FIG WORKING WEEK 2017
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From digitalisation to augmented reality
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3D Modeling of Urban Tree Crown Volumes Using Multispectral LiDAR Data

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- http://scsc.xmu.edu.cn/

Outline

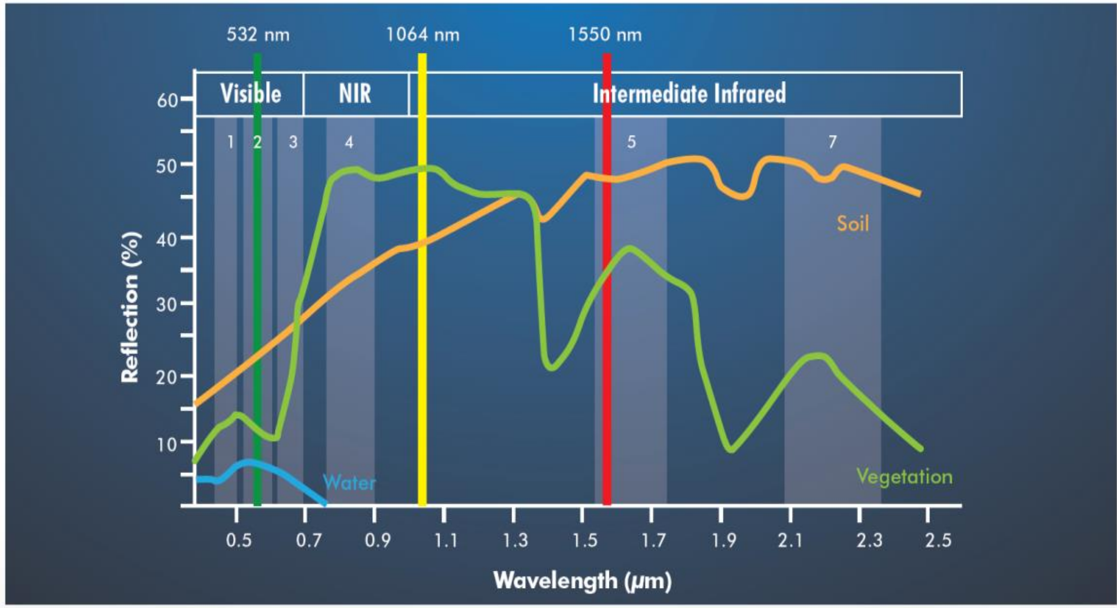
- Introduction
- Objectives
- Methodology
- Results and Discussion
- Concluding Remarks
- Our Software Solution

Introduction: Motivation of the Study

How to measure **urban tree crown volumes?**

- Field Measurements
  Expensive and time consuming
  Destructive

- Remote Sensing Techniques
  Multispectral imagery
  Airborne LiDAR or ALS
  Multispectral ALS



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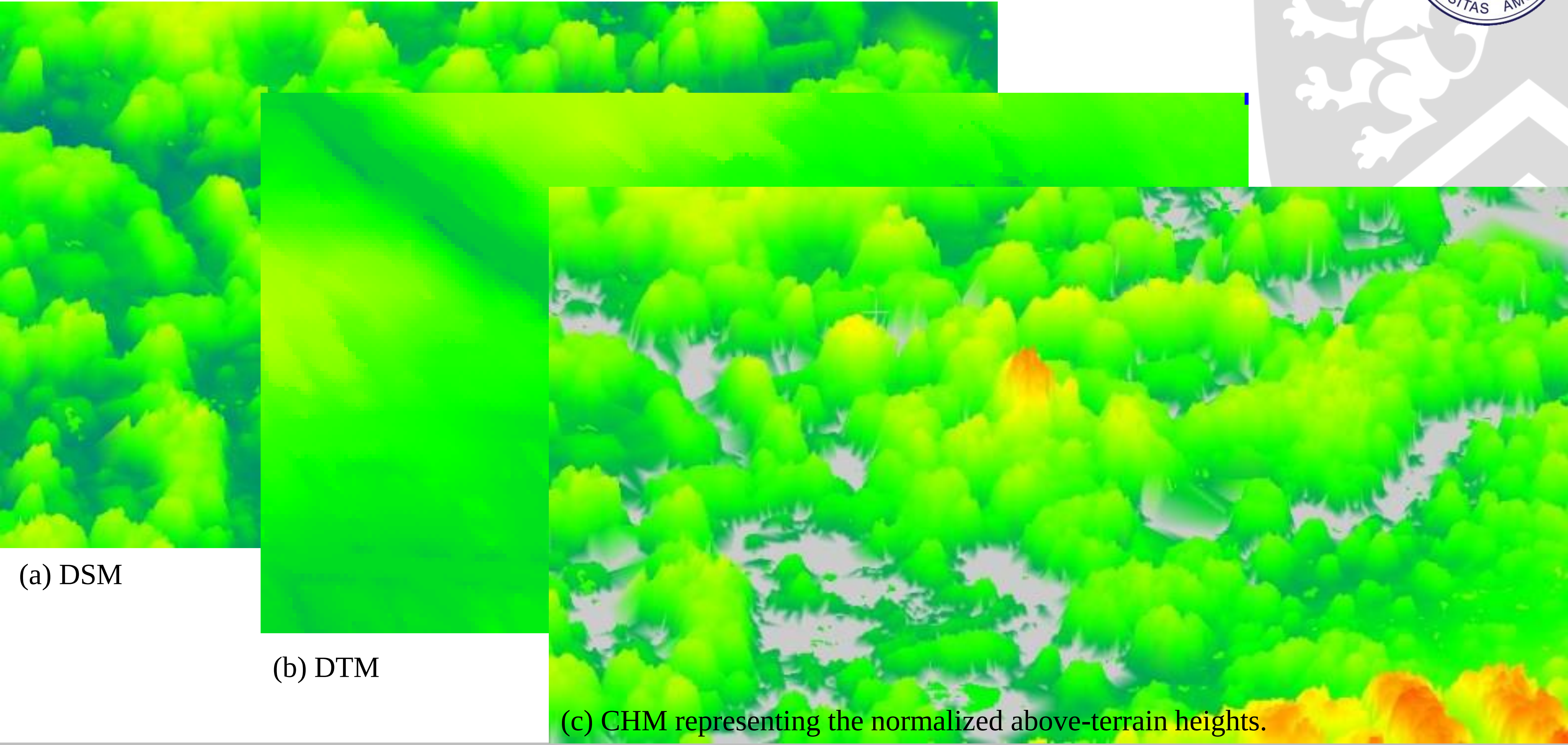
Introduction: ALS-derived products



