Automatic Extraction of Road Intersection Position, Connectivity, and Orientation from Raster Maps

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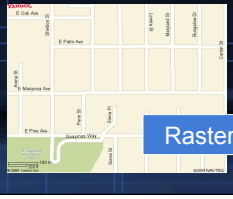
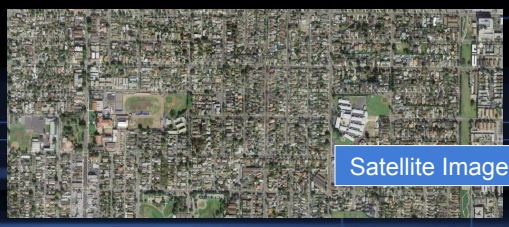
Introduction

- Road network commonly exists in geospatial data
- In [Chen et al. 2008], we utilize the sets of road intersection templates as the fingerprint of raster maps to integrate the maps with other geospatial data
  - Road intersection template - road intersection position, connectivity, and road orientation

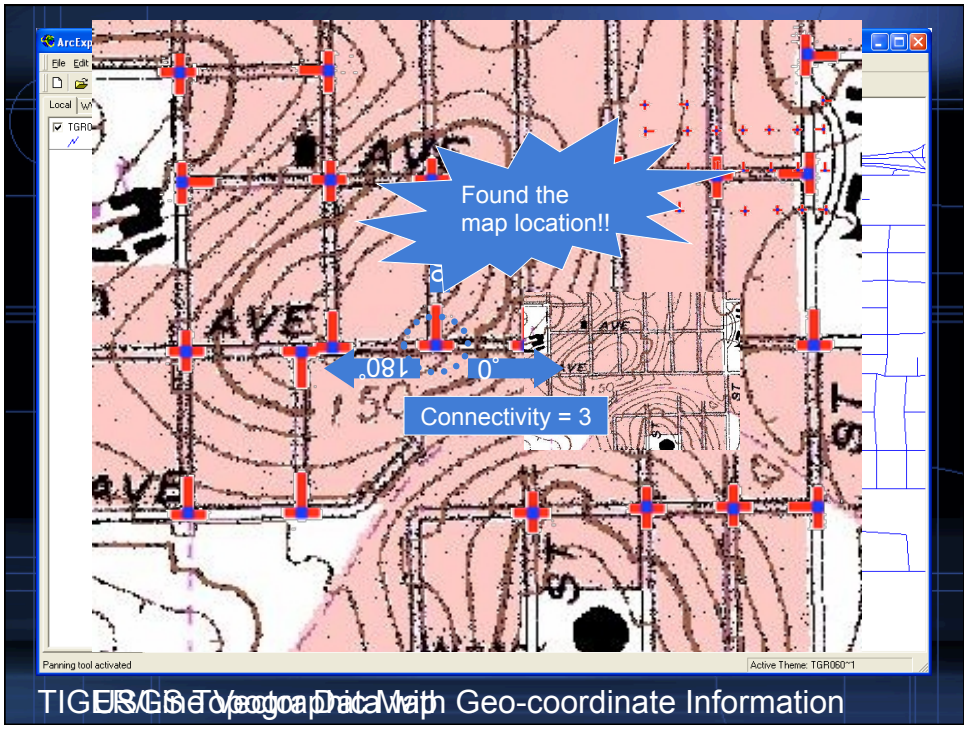
Vector data



Raster map



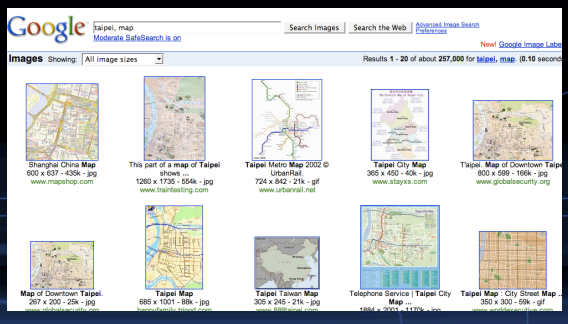
Satellite Imagery



TIGER/Line Vector Data with Geo-coordinate Information

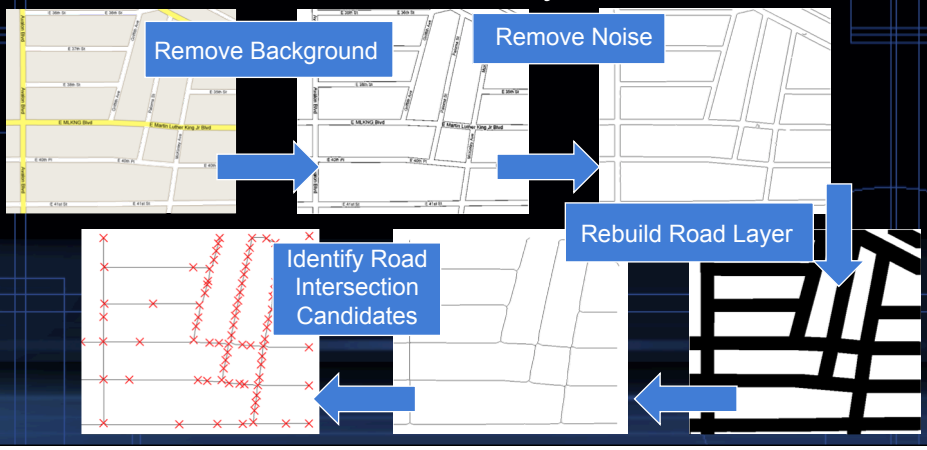
Previous Work

- The accuracy of the road intersection templates is important
  - Help to prune the search space during the matching
- Challenges for extracting the road intersection templates:
