Memorandum

CITY OF DALLAS

DATE October 22, 2009

TO Honorable Members of the Quality of Life Committee: Pauline Medrano (Chair), Vonciel Jones Hill (Vice Chair), Carolyn R. Davis, Angela Hunt, Sheffie Kadane, David A. Neumann, Steve Salazar

SUBJECT Urban Forestry Inventory Using Concurrent Airborne LiDAR & Hyperspectral Remote Sensing

On Monday, October 26, 2009, you will be briefed on the Urban Forestry Inventory. The briefing will be presented by Steve Houser, Chair of the Dallas Urban Forest Advisory Committee and Dr. Fang Qiu, Associate Professor at the University of Texas at Dallas. The briefing material is attached for your review.

If you have questions or need additional information, please let me know.

Forest E. Turner
Assistant City Manager

cc: Honorable Mayor and Members of the City Council
Mary K. Suhm, City Manager
Deborah A. Watkins, City Secretary
Thomas P. Perkins, Jr., City Attorney
Craig D. Kinton, City Auditor
Judge C. Victor Lander, Administrative Judge Municipal Court
Ryan S. Evans, First Assistant City Manager
A.C. Gonzalez, Assistant City Manager
Jill A. Jordan, P.E., Assistant City Manager
David K. Cook, Chief Financial Officer
Frank Librio, Public Information Office
Helena Stevens-Thompson, Assistant to the City Manager

Urban Forest Inventory Using LiDAR & Hyperspectral Images

- Larger existing trees provide 60-70 times the benefit of newly planted trees
- Highest priority in managing <u>any</u> urban forest is a complete tree inventory
- Traditional method of inventory involves volunteers surveying only public trees
- These methods were very labor intensive, time consuming and often inaccurate
- Since public trees comprise only 15-20% of the entire urban forest, the traditional method only provides a small part of the picture

Project History

- Since a traditional survey was not ideal, extensive researched was completed which included hyperspectral images (a new type of image)
- Dr. Fang Qiu was asked by the chair if the new images could be used for a complete tree inventory.
- “It may be possible…but it has never been done”
- Chair works diligently to convince others of the value by personally funding the field work portion of the project ($13K) and contributing almost a year of time
- Chair raises over $100K to complete the project
- Chair authorized the project to move forward lacking $30K of the required budget

Dallas on the “Cutting Edge”

- First complete tree inventory **ever** based on laser scanning and hyperspectral images using highly advanced computer algorithms
- New technology developed by Dr. Qiu and the chair which allows all tree inventory data to be easily accessed and utilized in making critical urban forest management decisions
- This is a **first** in the history of urban forestry in that someone can now effectively manage ALL trees (public & private) by simply sitting at their computer
- Hyperspectral images can also be used to manage water quality & quantity, street markings or light fixtures and many others relating to existing land cover management (grey & green infrastructure)

Cost and Next Steps

- The projected cost to complete all of the city is 1.25 million for collection and 1.25 million for processing
- When other city departments understand the potential use of the images in infrastructure management, the cost can be shared and become very economical
- As the use of hyperspectral images increases in the future, the cost will decrease
- Brief other departments on the potential uses
- Brief NCTCOG, EPA, Texas Forest Service and others to gain backing & financial support in completing a city & regional tree inventory & infrastructure mapping project

Urban Forestry Inventory using Concurrent Airborne LiDAR and Hyperspectral Remote Sensing

