Detecting trees in an urban environment using airborne LiDAR and GIS

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Andrew Plowright
M.Sc. Candidate
University of British Columbia
plowright.andrew@gmail.com
Outline

- The importance of urban forests
- Uses of LiDAR in forestry
- Adapting existing techniques to an urban context
- Leveraging municipal GIS databases
The urban forests

Key benefits

- Reduces energy costs
- Improves air quality
- Prevents runoff and erosion
- Provides habitat for wildlife
- Adds aesthetic value
- Increases property value
Will Toronto's ambitious push to grow its urban canopy pay off?

Kat Seniuc
The Globe and Mail
Published Friday, Aug. 08 2014, 5:22 PM EDT
Last updated Friday, Aug. 08 2014, 5:55 PM EDT

If you take down a tree in Toronto, you’ll be required to plant new trees to replenish the urban forest. But how many saplings does it take to fill the place of a mature tree?

That’s a crucial question for those trying to maintain Toronto’s urban forest, where new trees frequently replace those being removed for construction or lost to disease. “If you took down an 80-year-old tree, it’s going to take 80 years to grow a new tree back to replace that,” said Ian Bruce, an arborist and owner of Bruce Tree Expert Company.

And yet the City of Toronto is committed to that near-impossible task for many thousands of trees. The urban forest is an important part of the city’s identity, and city hall has made a formal commitment to increasing the number of trees – citing their environmental benefits as well as their positive impact on the city’s streetscapes.

This means battling a series of threats to the canopy, including mistreatment of older trees and the removal of some for new development. If Toronto is a “city in a park,” the health of its green canopy is unclear.

There are about 10 million trees of at least 116 different species in Toronto: 60 per cent grow on private property, 34 per cent are found in parks and only 6 per cent are owned by the city.

Sources: The Globe and Mail, City of New York
Le programme de plantation est un échec

Près de 183 000 arbres ont été plantés entre 2005 et 2009, à Gatineau. Le problème, c’est que la plupart des pousses ont péri, constate Simon St-Pierre dans un essai présenté au centre universitaire de formation en environnement de l’Université de Sherbrooke.

SIMON SÉGUIN-BERTRAND, LEDROIT

PATRICK DUQUETTE
Le Droit

Le programme de plantation de 100 000 arbres est un échec à Gatineau. À peine une fraction des arbres a survécu, conclut une étude réalisée sur le terrain par un étudiant à la maitrise en environnement de l’Université de Sherbrooke.

DU MÊME AUTEUR
Une tape sur les doigts
Occasion ratée
Maxime Pedneaud-Jobin, le joueur d’échecs
Une pensée pour Kobané
L’image de la guerre

Pierre angulaire de la plate-forme électorale du maire Marc Bureau en 2005, la plantation de 100 000 arbres devait revoir la Ville de Gatineau et mobiliser les citoyens autour d’un projet environnemental. Du strict point de vue du nombre, le programme est un succès. Près de 183 000 arbres ont finalement été plantés entre 2005 et 2009. Le problème, c’est que la plupart des pousses ont péri, constate Simon St-Pierre dans un essai présenté au centre universitaire de formation en environnement de l’Université de Sherbrooke.

Gatineau, QC

183,000 trees planted

Three years later, survival rate: 5%

Source: Le Droit
Welcome to Surrey, BC

- One of Canada’s fastest growing cities
- Manages 75,000 trees on city property
- Spends C$750,000 a year on watering alone

Photo: City of Surrey
Light Detection And Ranging

LiDAR

- High precision three-dimensional measurements
- Operationalized use in commercial forestry
- Acquired over Surrey in 2013
- High density: \(25 \text{ pts/m}^2\)
Objectives

- Adapt LiDAR tree detection and crown delineation techniques to an urban context
- Examine the potential for data fusion between the city’s GIS database and airborne LiDAR data
- Evaluate the health of urban trees
We need to...

- **Locate** trees
- Define their **spatial extent**
We start with the raw elevation points.

We then extract a digital terrain model, which represents the elevation of the underlying surface.

The digital terrain model is then subtracted from the raw data to give us the height of the canopy.
RAW LIDAR DATA
Imagery

Canopy height model

(Pixels unders 1.5 m masked out)
Watershed segmentation

Images: Chen et al., 2006
Watershed segmentation
PROBLEM: The canopy is clearly **oversegmented**.
How do we locate tree tops?

Photo: Alfred Molon
How do we locate tree tops?
- Cell is tagged as a **tree top** if it is the **highest** within its circular search window.

- **Window size** is calculated using the **height** of the cells.

- Based on the relationship between **tree height** and **crown width**.
VARIABLY-SIZED SEARCH WINDOW

MARKER-CONTROLLED SEGMENTS

\(\bullet\) = Tree top
Tree detection and crown delineation algorithms are developed for **natural** or **semi-natural** forest structure

**Urban forest composition:**

- Wide range of **species**
- Multiple **age classes**
- Presence of buildings, powerlines, etc.
### Tree inventory

- Coordinates of all trees maintained by the city
- Information on:
  - Species
  - Planting date
  - Location (boulevard, park, median, pathway, etc.)

#### GIS database

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Imagery: Google
Opportunity

- **Leverage** GIS data

- Apply algorithms locally: “seeding”

- Algorithms are **recalibrated** at each iteration based on tree’s characteristics
**SPECIES**: Western redcedar

**AGE**: 15 years
Large trees, open area

Small trees, open area

Overshadowed trees

Imagery: Google
Results

- Tested against **128** manually delineated *reference trees*
- Successfully detected **94%** of reference trees
- Average similarity ratio of **66%**
Next steps

- Use tree outlines to **extract tree metrics** from raw data
- Tree **height, density, exposure** to the sun
- Evaluate **tree health**
- Map **patterns** of tree health
- Investigate **causes** of tree stress
Conclusion

- Great **potential** for LiDAR in urban forestry
- **Fusion** with GIS data offers opportunities to augment analysis
- Allow city managers to take advantage of **remote sensing technology**
PROJECT FUNDING
City of Surrey
NSERC

SCHOLARSHIPS
University of British Columbia
   Strategic Recruitment Fellowship
ESRI Canada
   Higher Education Scholarship
Canadian Wildlife Federation
   Orville Erickson Memorial Scholarship
Canadian Council on Ecological Areas
   Stan Rowe Home Place Award

KEY REFERENCES


THANK YOU
Andrew Plowright
M.Sc. Candidate
University of British Columbia
plowright.andrew@gmail.com

Dr. Nicholas Coops
Supervisor
University of British Columbia
nicholas.coops@ubc.ca