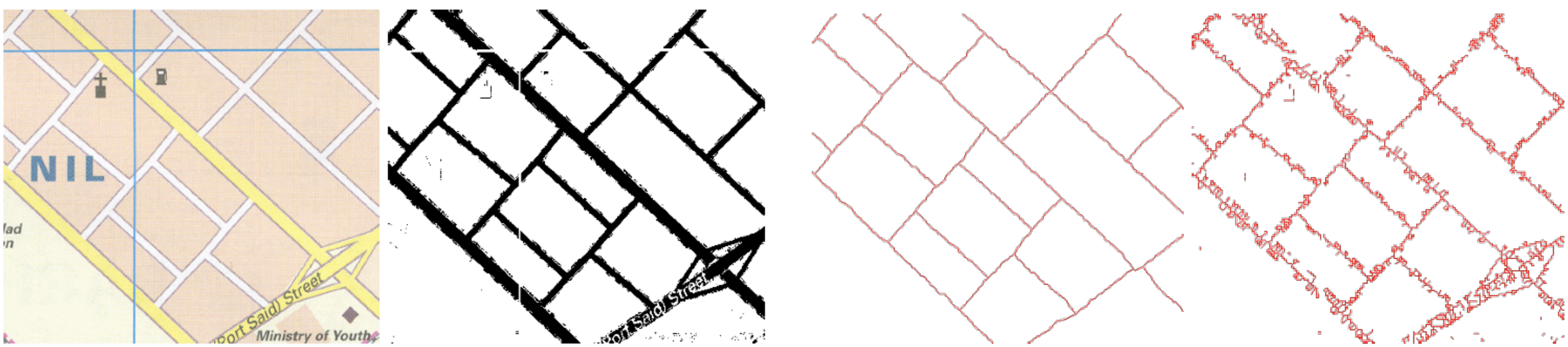
Experiments

- Implemented the road vectorization techniques in a system called Strabo
- Tested Strabo on 16 maps from 11 sources (4 scanned and 11 computer-generated maps)
- Tested a map digitizing product called R2V from Able Software for comparison

Experiments (Cont'd)

- For the 6 maps that need user labeling, Strabo extracted 6 road layers using 34 user labels (avg. 5.56)
- Strabo generated high quality road vector data with low redundancy, and with considerably less user input

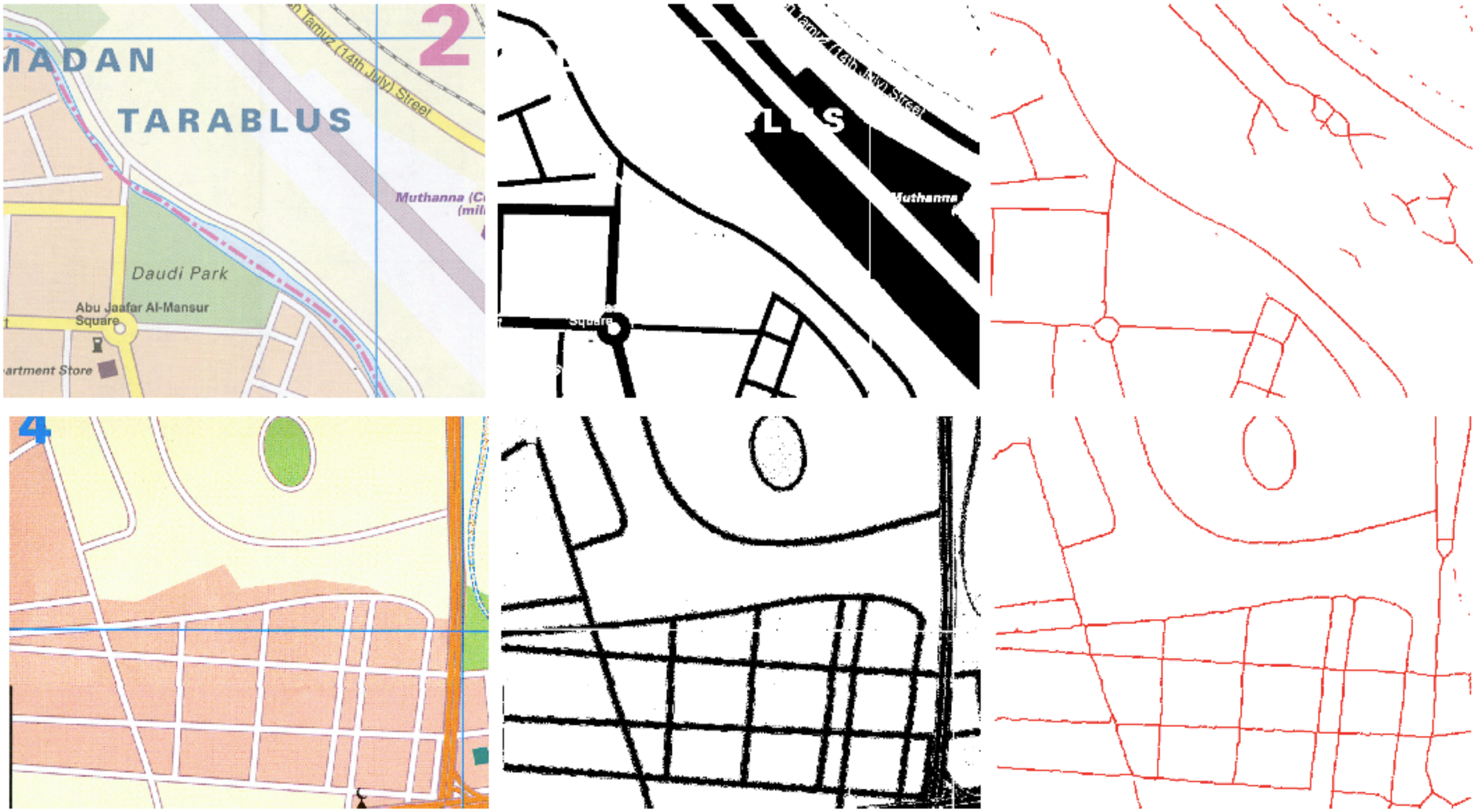
	Comp.	Corr.	Quality	Redundancy	RMS
Avg. (Strabo)	96.53%	97.61%	94.41%	0.19%	2.79
Avg. (R2V)	94.90%	87.41%	79.73%	42.81%	16.12



