The Digital Forest

Geospatial Technologies in Urban Forest Management

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Why Measure a Tree?

• Determine annual growth
• Determine value
  – CTLA
  – STEM
• Find champions
  = Trunk Circumference
    + Height
    + $\frac{1}{4}$ Avg Crown Spread

Photo credit: Brad Cadwallader
How do we measure trees?

• Diameter (DBH)
  – Tape, calipers

• Height
  – Height pole, clinometer, vertex, tape drop

• Crown diameter and depth
  – Tape measure

• We’ve been measuring this way for a long time!
Problems with Girth

• Simple measures can still be complex
  – Because trees are complex

• Even DBH not universally accepted

• Tape method converts circumference to diameter
  – Assumes a circular tree
Problems with Height

- Finding ‘true’ top of tree is challenge
- Estimation methods applied incorrectly

\[ HT = b \times \tan(A) + b' \times \tan(A') \]

\[ HT = c \times \sin(A) + c' \times \sin(A') \]
Problems with Current Techniques

• ‘False’ champions
• ENTS shows examples of errors of up to 54%!
• 58m Hickory actually 37.5m
• 54.5m Maple actually 36.5m
• 45m Ginkgo actually 30m

Photo credit: Brad Cadwallader
Problems with Current Techniques

• Benefits rely on total volume:
  – Carbon sequestration, air pollution removal, climate moderation

• Volume only by allometric equations
New Approaches - TLS

- Terrestrial laser scanning - aka LiDAR
- Specialised transmitter/receiver of laser pulses
- Glorified range finder
New Approaches - TLS

- Each pulse has an XYZ coordinate
- Calculate distance b/w points for height, diameter
New Approaches - TLS

- Create an envelope covering the extent of the points
- Allows non-destructive estimates: stem, crown volume
TLS Street Tree Inventory
New Approaches - SfM

- Structure from Motion
- Used in video games, movies
- Create 3D models of objects
TLS and SfM – Accuracy Assessment

• Great technologies, but do they work?
  – TLS can produce highly accurate (> 95%) estimate of diameter
    • Height and volume are less accurate, but promising
  – SfM can produce highly accurate (> 95%) estimates of diameter and height
    • Volume is currently untested

• Will they replace traditional methods?
Why Measure the Urban Forest?

• Resource assessment
  – Budgeting, planning
• Species, size, and age-class distributions
  – Minimise problems associated with geriatric forests, pests
• Quantify Benefits:
  – Timber volume
  – Air pollution removal
  – Carbon sequestration and storage
  – Building energy use savings
  – Stormwater attenuation
  – Water quality
How do we measure the UF?

• Measure every tree?
  – How many trees in the UF?

• Sampling
i-Tree

Use easily measured attributes to estimate complex metrics

# trees, size, species allow us to estimate leaf area and biomass

Use leaf area and biomass to estimate values
# Case Study: Chicago Summary

<table>
<thead>
<tr>
<th>Feature</th>
<th>Measure</th>
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<tbody>
<tr>
<td>Number of trees</td>
<td>3,585,000</td>
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<tr>
<td>Tree cover</td>
<td>17.2%</td>
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<tr>
<td>Most common species</td>
<td>white ash, mulberry, green ash, tree-of-heaven</td>
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<tr>
<td>Percentage of trees &lt; 6-inches diameter</td>
<td>61.2%</td>
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<tr>
<td>Pollution removal</td>
<td>888 tons/year ($6.4 million/year)</td>
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<tr>
<td>Carbon storage</td>
<td>716,000 tons ($14.8 million)</td>
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<tr>
<td>Carbon sequestration</td>
<td>25,200 tons/year ($521,000/year)</td>
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<tr>
<td>Building energy reduction</td>
<td>$360,000/year</td>
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<tr>
<td>Increased carbon emissions</td>
<td>-$25,000/year</td>
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<tr>
<td>Structural value</td>
<td>$2.3 billion</td>
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Ton – short ton (U.S.) (2,000 lbs)
Problems with Current Techniques

• Require huge manual effort
  – expensive

• Sampling is always wrong
  – How do we know if we sampled enough?
  – How do we know our sample is representative?

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New Approaches - ALS

• Aerial laser scanning (aka LiDAR)
  – Uses laser pulses to map the surface of the earth
• Can give vertical structure of tree canopy
New Approaches – Satellite Imagery

- Multispectral
  - Easily identifies vegetation
  - Can ‘see’ stress
Image Classification
ALS and Satellite Imagery

- Can measure WHOLE urban forest
  - Not limited by sampling
  - Not limited by property boundaries
- Efficient measurements of tree canopy cover
- Tree counting, species differentiation, and 3D structural measurements are improving
The Digital Forest

- Traditional measurements are simple and trusted
- If applied incorrectly, high level of error
  - Can cause inaccuracy in resource assessment, budgeting, calculation of benefits
- New approaches are still emerging, but show great promise
- NZ could have world’s first national urban forest map