INTEGRATION OF TREE DATABASE DERIVED FROM SATELLITE IMAGERY AND LIDAR POINT CLOUD DATA

S. C. Liew\textsuperscript{1}, X. Huang\textsuperscript{1}, E. S. Lin\textsuperscript{2}, C. Shi\textsuperscript{1}, A. T. K. Yee\textsuperscript{2}, A. Tandon\textsuperscript{2}

\textsuperscript{1} Centre for Remote Imaging, Sensing & Processing, National University of Singapore, \textsuperscript{2} National Parks Board, Singapore

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NParks, SLA, IHPC, CRISP, GovTech, RoaData
Outline

• Background
• Methodology
• Result
• Conclusion
3D Tree Database

• 3D tree database provides essential information
  – tree species abundance
  – spatial distribution
  – tree height, crown size, diameter at breast height (DBH)

• 3D tree database can be used in
  – forest mapping
  – sustainable urban planning
  – 3D city modelling

• 3D tree database can be integrated from multiple data sources
  – field surveys
  – aerial imagery
  – passive and active remotely sensed data
    • Satellite Imagery
    • LIDAR point cloud data
Purpose

To propose an approach for integrating 3D tree information extracted from passive and active data into existing tree database

- Tree crowns identification and delineation from Lidar Point Cloud data
- Tree crowns identification and delineation from Satellite Imagery
- Integration with 3D tree database
Methodology

1. Tree crowns identification and delineation from LIDAR point cloud data
   - Canopy Height Model (CHM) generation
   - Tree crowns identification and delineation

2. Tree crowns identification and delineation from Worldview-2 Satellite Image
   - Image bands
     - 8 multispectral bands - 2m/pixel
     - Coastal blue, blue, green, yellow, red, red edge, nir, nir2
     - Panchromatic band – 0.5m/pixel
   - Conversion (reflectance)
     - converted to the top-of-atmosphere band-average spectral radiance
       - Correction of effective bandwidth difference
     - converted to the top-of-atmosphere band-average spectral reflectance
       - Geometric correction: Earth-sun distance, solar zenith angle
       - Atmospheric correction
   - Orthorectification
     - Geometric transformation - camera model
     - Fine DEM
Methodology – 2. Tree crown extraction from WV2

- **Pansharpen**
  - Preserves both spectral fidelity of the multispectral bands
  - Preserves spatial resolution of the panchromatic band (0.5 m/pixel)
  - Easier for crown separation
  - Easier for species identification

- **Multi-resolution segmentation**
  - Divide image layers to relatively homogenous objects
    - Spectral and spatial/contextual properties

- **Classification**
  - Generate Indices
    - Ndvi, brightness, green index, etc.
  - Separate classes according to the indices and image layers
    - Trees
    - Non-trees (grass/buildings/roads/water/bare soil, etc.)
Methodology – 2. Tree crown extraction from WV2

– Watershed transformation
  • Watershed refers to a ridge that divides areas drained by different river systems
  • Watershed transformation treats the image like a topographic map, with the brightness of each point representing its height, and finds the lines that run along the tops of ridges
  • Local intensity minima (maxima) are used as seed objects, and the objects grow with rising intensity levels into the neighbourhood until they touch objects growing from neighbouring seeds.
  • separate objects from the background, as well as from each other

– Morphology filter
  • Opening/closing, dilution/erosion
  • Smooth the shape

– Region growing
  • Remove holes
  • Fill gaps between trees

– Shape optimization
  • Generate circles as tree crown
    – radius from area
    – Center of mass/gravity

Opening operation of the morphology algorithm
Tree crowns identification and delineation from CHM
Methodology - Tree crowns identification and delineation from WV
Tree crowns (cyan) detected from CHM (grey)
Tree crowns from CHM + Tree Database (NParks, red dots)

- 866 trees from CHM, 182 in database (174 detected, 8 undetected)
- Match well for locations
- More trees from CHM
Individual trees delineated from WV2 (transparent outline objects)
Tree crowns (red) detected from WV (R/G/Y)

- Tree tops are marked
- The higher the tree, the further the base
Accuracy assessment for trees extraction from WV2 satellite imagery

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual trees</td>
<td>815</td>
</tr>
<tr>
<td>Detected trees</td>
<td>844</td>
</tr>
<tr>
<td>Falsely detected trees</td>
<td>51</td>
</tr>
<tr>
<td>Undetected trees</td>
<td>22</td>
</tr>
<tr>
<td>Omission error</td>
<td>3 %</td>
</tr>
<tr>
<td>Commission error</td>
<td>6 %</td>
</tr>
<tr>
<td>Producer’s accuracy</td>
<td>97 %</td>
</tr>
<tr>
<td>User’s accuracy</td>
<td>94 %</td>
</tr>
</tbody>
</table>