(a) ITM map (portion) (b) Extracted road pixels (c) Strabo results (d) R2V results

Example Results

Example Results (Cont'd)



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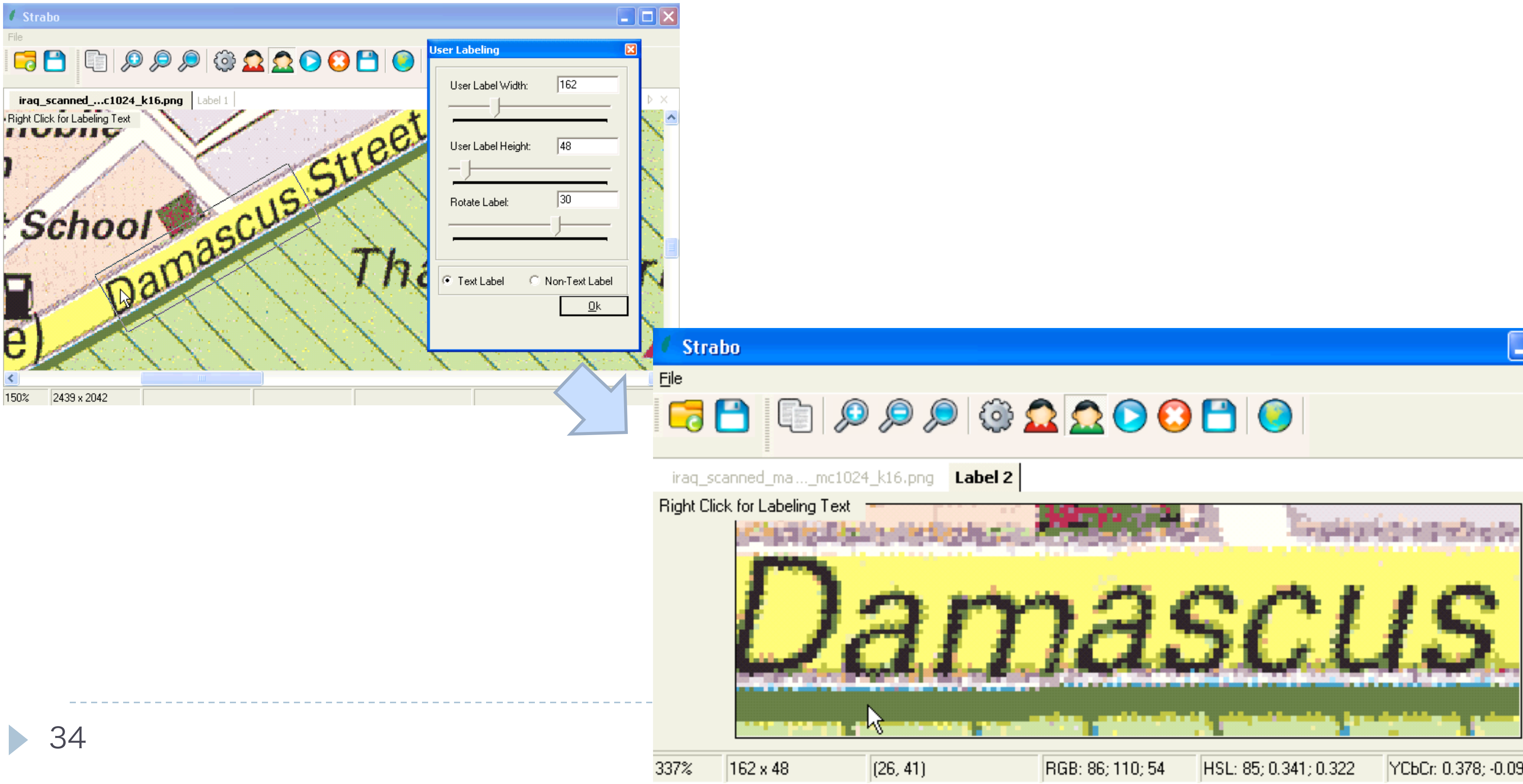