(a) DSM

(b) DTM

(c) CHM representing the normalized above-terrain heights.

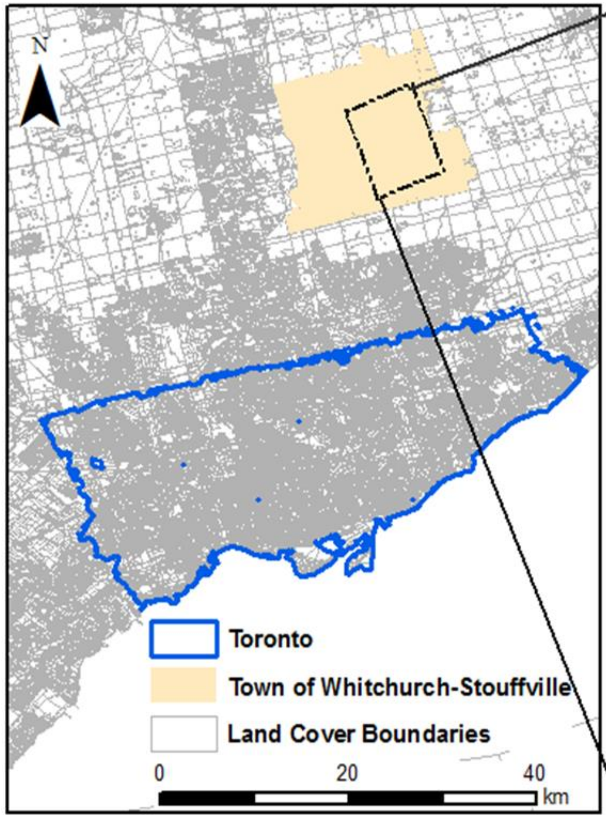
Objectives

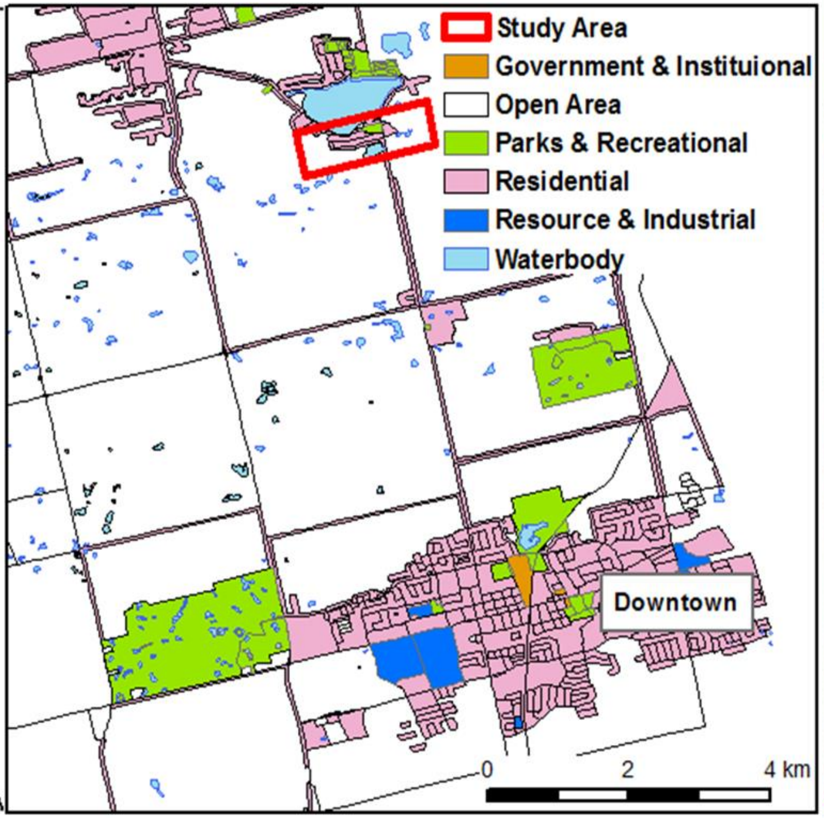
To develop a workflow that can create **3D Models of Urban Tree Crown Volumes** using multispectral ALS data.