Fang Qiu

University of Texas as Dallas

Sponsored by

Dallas Urban Forest Advisory Committee

Outline

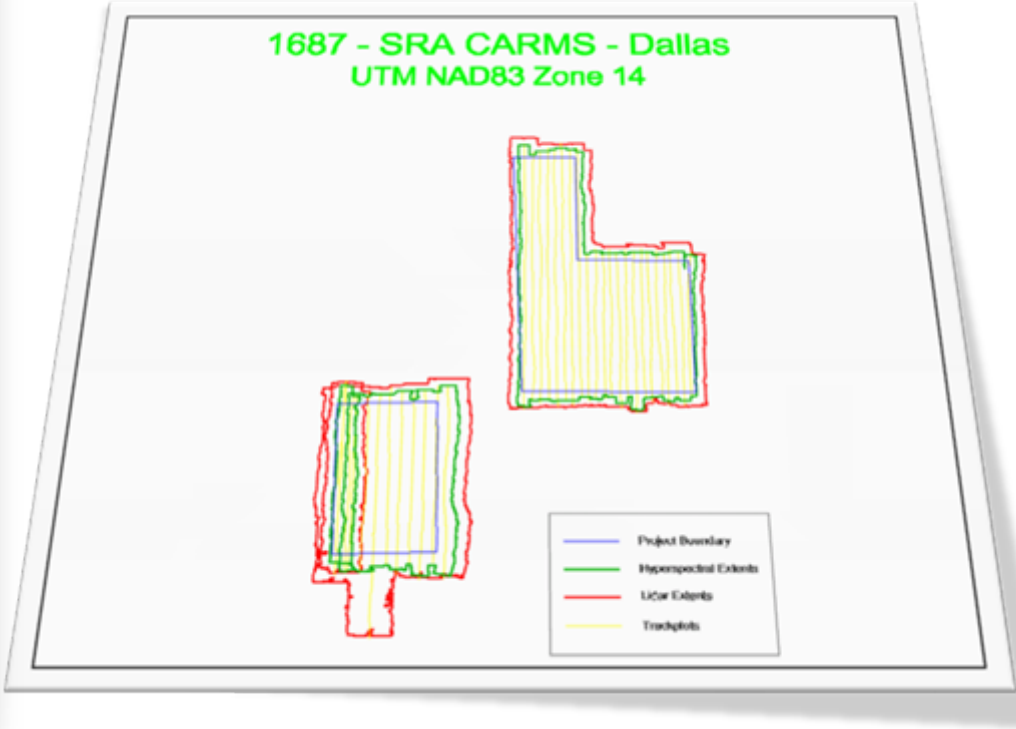
- Study area
- Remote Sensing Data Collection
  - LiDAR, Hyperspectral
- Field Data Collection and Analysis
  - In situ spectroradiometer data collection and analysis
  - Field tree specie, GPS location collection
- LiDAR Data Filtering
  - Segmentation and DTM generation
  - Ground/non-ground separation
- LiDAR Tree Mass Point Extraction
  - Hyperspectral NDVI

Outline

- Urban Tree Top (UTT) Identification
  - Tree Top Climbing
  - Tree height
- Urban Tree Canopy (UTC) Delineation
  - Donut Expanding and Sliding – Canopy Diameter
  - Base height, crown depth
- Urban Tree Species (UTS) Identification
  - Neuro-fuzzy classification
- Digital 3D Tree Canopy Model Construction
  - Individual Tree Modeling