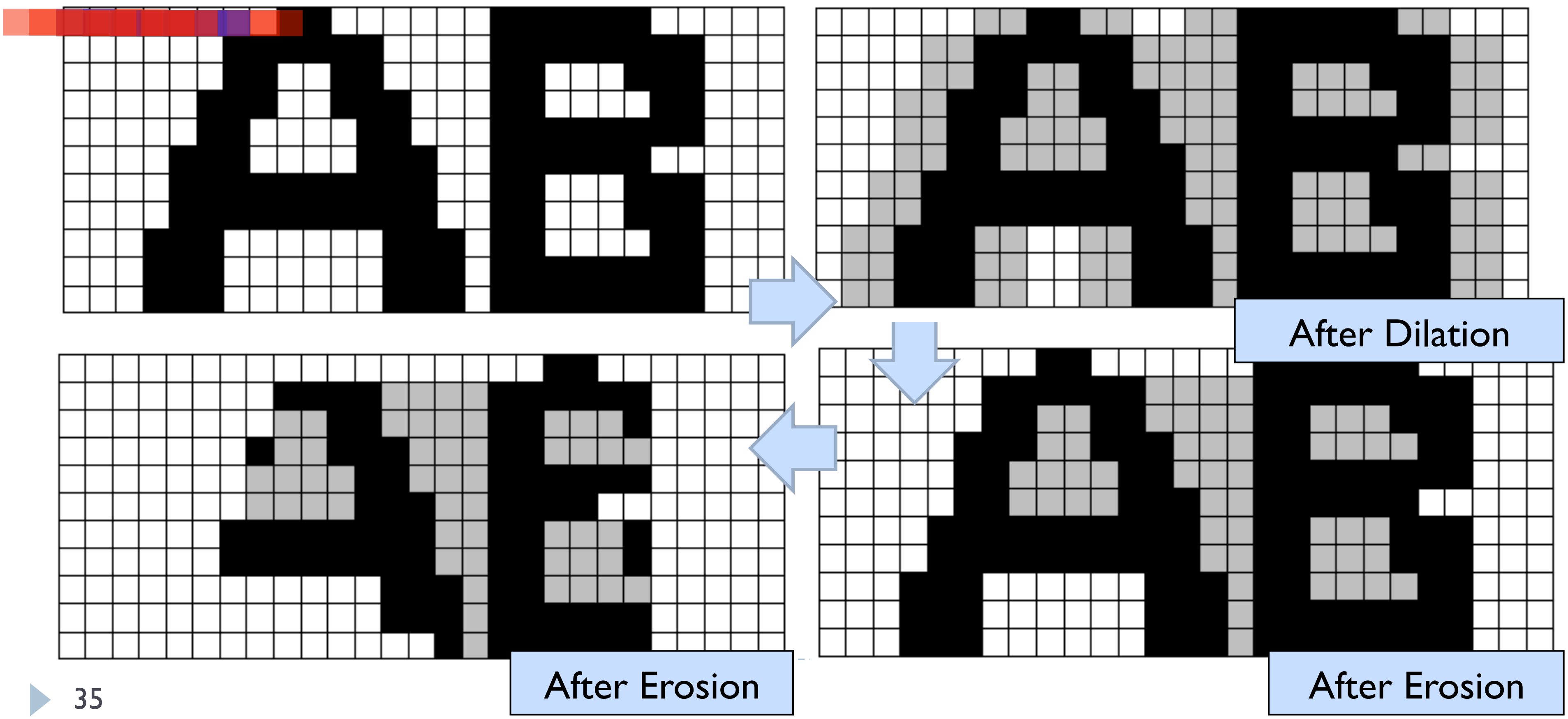
Supervised Extraction of Text Layers

- Use color segmentation to reduce the number of colors
- User provides examples of text areas for identifying text colors