- to classify vegetation covers in urban areas using multispectral ALS ranging and intensity data and the land cover classifier;
- to derive dendrometric parameters such as tree height and crown diameter from the multispectral ALS data;
- to establish allometric relationships between the ALS-derived measurements (tree height and crown width) and the field-measured diameter at breast height (DBH).

Study Area & Data Sources

- **Study area**, Titan multispectral LiDAR datasets, field measurements





Data Providers: DMTI Spatial Inc.; Google & First Base Solutions

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Titan Multispectral LiDAR Datasets

Number of ALS strips	2
Laser channels	1550 nm; 1064 nm; 532 nm
Flight of View (FOV)	30°
Pulse repetition frequency	100 kHz per channel
Flight Height	1030 m; 1043 m
Average Point Density	7.7 points/m^2
Average Point Spacing	0.8 m/point

Three laser channels at wavelength of
1550 nm (shortwave infrared, SWIR), 1064 nm (near infrared, NIR), 532 nm (green)

Field Measurements

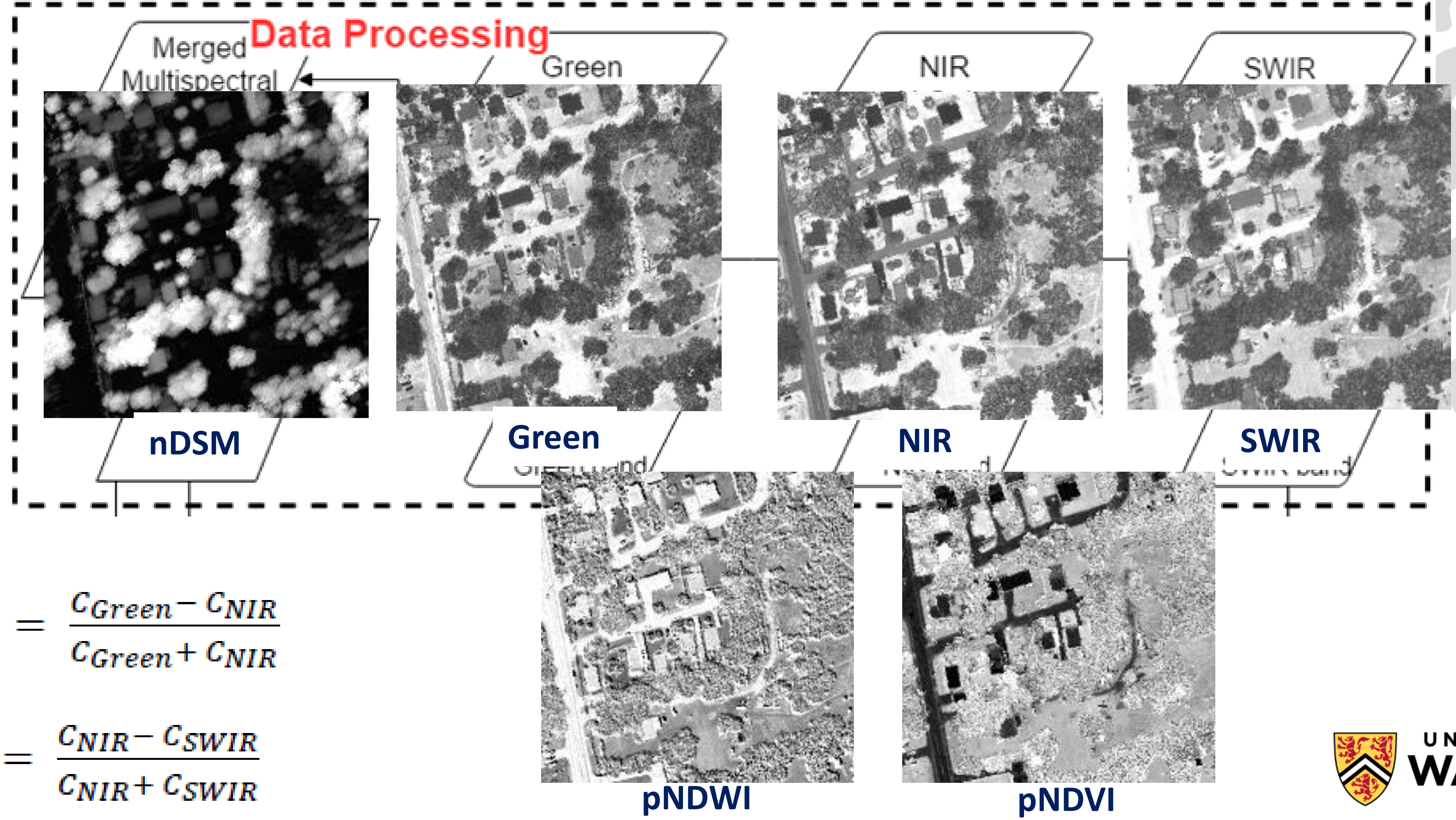
	Height (m)	Crown Width (m)	DBH (cm)
Maximum	26.90	16.57	98.0
Minimum	9.70	4.64	27.0
Mean	17.48	9.11	48.8
Std	4.57	3.07	14.6

