A Novel Algorithm for Road Extraction from Airborne Lidar Data

Li Liu & Samsung Lim
School of Civil & Environmental Engineering
University of NSW
Introduction

◆ In 2007, European Union started to update its current road database

◆ In 2012, police in Victoria, Australia, issued a warning to motorists, cautioning them against relying on Apple's Maps

◆ In 2013, an Alaskan airport closed an aircraft access route because of a flaw with Apple's Maps app
Problems of Road Map

- 2D Data
- Generalization of real road
- Not measurable
Feature of Lidar

- Light Detection and Ranging
- 3D Lidar points
<table>
<thead>
<tr>
<th></th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lidar</td>
<td>• Accurate height value</td>
<td>• Less contextual info</td>
</tr>
<tr>
<td></td>
<td>• In real time</td>
<td>• Complicate to process</td>
</tr>
<tr>
<td></td>
<td>• More details</td>
<td></td>
</tr>
<tr>
<td>Image</td>
<td>• More contextual info</td>
<td>• No height value</td>
</tr>
<tr>
<td></td>
<td>• Mature algorithms</td>
<td>• Shadows of trees, buildings</td>
</tr>
<tr>
<td></td>
<td>Advantages</td>
<td>Disadvantages</td>
</tr>
<tr>
<td>----------------</td>
<td>-----------------------------------------------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td><strong>Lidar</strong></td>
<td>• Accurate height value</td>
<td>• Less contextual info</td>
</tr>
<tr>
<td></td>
<td>• In real time</td>
<td>• Complicate to process</td>
</tr>
<tr>
<td></td>
<td>• More details</td>
<td></td>
</tr>
<tr>
<td><strong>Vector Data</strong></td>
<td>• Reflection of real road</td>
<td>• Map scale</td>
</tr>
<tr>
<td></td>
<td>• Easy to process</td>
<td>• Suffer from generalization</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Few available GIS maps</td>
</tr>
</tbody>
</table>
Research Aims

- What properties can be used or analyzed to distinguish road points from other points?
- How can the structured roads and unstructured roads be extracted within one algorithm?
- How can the combination and fusion of other data sources and Lidar be used to improve the accuracy and the efficiency of the result?
Procedure

Lidar point → Rough Extraction → Refinement → Road point
Proposed Methodology

Flow chart of the proposed algorithm

ALS Point Clouds

X Coordinate

Y Coordinate

Moving Window

Partition

Reordering

$S_c < S_{Max}$

Road Extraction

$S_c \geq S_{Max}$

Candidate Point

Create Buffer

Interpolation

3D Road Points

Further Refinement

Y Direction

X Direction

$S_c < S_{Max}$

$S_c \geq S_{Max}$
Basic Idea

A sample of airborne Lidar

Part of Profile of Lidar point from transect line
Moving Window

Vegetation Point  Building Point  Road Point

Window Size L0

Window Size L1

Window Size L2

Window Size L0

Window Size L1

Window Size L2

Window Size L0

Window Size L1

Window Size L2

Vegetation Point  Building Point  Road Point

[Diagram showing different window sizes with vegetation, building, and road points]
Moving Window

- Rule 1: Slope
  \[ \Delta S \leq \Delta S_{max} \]

- Rule 2: Elevation and Height Differences
  \[ \begin{cases} 
  E_P \leq E_{max} \\
  E_{P_{max}} - E_{P_{min}} \leq \Delta H_{max} 
  \end{cases} \]

- Rule 3: Intensity
  \[ I_P \leq I_{max} \]
Refinement

Road point  False Positives  Vector Data

Road point  Interpolated point  Vector Data

Road point  False Positives  Vector Data

Road point  Interpolated point  Vector Data
Experiment

(a)

(b)

(d)

(c)
Experiment Result

(a) (b) (c) (d)
Experiment Result

(e)

(f)

(g)

(h)
Results Analysis

◆ Quantitative Analysis

Completeness = $TP/Lr$
Correctness = $TP/Le$
Quality = $TP/(Le + FN)$

Where:
- $Lr$ is the total length of the reference roads;
- $Le$ is the total length of the extracted roads;
- $TP$ is true positives, namely, the total length of the extracted roads that matches the reference roads;
- $FN$ is false negatives, namely, the total length of the undetected roads.
## Results Analysis

**Quantitative Analysis**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Length of reference roads (m)</th>
<th>Length of extracted roads (m)</th>
<th>Length of undetected roads (m)</th>
<th>Total length of Matched roads (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1: Residential area</td>
<td>2227.14</td>
<td>2218.51</td>
<td>32.31</td>
<td>1809.58</td>
</tr>
<tr>
<td>Sample 2: Anzac Parade</td>
<td>2493.20</td>
<td>2445.45</td>
<td>61.98</td>
<td>1740.50</td>
</tr>
<tr>
<td>Sample 3: Barker Street</td>
<td>1958.33</td>
<td>1949.94</td>
<td>0</td>
<td>1643.72</td>
</tr>
<tr>
<td>Sample 4: Botany Street</td>
<td>1268.89</td>
<td>1215.81</td>
<td>58.20</td>
<td>1167.55</td>
</tr>
</tbody>
</table>

Statistics for the datasets
## Results Analysis

#### Quantitative Analysis

<table>
<thead>
<tr>
<th></th>
<th>Completeness (%)</th>
<th>Correctness (%)</th>
<th>Quality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1: Residential area</td>
<td>81.25</td>
<td>81.57</td>
<td>80.40</td>
</tr>
<tr>
<td>Sample 2: Anzac Parade</td>
<td>69.81</td>
<td>71.17</td>
<td>69.41</td>
</tr>
<tr>
<td>Sample 3: Barker Street</td>
<td>84.30</td>
<td>83.93</td>
<td>83.93</td>
</tr>
<tr>
<td>Sample 4: Botany Street</td>
<td>92.01</td>
<td>96.03</td>
<td>91.64</td>
</tr>
</tbody>
</table>

Analysis Results
Concluding Remarks

◆ The method is suitable to both structured road and unstructured road;

◆ It is vulnerable to the problem of traffic island extraction;

◆ Window size is critical to the extraction results;

◆ The polyline road segment and the traffic island extraction will be the focus of further research.
Thank You