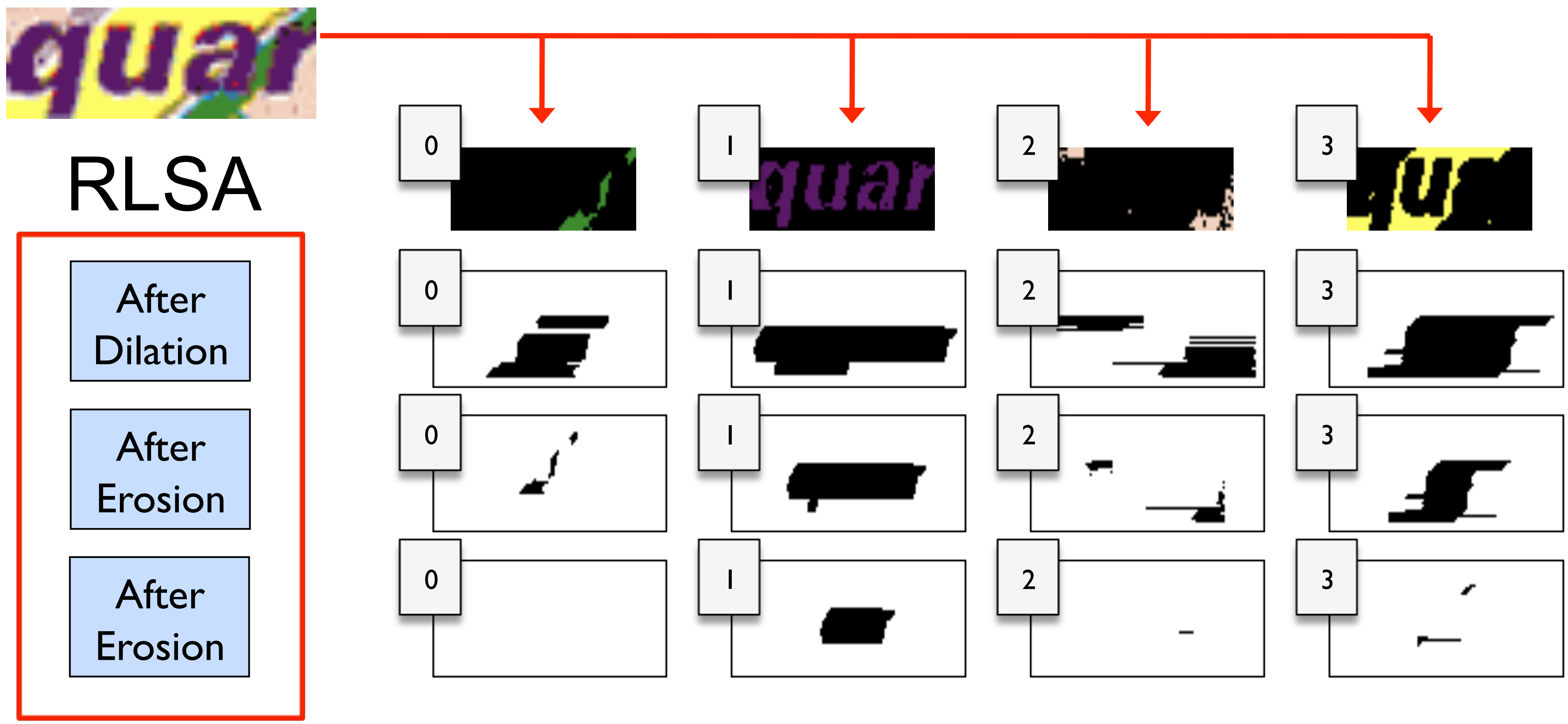
Run Length Smoothing Algorithm (RLSA)

- Apply Run Length Smoothing algorithm (RLSA) on user labels to identify text colors
- A RLSA example using a 5x1-pixel window

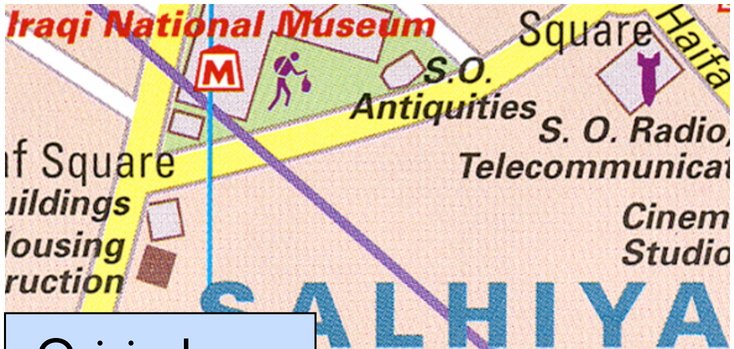


Determine Text Colors

- Decompose a user label into images, each of the images contains one color
- Apply Run Length Smoothing algorithm (RLSA) to identify text colors