A total of 40 trees are selected from the field Tree heights were measured using a hypsometer. DBH was measured with a diameter.

Methodology

- ALS data processing
- Vegetation isolation
- Dendrometric parameter estimation
- Allometry-based ALS-DBH modeling

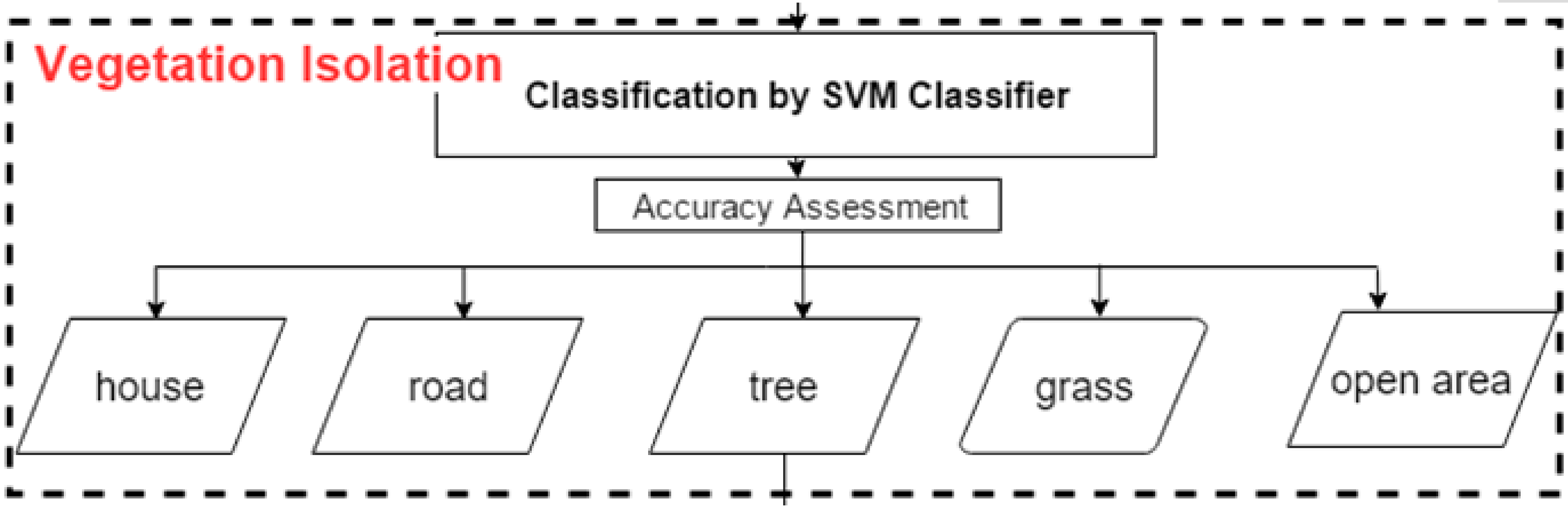
Step 1: ALS Data Processing



$$pNDWI = \frac{C_{Green} - C_{NIR}}{C_{Green} + C_{NIR}}$$

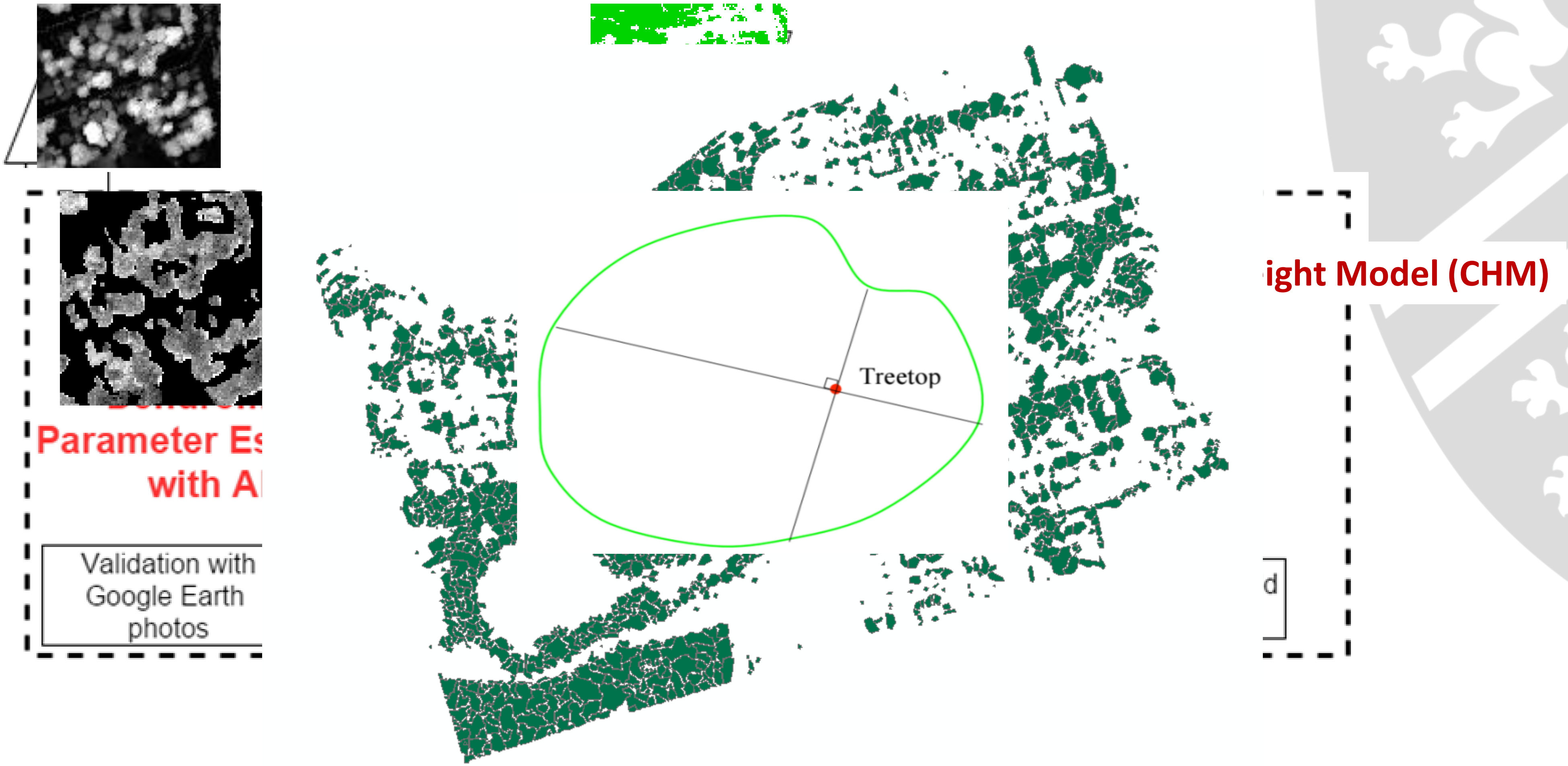
$$pNDVI = \frac{C_{NIR} - C_{SWIR}}{C_{NIR} + C_{SWIR}}$$

Step 2: Vegetation Isolation



Combinations of input data for SVM classification	
Selection 1	Green + NIR + SWIR + nDSM + pNDWI + pNDVI
Selection 2	Green + NIR + SWIR + nDSM
Selection 3	NIR + nDSM

Step 3: Dendrometric Parameter Estimation



Step 4: Allometry-based ALS-DBH modeling

- A multiple linear regression model was developed empirically to predict the DBH by the ALS-derived tree height and crown width.

$$\mathrm{DBH}_{Field} = a \cdot CD_{ALS} + b \cdot H_{ALS} + c$$

$$a = \frac{(\sum H_{ALS}{}^2)(\sum CD_{ALS} \cdot DBH_{Field}) - (\sum CD_{ALS} \cdot H_{ALS})(\sum CD_{ALS} \cdot DBH_{Field})}{(\sum CD_{ALS}{}^2)(\sum H_{ALS}{}^2) - \sum CD_{ALS} \cdot H_{ALS}{}^2}$$

$$b = \frac{(\sum CD_{ALS}{}^2)(\sum H_{ALS} \cdot DBH_{Field}) - (\sum CD_{ALS} \cdot H_{ALS})(\sum H_{ALS} \cdot DBH_{Field})}{(\sum CD_{ALS}{}^2)(\sum H_{ALS}{}^2) - \sum CD_{ALS} \cdot H_{ALS}{}^2}$$

$$c = \overline{DBH} - a \cdot \overline{CD}_{ALS} - b \cdot \overline{H}_{ALS}$$