  - Limited access to the metadata of the maps
  - Maps are complex



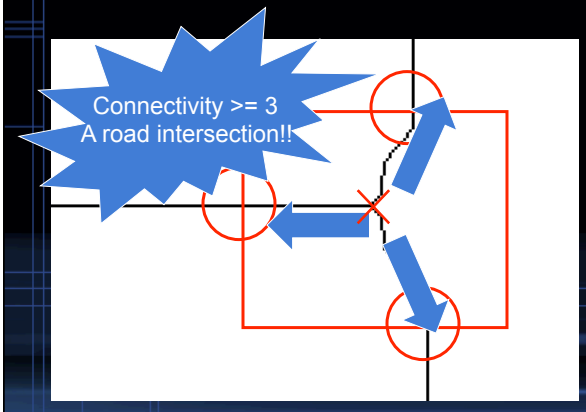
Previous Work

- In [Chiang et al. 2008], we worked on the pixel level to decompose the raster maps and to extract the road intersections automatically



Previous Work

- Identify actual road intersections from the road intersection candidates and extract the road intersection templates
  - A simpler method was used



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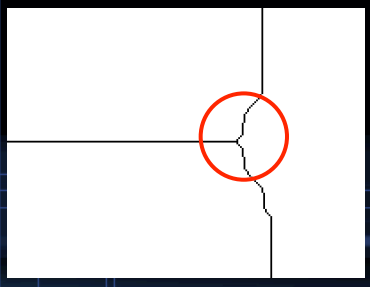
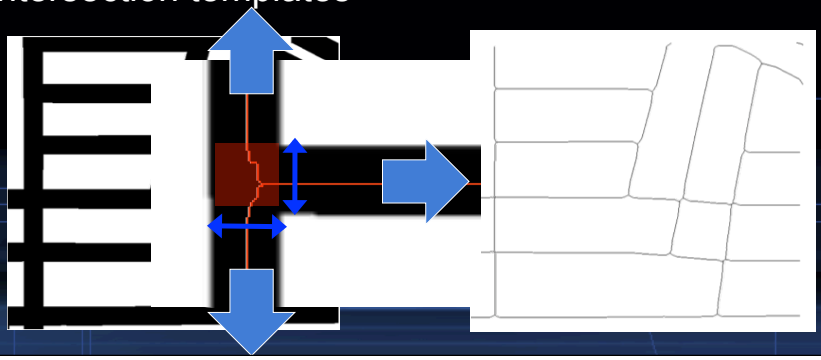
Previous Work

- Lines are distorted by the thinning operator
- The extracted road intersection templates are not accurate

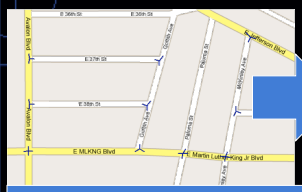


Extract Accurate Road Intersection Templates

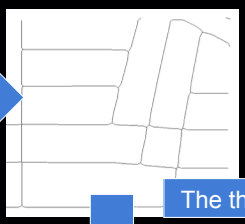
- The extent of the distortion is determined by the width of the thick lines
- In this work, we skip the distorted areas and trace the straight lines to extract accurate road intersection templates