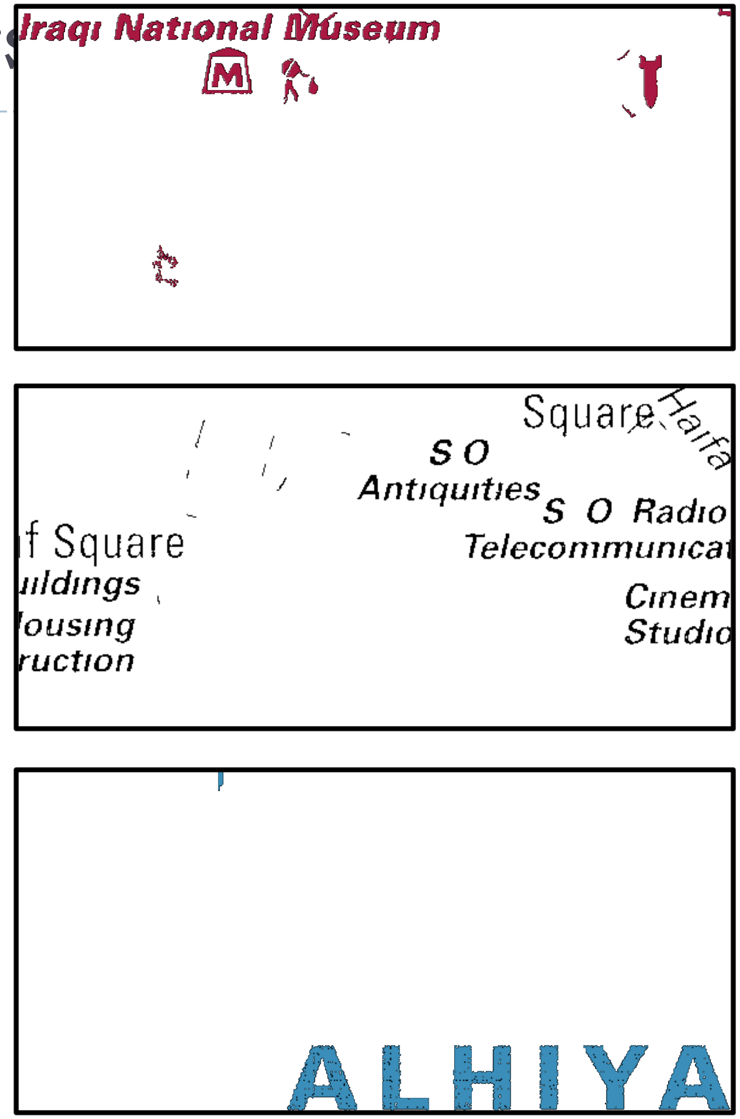


Extracted Text Layers



Original map

User Labels



Extracted text layers

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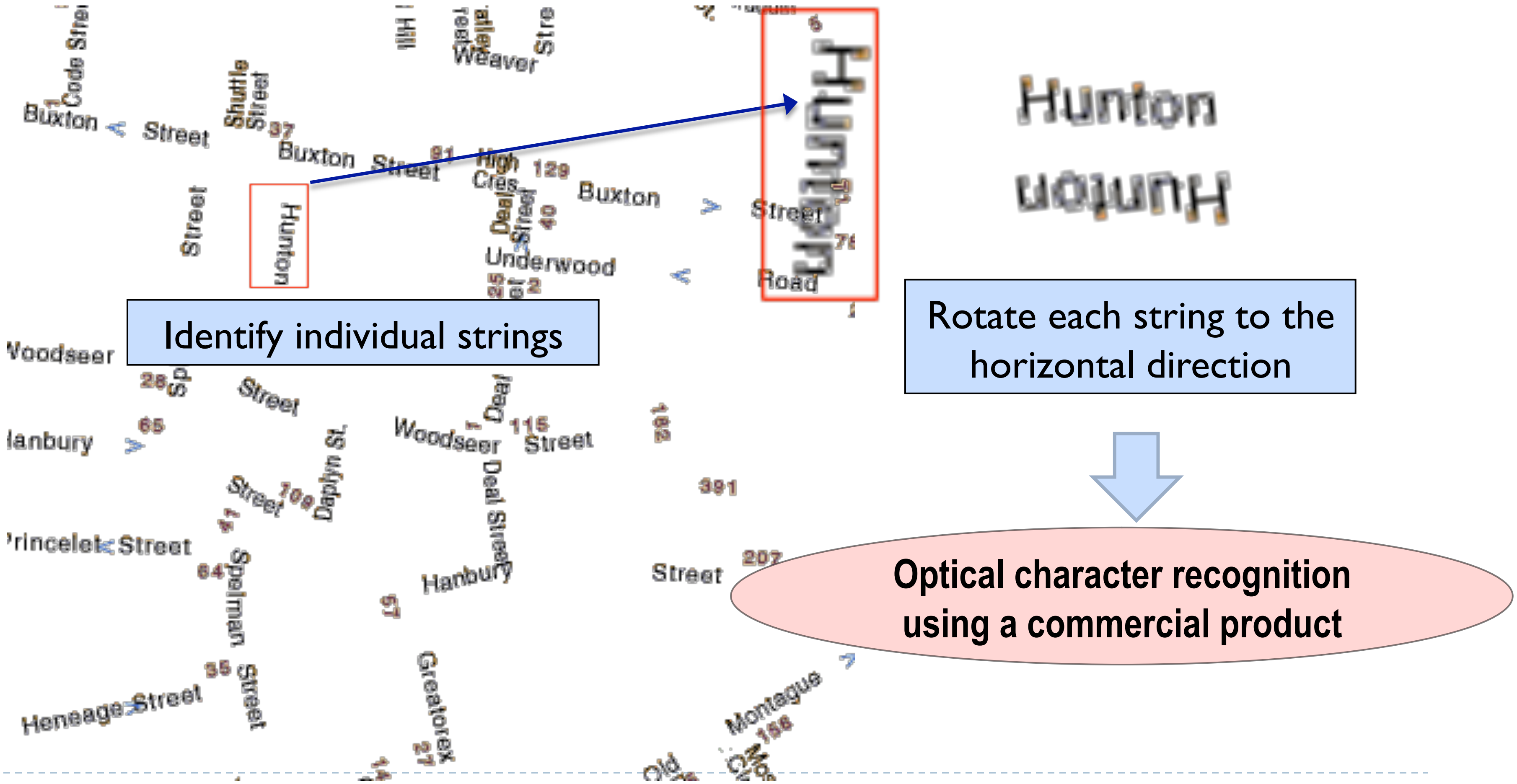
Text Recognition from Identified Text Layers