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Results and Discussion

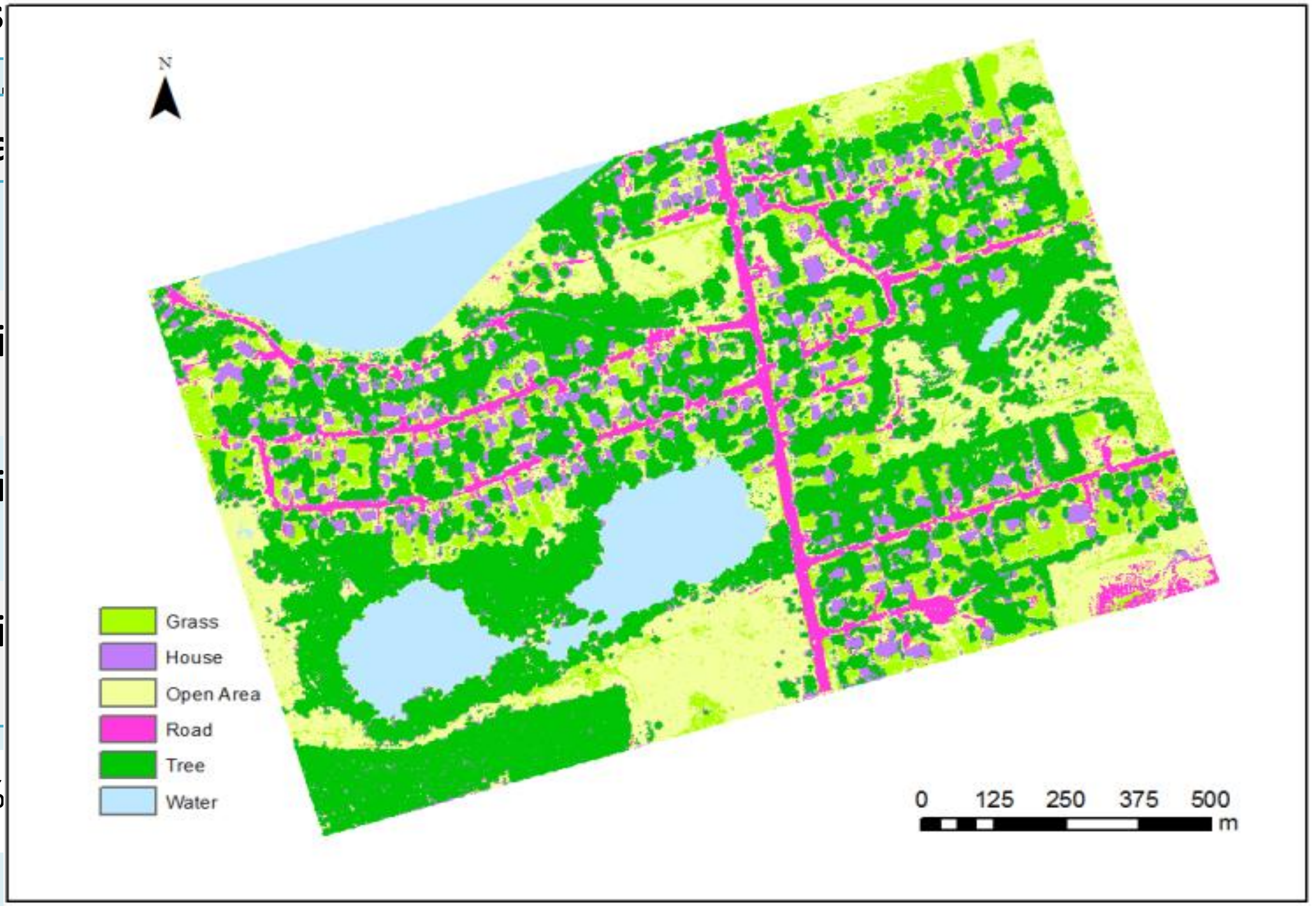
- Accuracy assessment of the classification results
- Performance of the watershed segmentation
- Validations for the ALS-derived dendrometric parameters
- Validation of the ALS-DBH linear regression modeling

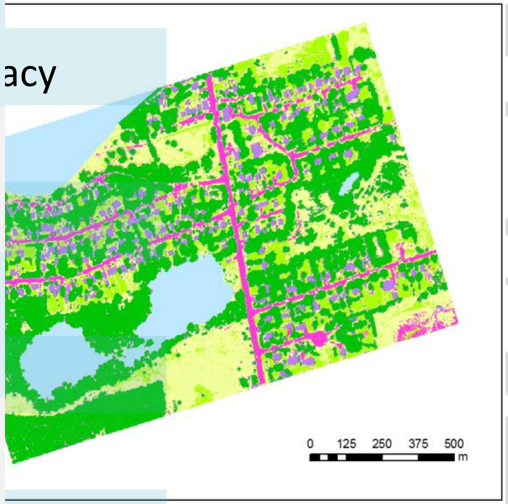
Assessment of Classification Accuracy

Confusion Matrix for the Clas

	Accura	
Classified Pixels		acy
Grass	Selecti	
Tree		
House	Selecti	
Road		
Open Area	Selecti	
Total		
Producer's Accuracy	83.19%	