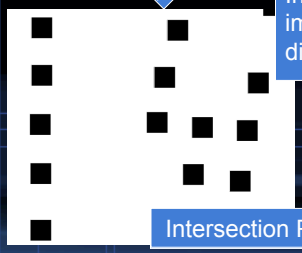
Cover the distortion areas



Blob size is determined using the thick-line width

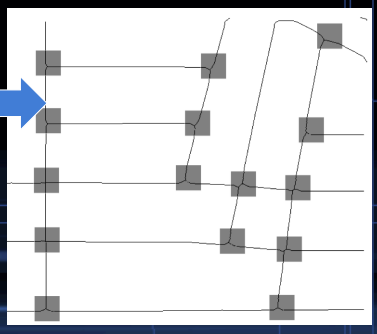


The thinned lines



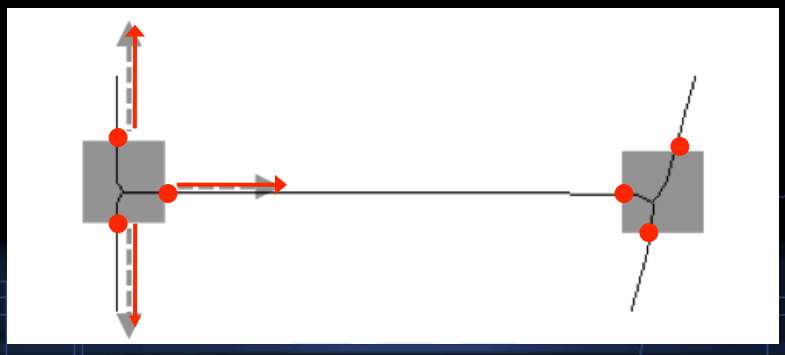
Intersection Positions

Intersect the two images to cover the distortions



Trace Road Line Candidates

- Identify contact points
- Trace road line candidates from contact points



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Trace Road Line Candidates

- Trace only a small amount of line pixels
  - Road lines are straight within a small distance (e.g., 5 pixels)
  - Fit a line function (Y= aX+b) to the traced pixels using Least-Squares Fitting algorithm
  - To prevent looping

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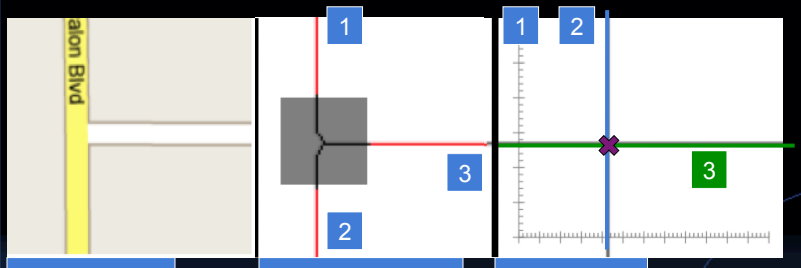
Update Positions of Road Intersection Templates (1 of 3)

- Update road intersection templates
  - Keep every road line candidate
  - Use the intersection of the line candidates to update the template



Original map | Blob image intersected with thinned lines | Traced line functions

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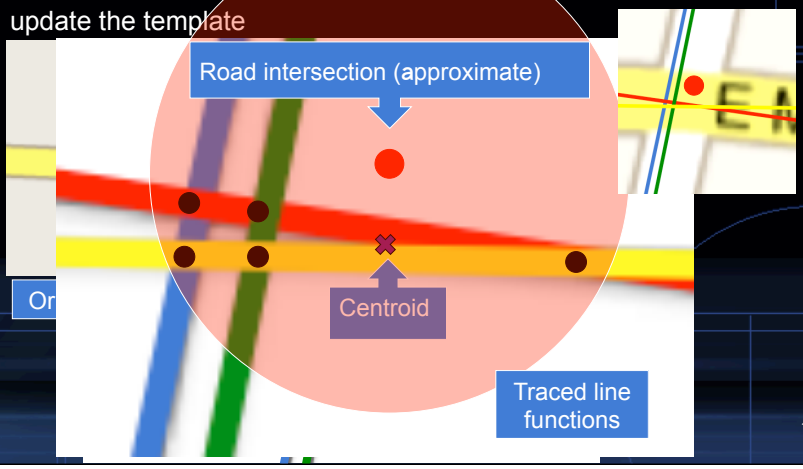
Update Positions of Road Intersection Templates (2 of 3)