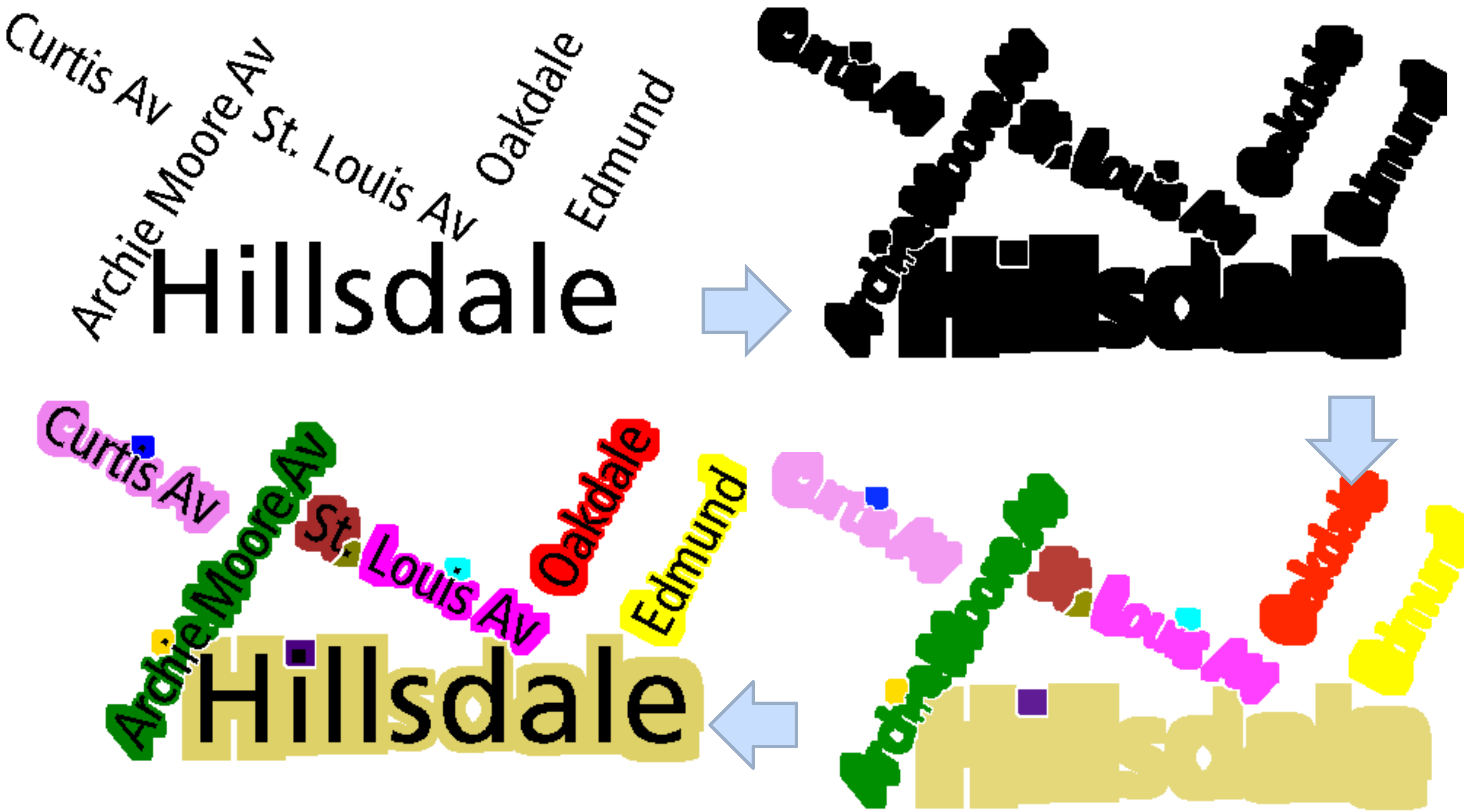
- Multi-oriented text labels
- Characters can have various sizes



