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

Yao-Yi Chiang and Craig Knoblock

University of Southern California
Department of Computer Science and Information Sciences Institute
Introduction

• Raster maps are one important source of geospatial data:
  • Contain information that is difficult to find elsewhere
  • Contain the most complete set of data

Map of Tehran, Iran

USGS topographic map
Introduction

• In [Chen et al. 2008], we utilize the set of road intersection templates as the fingerprint of the raster map to integrate raster maps with other geospatial data.

• Road intersection template:
  • Road intersection position, connectivity, and road orientation.
USGS Topographic Map, El Segundo, CA USA
TIGER/Line Vector Data with Geo-coordinate Information
TIGER/Line Vector Data with Geo-coordinate Information
TIGER/Line Vector Data with Geo-coordinate Information
TIGER/Line Vector Data with Geo-coordinate Information
TIGER/Line Vector Data with Geo-coordinate Information
Previous Work

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

• A simpler method to identify road intersections and extract the road intersection templates
• We also determine the road format (i.e., single or double line) and extract the road width
Previous Work

• A simpler method to identify road intersections and extract the road intersection templates
• We also determine the road format (i.e., single or double line) and extract the road width
Previous Work

• Lines are distorted by the thinning operator
• The extracted road intersection templates are not accurate
Extract Accurate Road Intersection Templates

• The distortion is caused by using the thinning operator on thick lines
• The extent of the distortion is determined by the road width

Rebuild road layer
Extract Accurate Road Intersection Templates

• In this work, we skip the distorted areas and trace the straight lines to extract accurate road intersection templates.
Extract Accurate Road Intersection Templates

The thinned lines

Intersection Positions
Extract Accurate Road Intersection Templates

The size of a blob is determined using the road with for covering the distorted lines.

The thinned lines

Intersection Positions
Extract Accurate Road Intersection Templates

The size of a blob is determined using the road with for covering the distorted lines.

Intersect the thinned line image with the blob image.

Intersection Positions

The thinned lines
Extract Accurate Road Intersection Templates

• Identify contact points
• Trace road line candidates from contact points
Extract Accurate Road Intersection Templates

• Trace road line candidates from contact points
  • Trace only a certain amount of line pixels to prevent looping
  • 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
Extract Accurate Road Intersection Templates

• Trace road line candidates from contact points
  • Trace only a certain amount of line pixels to prevent looping
  • 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
Extract Accurate Road Intersection Templates

• Trace road line candidates from contact points
  • Trace only a certain amount of line pixels to prevent looping
  • 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
Extract Accurate Road Intersection Templates

• Update road intersection templates
  • Keep every road line candidate
  • Use the intersection of the line candidates to update the template
Extract Accurate Road Intersection Templates

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

Original map

Blob image intersected with thinned lines
Extract Accurate Road Intersection Templates

- Update road intersection templates
  - Keep every road line candidate
  - Use the centroid of the intersections of the line candidates to update the template
Extract Accurate Road Intersection Templates

• Update road intersection templates
  • Keep every road line candidate
  • Use the centroid of the intersections of the line candidates to update the template
Extract Accurate Road Intersection Templates

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

Traced line functions
Extract Accurate Road Intersection Templates

• Update road intersection templates
  • Keep every road line candidate
  • Use the centroid of the intersections of the line candidates to update the template
Extract Accurate Road Intersection Templates

- Update road intersection templates
  - Keep every road line candidate
  - Use the centroid of the intersections of the line candidates to update the template
Extract Accurate Road Intersection Templates

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

Original map

Blob image intersected with thinned line
Extract Accurate Road Intersection Templates

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

Original map

Blob image intersected with thinned line

Traced line functions

Intersection (approximate location)
Extract Accurate Road Intersection Templates

- Update road intersection templates
- Remove outliers and use the centroid of remaining intersections
Extract Accurate Road Intersection Templates

• Update road intersection templates
  • Remove outliers and use the centroid of remaining intersections
Extract Accurate Road Intersection Templates

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

![Diagram showing updates to road intersection templates with outliers and centroids marked.](image-url)
Extract Accurate Road Intersection Templates

Previous Results

This Paper
Experiments – Ground truth

- We evaluate 10 raster maps from five different sources
- Manually verify each extracted road intersection templates with the ground truth
• Positional offset:
  • The average number of pixels between the extracted road intersection templates and the actual road intersections in the raster maps
Experiments - Metrics

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

• The connectivity offset:
  • The total number of missed road lines.
Experimental Results

• Extracted 139 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
Positional Offset Compared to Previous Work

Pixel

<table>
<thead>
<tr>
<th>Service</th>
<th>Previous Work</th>
<th>This Paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Google Maps</td>
<td>3.66</td>
<td>0.12</td>
</tr>
<tr>
<td>Live Maps</td>
<td>2.44</td>
<td>0.52</td>
</tr>
<tr>
<td>OpenStreetMap</td>
<td>4.52</td>
<td>0.37</td>
</tr>
<tr>
<td>MapQuest Maps</td>
<td>3.14</td>
<td>0.69</td>
</tr>
<tr>
<td>Yahoo Maps</td>
<td>2.7</td>
<td>0.35</td>
</tr>
</tbody>
</table>
Orientation Offset Compared to Previous Work

<table>
<thead>
<tr>
<th>Service</th>
<th>Previous Work</th>
<th>This Paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Google Maps</td>
<td>11.58</td>
<td>0</td>
</tr>
<tr>
<td>Live Maps</td>
<td>8.64</td>
<td>0.37</td>
</tr>
<tr>
<td>OpenStreetMap</td>
<td>19.26</td>
<td>0.29</td>
</tr>
<tr>
<td>MapQuest Maps</td>
<td>10.19</td>
<td>0.55</td>
</tr>
<tr>
<td>Yahoo Maps</td>
<td>6.48</td>
<td>0.24</td>
</tr>
</tbody>
</table>
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 templates

• 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
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 searching space for map conflation application
  • Use the intersection templates as seed points to extract road from imagery
  • More…
Future Work

• Include manual training to extract more information from raster maps
  • Labels, landmarks

• Include manual training to 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
Thank You
Introduction

• In our previous work [Chen et al. 2008], we extract the road intersection templates to integrate raster maps with imagery.

• Road intersection template:
  • Road intersection position, connectivity, and road orientation.
Introduction

- Label the imagery with features on the map

Satellite imagery of Tehran, Iran from Google Maps

Tehran map from Google Image Search

Align the map with the satellite imagery
Introduction

• Use the intersection templates as seed points to extract road from imagery
Experiments - Metrics

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

• Orientation offset:
  • The average number in degrees between the extracted road orientations and the actual road orientations.

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