Study Area

- City of Dallas
  - Two pilot study sites, with a total area of 20 square miles

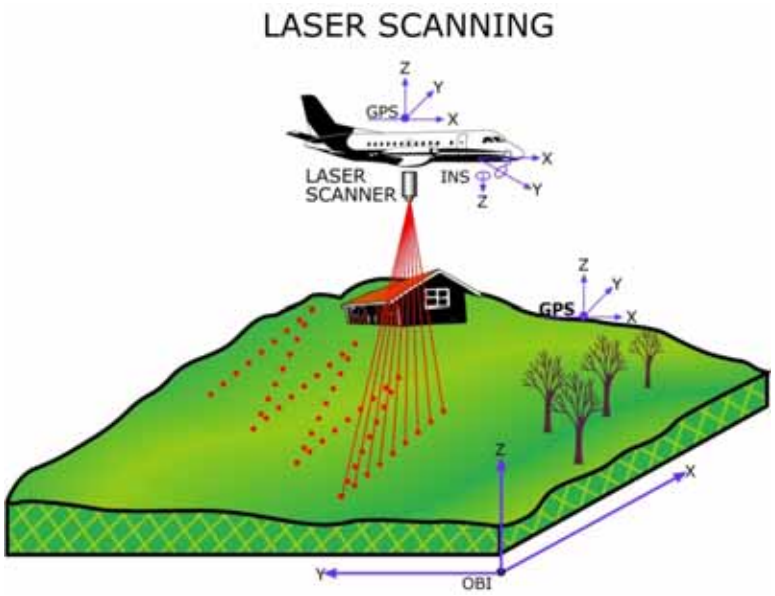


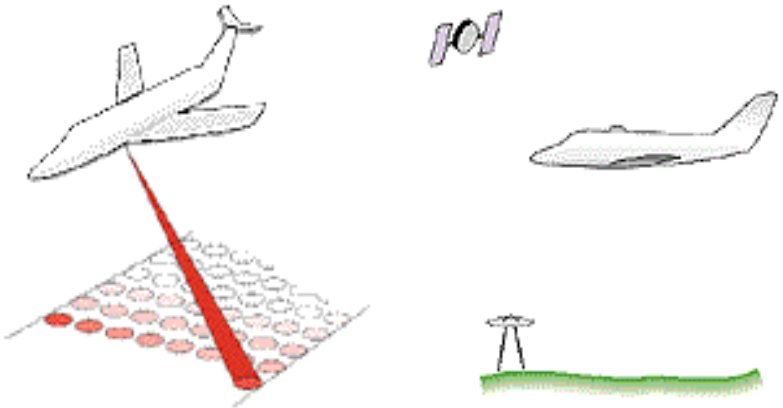
Remote Sensing Data Collection

- Terra Remote Sensing, Inc (TRSI)
  - Sydney, British Columbia, Canada
- Mission partner at University of Victoria
- Date: September, 23-24, 2008
- Aircraft Type: Piper Navajo
  - Altitude: 960 m and 1260 m
  - Flying air speed: 235km/hr
- Total Data Volume
  - Hyper-Spectral Imaging Data: 181 GB
    - Radiance (60.6 GB) +Reflectance (121 GB)
  - LiDAR Data: 3.4 GB
    - 64 GB after uncompressed