Identify Individual Strings

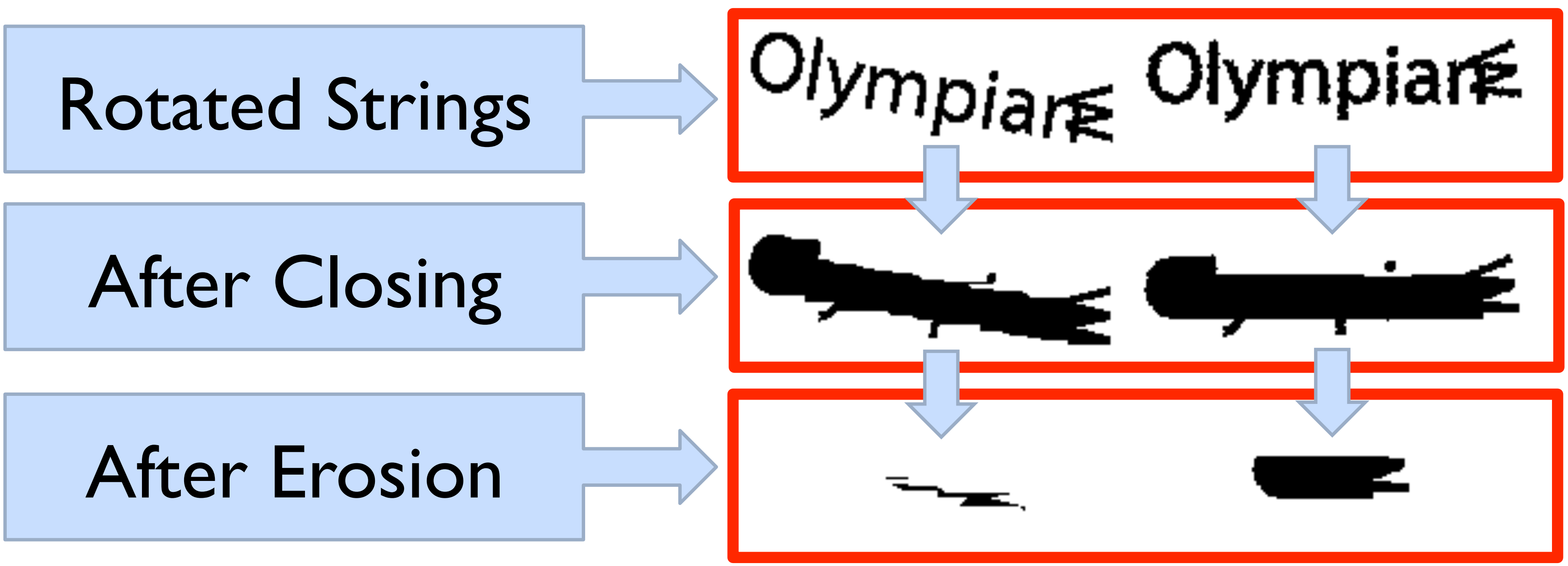
- Conditional Dilation Algorithm:
  - Expand the foreground area of the connected components (i.e., characters) when certain conditions meet
  - To determine the connectivity between the characters
- **Conditions:**
  - A character can only connect to at most two other characters
  - Two characters can be connected only if they have a similar size
  - A character can only connect to characters in a local area
  - Two strings can only be connected if they have a similar orientation