Overall Accuracy = 90.23%





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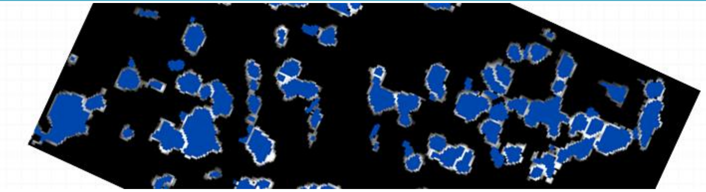
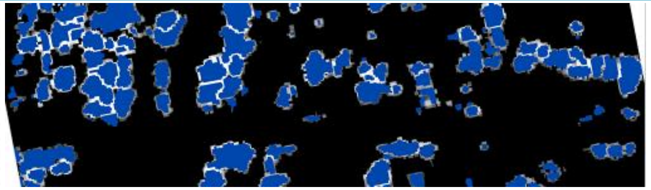
Performance of Watershed Segmentation

Evaluations of the segmentation result		
	Site1	Site2
Reference		
Segmentation Results		
$N_{1,1}$	49	80
Total	65	114
Accuracy	75.4%	70.2%

$$\text{absolute accuracy}_{tree\ isolation} = \frac{n_{1,1}}{n_{total}}$$

Validations of ALS-derived Dendrometric Parameters

$$\text{Bias} = \frac{\sum_{i=1}^{n} X_{ALS,i} - X_{field,i}}{n}$$

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}(X_{field,i} - X_{ALS,i})^2}{n}}$$

$$\text{RMSE\%} = \frac{\text{RMSE}}{\bar{X}_{ALS}}$$

Validation statistics for the ALS-derived dendrometric parameters

Parameter	RMSE	RMSE%	Bias	Bias%
Height (m)	1.21	6.8%	-0.20	-0.1%
Crown Width (m)	1.47	16.4%	0.18	2%

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ALS-DBH Regression Models

Models for predicting

Model	# of training samples		l Equation
1	20		= 4.12 - 0.03 × CD + 2.51 × H
2	20		= -11.28 + (-0.30)× CD+ 3.26 × H
3	20		= 4.37 + (-0.38) × CD + 2.59 × H
4	20		= -3.52 + 0.62 × CD + 2.70 × H
5	20		= 7.28+ (-0.16) × CD + 2.41 × H
6	20		= -13.15 + 0.05× CD+ 3.43 × H

Results of model fitting and model validation

Model	Model Fit R^2	Model Fit RMSE (cm)	Validation R^2	Validation RMSE (cm)
1	0.83	5.35	0.80	6.82
2	0.86	6.60	0.76	5.60
3	0.86	3.86	0.71	8.25
4	0.75	7.89	0.77	4.82
5	0.78	5.59	0.85	6.55
6	0.81	7.00	0.83	5.20

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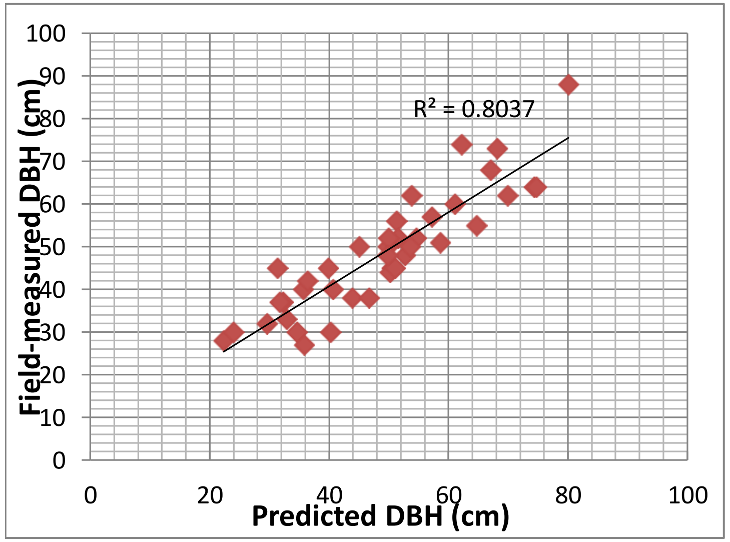
Validation of ALS-estimated DBH



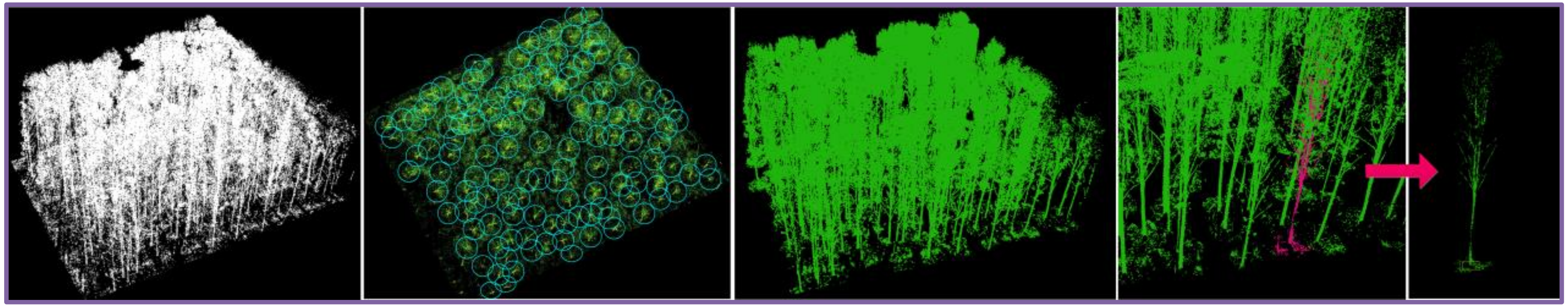
Accuracy of ALS-derived vs. field-measured results				
Parameter	RMSE	RMSE%	Bias	Bias%
DBH (cm)	6.39	13.1%	-0.44	-0.1%