- Update road intersection templates
  - Keep every road line candidate
  - Use the centroid of the intersections of the line candidates to update the template



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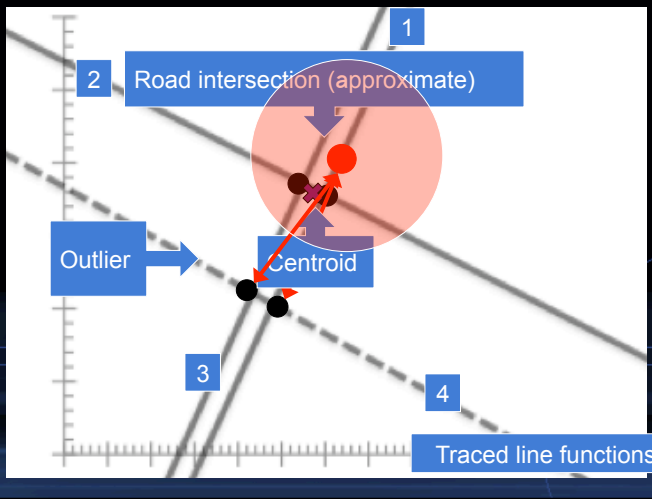
Update Positions of Road Intersection Templates (3 of 3)

- Update road intersection templates
  - Remove outliers and use the centroid of remaining intersections



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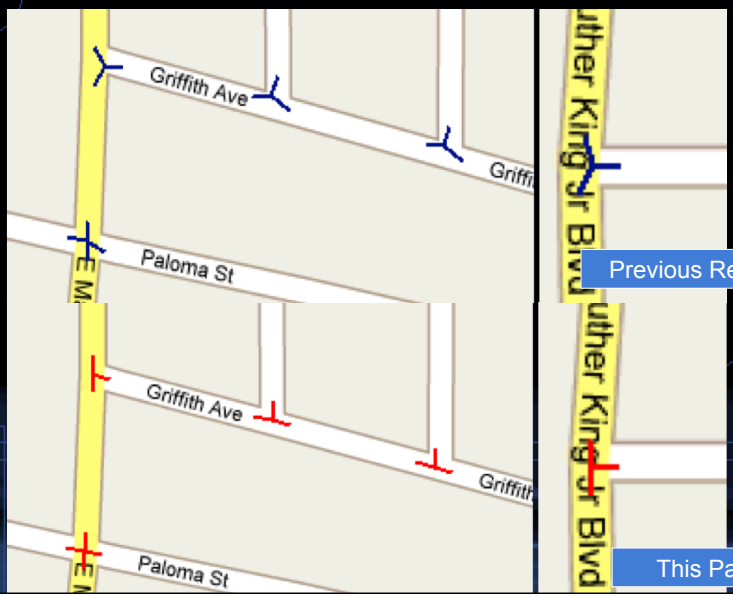
Road Intersection Templates



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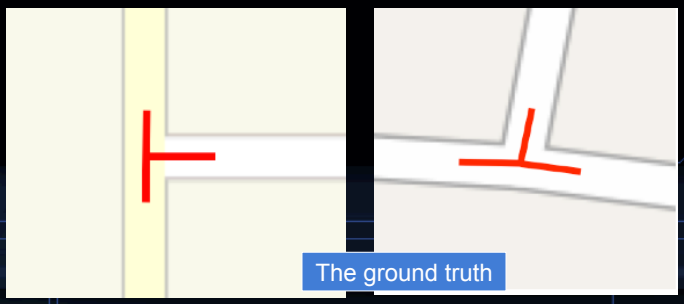
Experiments – Ground truth

- We evaluate 10 raster maps from five different sources
- Manually verify each extracted road intersection templates with the ground truth



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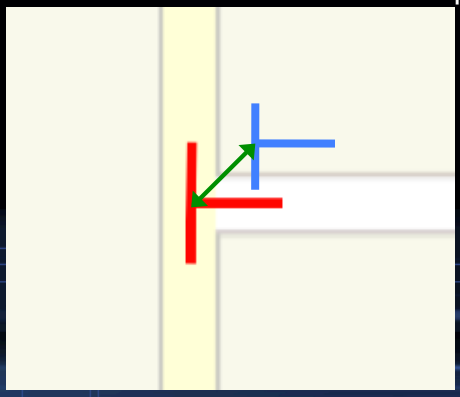
Experiments - Metrics