Conditional Dilation Results



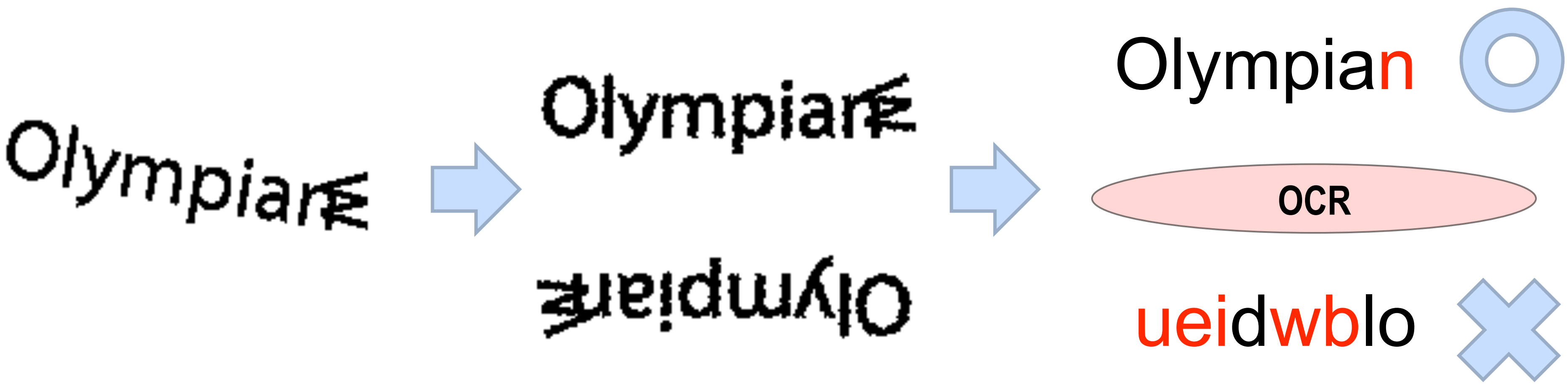
Detect String Orientation

- Rotate a string from 0° to 180°
- Apply Run Length Smoothing algorithm



Recognize Characters in the Horizontal Text Strings

- Feed the horizontal text strings to a commercial OCR product
- Use the OCR returned confidence to determine the correctly oriented horizontal string
  - Number of suspicious characters
  - Number of recognized characters



Experiments

- Tested on 15 maps from 10 sources
- Tested the 15 test maps using an OCR product called ABBYY FineReader alone for comparison

Examples of Test Maps

Experiments (Cont'd)

- Strabo extracted 22 text layers using 74 user labels (avg. 3.36)
- Strabo extracted 6,708 characters and 1,383 words
- ABBYY FineReader extracted 2,956 characters and 655 words

	Char. P.	Char. R.	Char. F.	Word P.	Word R.	Word F.
Avg. (Strabo)	92.77%	87.99%	90.32%	82.07%	77.58%	79.76%
Avg. (ABBYY)	71.99%	30.09%	42.44%	46.11%	20.64%	28.52%

Related Work

- **Separation of Feature Layers form Raster Maps**
  - Do not further recognize features from the separated layers (Podlasov and Ageenko, 05; Leyk and Boesch, 10; Henderson et al., 09; Lacroix, 09)
- **Recognition of Features in Raster Maps**
  - Require intensive user interaction (Leberl and Olson, 82; Suzuki and Yamada, 90; MapScan, 98)
  - Rely on prior knowledge (Cofer and Tou, 72; Samet and Soffer, 96; Myers et al., 96)
  - Develop recognition rules for a specific type of map (Dhar and Chanda, 06; Kerle and de Leeuw, 09)
- **Extraction of Contour Lines**
  - Laborious training process (Khotanzad and Zink, 03; Salvatore and Guitton, 04; Chen et al., 06)

Related Work

- **Road Vectorization**
  - Work on one type of map, e.g., computer-generated maps (Cao and Tan, 02; Li et al., 00; Bin and Cheong, 98; Habib et al.,99; Henderson et al., 09; Itonaga et al., 03)
  - Intensive manual process (Itonaga et al., 03, R2V, 10)
- **Text Recognition**
  - Work on one type of map (Fletcher and Kasturi,88; Bixler, 2000; Chen and Wang, 97)
  - Require training for each input map (Adam et al., 00; Deseilligny et al., 95; Pezeshk and Tutwiler, 10)
  - Require manual processing to prepare each string for OCR (Cao and Tan, 02; Li et al., 00; Pouderoux et al., 07;Vel □azquez and Levachkine, 04, ABBYY FineReader, 10)
  - Require additional knowledge of the input map (Gelbukh et al., 04; Myers et al., 96)

Publications

- First and Second Contributions:
  - Automatic Map Decomposition and Road-Intersection Template Extraction
    - ACM-GIS 05, ACM-GIS 08, and GeoInformatica 08
- Third Contribution:
  - Road Vectorization
    - ICDAR 09, GREC (LNCS) 09, and ACM-GIS 10
- Forth Contribution:
  - Text Recognition
    - ICPR 10

Conclusion: Contributions

- A general approach to exploit the information in heterogeneous raster maps by:
  - Decomposing the maps into feature layers
  - Recognizing features from the layers
  - Aligning the raster maps, extracted layers, and recognized features to other geospatial data
- Support map alignment
- Not limited to a specific type of map
  - Handle raster maps with varying map complexity, color usage, and image quality
- Require minimal user input
- Outperform state-of-art commercial products with considerably less user input

Conclusion: Future Work

- Automatically improve the feature recognition results
  - Automatic post-processing of road vector data
    - Exploit the identified map scale
  - Help the OCR component with additional knowledge of the map region
    - Exploit the identified map geocoordinates
- Research extensions:
  - Recognize languages other than English?
  - Infer the relationship between the extracted geographic features