Concluding Remarks

- A workflow for mapping a tree-covered urban area at the spatial resolution of 1 m was presented;
- A 90% land cover classification accuracy was achieved using multispectral ALS data;
- It was shown that the detection of treetops can be improved by the use of spectral and geometric properties of the multispectral ALS data;
- It was demonstrated that the DBH can be estimated using multispectral ALS data.
- Due to the scanning angle of ALS, the DBH cannot be directly measured using ALS compared with TLS or PLS.

Tree Scanning Using A TLS

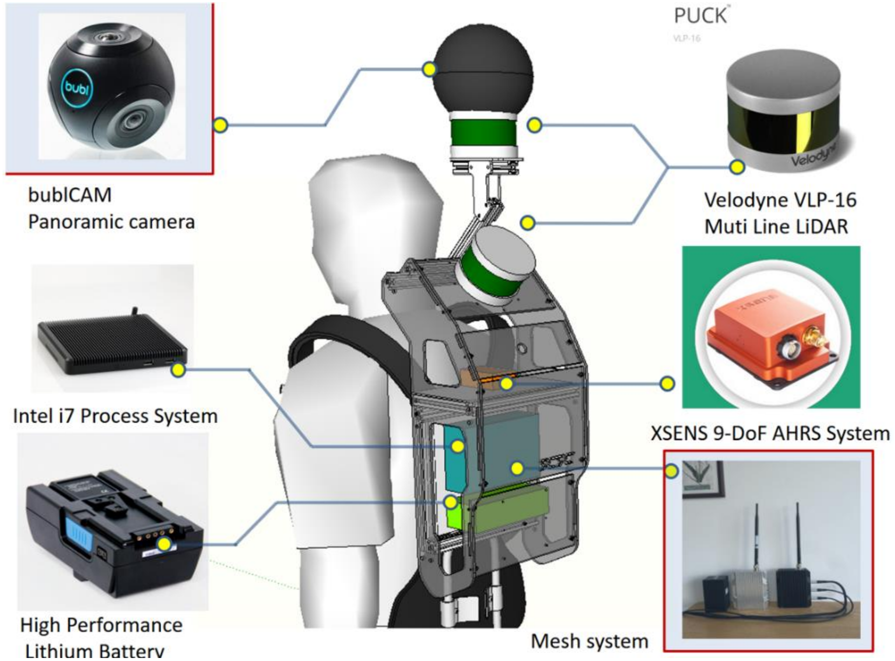
Four forest scenes covered by point clouds data I, II, III, and IV.
82.65 million points with a data size of **2.61 GB**.
427 individual trees manually counted as ground truth.

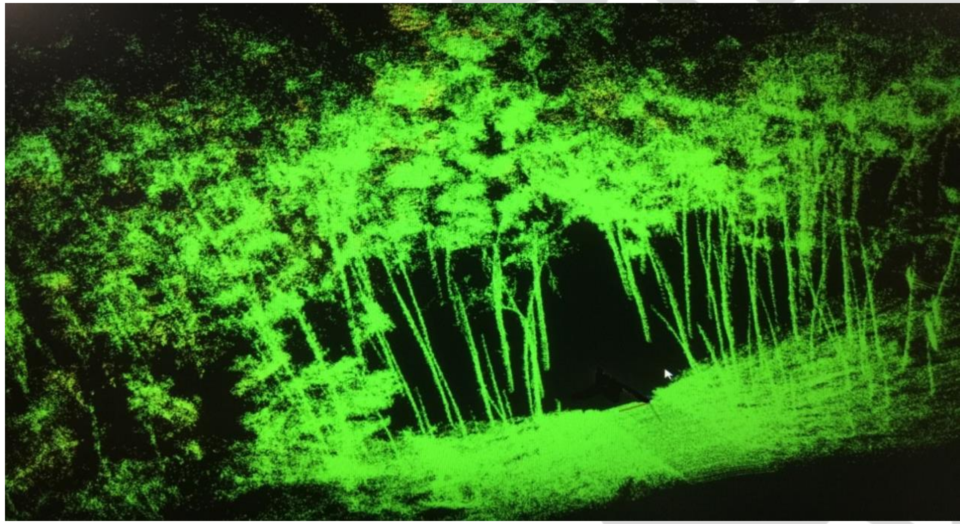


(a) (b) (c) (d)

Results of individual tree extraction: (a) original point clouds; (b)-(c) tree detection result in top view and side view; (d) individual tree extraction result.

Tree Scanning Using A Backpack PLS





Thank you for listening! Any questions?