- Positional offset:
  - The average number of pixels between the extracted road intersection templates and the actual road intersections in the raster maps



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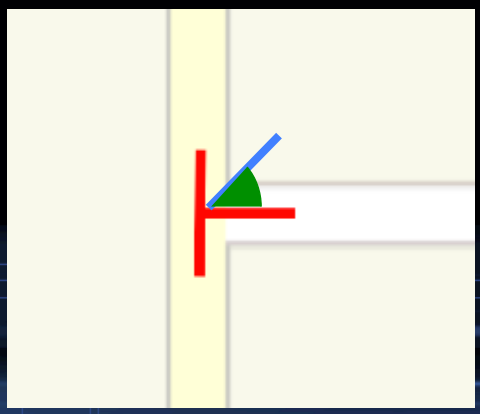
Experiments - Metrics

- Orientation offset:
  - The average number in degrees between the extract road orientations and the actual road orientations.



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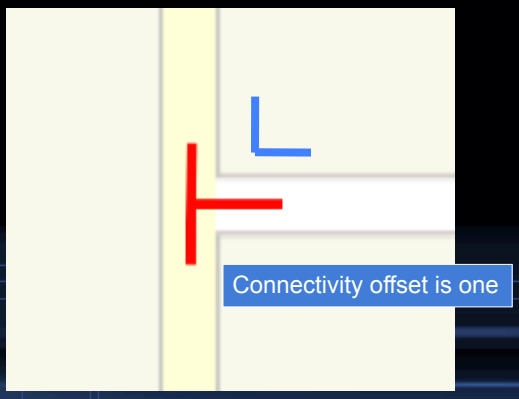
Experiments - Metrics

- The connectivity offset:
  - The total number of missed road lines.



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Experimental Results

- Extracted139 road intersection templates with 438 lines from 10 test maps
- The average positional offset:
  - 0.4 pixels
- The average orientation offset:
  - 0.24 degrees
- Extracted road intersection templates are very close to the ground truth
- The connectivity offset:
  - We missed 13 lines from a total of 451 lines – 97% of the lines are extracted
  - Lines that do not have accurate orientations were discarded