Omission error = number of undetected trees / actual trees
Commission error = number of falsely detected trees / total detected trees
Integration of tree database
Tree crowns from CHM (cyan) + WV (red) : not match well

- Base for CHM, top for WV (sat_el ~ 64°)
Methodology – 3. Integration of Tree Database

3. Integration of tree crowns from CHM and WV

- Camera model of Worldview-2
- Crowns of CHM are transformed from base positions to their respective crown top positions on the orthorectified image
- Finding the height of trees of WV
- Crowns of WV are transformed from top positions to their respective base positions on the orthorectified image
Transformation of tree crown from top to base position
- Camera Model (Rational Polynomial Coefficients) of WV-2

- \( P = (\text{Latitude} - \text{LAT\_OFF}) / \text{LAT\_SCALE} \)
- \( L = (\text{Longitude} - \text{LONG\_OFF}) / \text{LONG\_SCALE} \)
- \( H = (\text{Height} - \text{HEIGHT\_OFF}) / \text{HEIGHT\_SCALE} \)
- \( r_n = (\text{ROW} - \text{LINE\_OFF}) / \text{LINE\_SCALE} \)
- \( c_n = (\text{Column} - \text{SAMP\_OFF}) / \text{SAMP\_SCALE} \)

\[
\begin{align*}
    r_n &= \frac{\sum_{i=1}^{20} \text{LINE\_NUM\_COEF}_i \cdot p_i(P, L, H)}{\sum_{i=1}^{20} \text{LINE\_DEN\_COEF}_i \cdot p_i(P, L, H)} \\
    c_n &= \frac{\sum_{i=1}^{20} \text{SAMP\_NUM\_COEF}_i \cdot p_i(P, L, H)}{\sum_{i=1}^{20} \text{SAMP\_DEN\_COEF}_i \cdot p_i(P, L, H)}
\end{align*}
\]

\[
f(P, L, H) = C_1 + C_2 L + C_3 P + C_4 H + C_5 LP + C_6 LH + C_7 PH + C_8 L^2 + C_9 P^2 + C_{10} H^2 + \\
C_{11} PLH + C_{12} L^3 + C_{13} LP^2 + C_{14} LH^2 + C_{15} L^2P + C_{16} P^3 + C_{17} PH^2 + C_{18} L^2H + C_{19} P^2H + \\
C_{20} H^3
\]

Map \( (L, P, H) \) → Image \( (c, r) \)
Camera Model (RPC) of WV-2

- Map coordinates to image coordinates for top and base points

Top: \((lat, lon, h + h_b) \xrightarrow{RPC} (l, s)\)

Base: \((lat, lon, h_b) \xrightarrow{RPC} (l_b, s_b)\)

\((lat, lon) \xrightarrow{DEM} (h_b)\)

- Any point in the ray of light shares the same pixel in the image
  - For crown top of WV, the base can’t be derived as height is unknown.
  - For crown of CHM, the pixel position for tree top in the satellite image can be derived using RPC.
Tree crowns from CHM shifted to WV geometry (yellow) + WV (red) : match well

- Since height of trees from WV is not known, trees can’t be shifted from top to base
- Since height of trees from CHM is known, trees can be shifted from base to top to match geometry of WV
- Height of trees from WV can be estimated using weighted average (area) of CHM
Height of trees from WV - derived by weighted average of CHM

\[ H_{wv} = H_{chm} \]

\[ H_{wv} = (H_{1chm} A_1 + H_{2chm} A_2) / (A_1 + A_2) \]

Height is derived by weighted average
Tree crowns from CHM (yellow) + WV shifted to base location (magenta) : match well
Tree crowns from CHM (yellow) + WV shifted to base location (magenta) : match well

- Camera model is applied
- Height is derived from weighted average of CHM
- Some trees can't be shifted to base due to lack of common area (marked separately)
Conclusion

• Both the automated methodologies of individual tree crown detection and delineation from CHM and WV2 are presented;
• Tree crowns from WV2 are geometric corrected from the top to base location;
  – Tree crowns from CHM are geometric transformed to the satellite image to match the crowns extracted from the WV2 using the satellite camera model;
  – The height of tree crowns from WV2 can be derived from the height of CHM.
• The result shows that tree crowns from CHM and WV2 match very well;
• Accuracy assessment for tree crowns is performed with ground truth data and visual examination. An overall accuracy around 96% is achieved.
• Tree crowns from both CHM and satellite data with attributes of position, crown size can be integrated into the existing tree database.
Thank you!