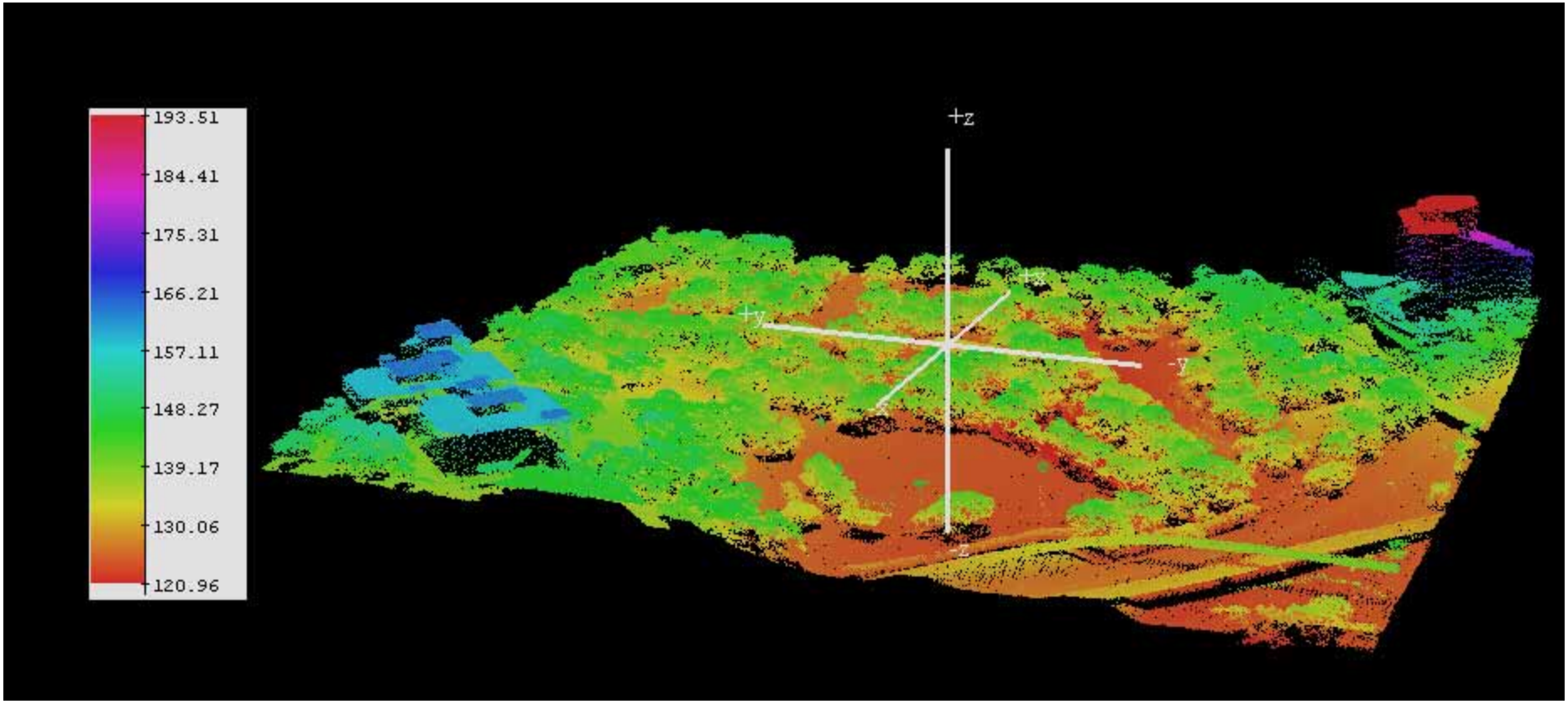
LiDAR Data

- Terrain Scanning Laser System
- LiDAR Point Cloud Density
  - (Average Spacing: $1/D^{1/2}$)
  - 9/23/2008: 2 pts/m^2 (0.7 m)
    - Due to overlap, 3.5 pts/m^2 (0.53 m)
  - 9/24/2008: 1.25 pts/m^2 (0.89 m)
    - Due to overlap, 2 pts/m^2 (0.7 m)
- %Overlap: 80
- Number of Returns: 2
  - First and Last Returns
- Bandwidth: 1064 nm
- Beam divergence: 0.45 mrad