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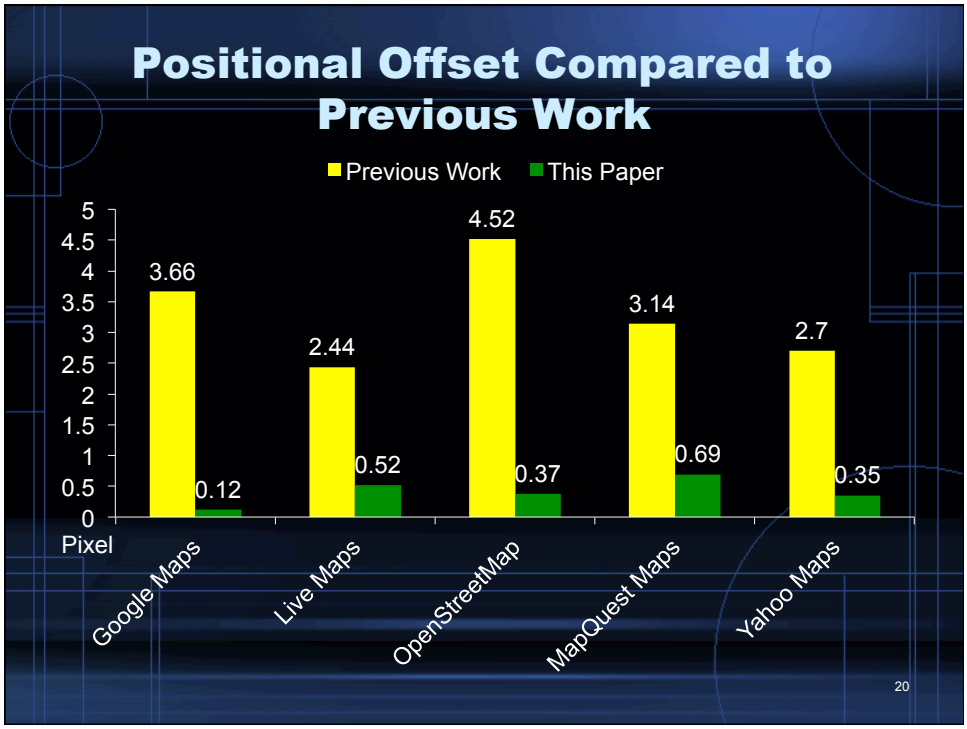
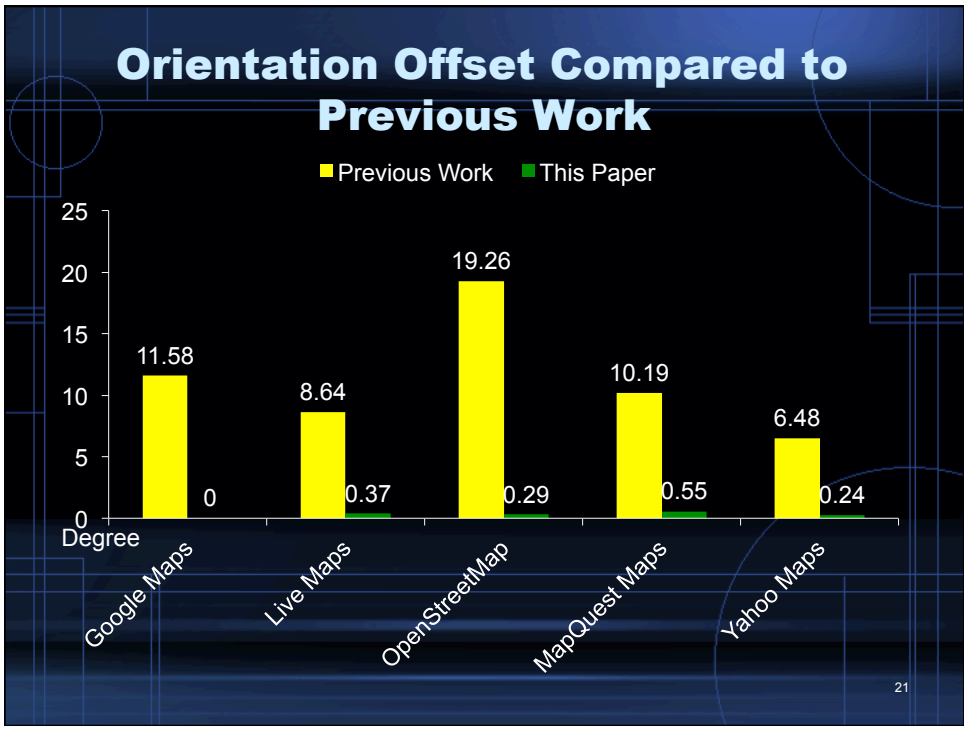

Positional Offset Compared to Previous Work
Previous Work
This Paper
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Pixel
3.66
0.12
2.44
0.52
4.52
0.37
3.14
0.69
2.7
0.35
Google Maps
Live Maps
OpenStreetMap
MapQuest Maps
Yahoo Maps
20


Orientation Offset Compared to Previous Work
Previous Work
This Paper
25
20
15
10
5
0
Degree
11.58
0
8.64
0.37
19.26
0.29
10.19
0.55
6.48
0.24
Google Maps
Live Maps
OpenStreetMap
MapQuest Maps
Yahoo Maps
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Related Work

- Localized Template Matching to improve the positional offset (Chiang et al. 08)
  - The templates used for matching are not accurate
- Cluster corner points to extract road intersections (Habib and Uebbing 99)
  - Cannot extract accurate intersection position and orientation
- Geometrical analyses to extract lines (Cao et al. 02 and Li et al. 00)
  - Do not extract intersection templates
- Color segmentation to extract lines (Khotanzad and Zink 03; Chen et al. 06)
  - Do not extract intersection templates

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Discussion

- Our technique automatically extracts accurate road intersection templates from raster maps.
  - Average positional offset: 0.4 pixels
  - Average orientation offset: 0.24 degrees
- Accurate road intersection templates help to:
  - Reduce search space for map conflation applications
  - Use the intersection templates as seed points to extract road from imagery
  - More…

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Future Work

- Include manual training
  - Extract more information from raster maps
    - Labels, landmarks
  - Process more complex maps
    - A metro map with different types of lines
- Identify the training process that minimizes human intervention
- Reuse the training results on similar maps

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Thank You

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