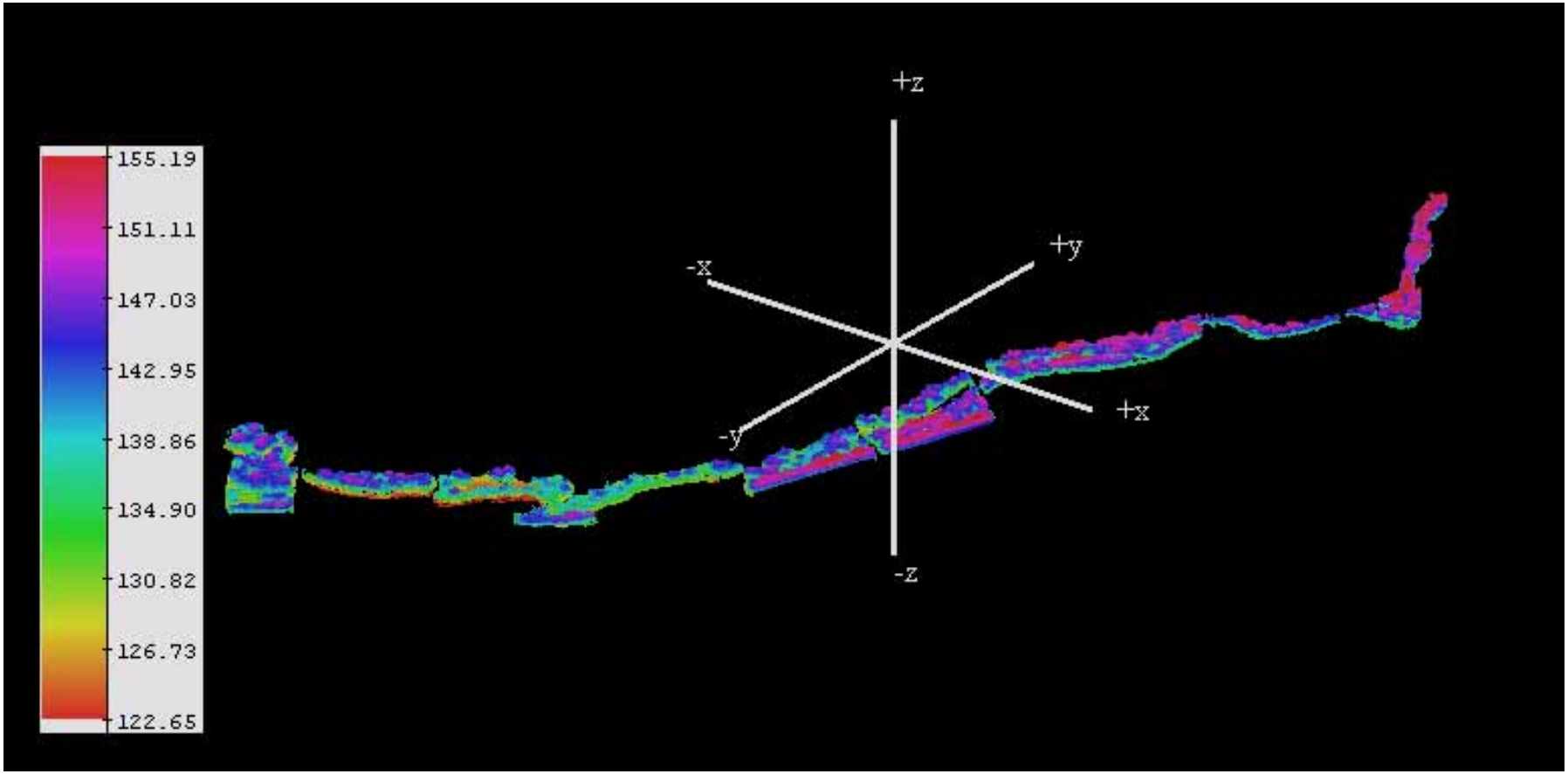


LiDAR Data



3D visualization of elevation of LiDAR points over the Reverchon park study area

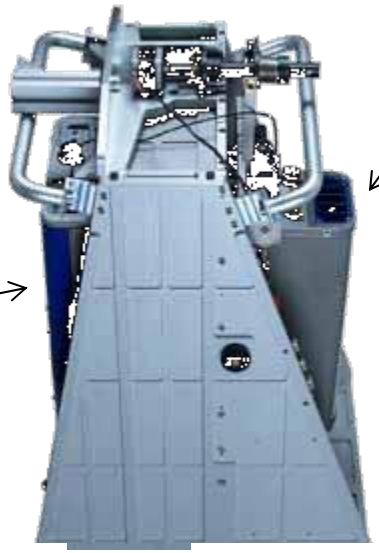
LiDAR Data: Turtle Creek Corridor

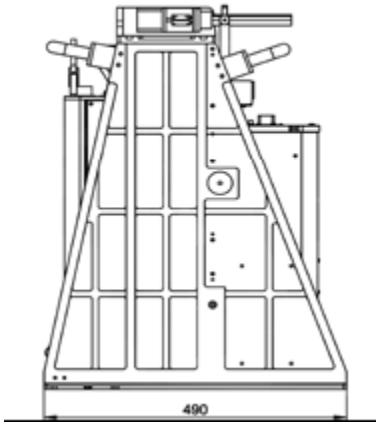


3D visualization of elevation of LiDAR points over the Turtle Creek Corridor

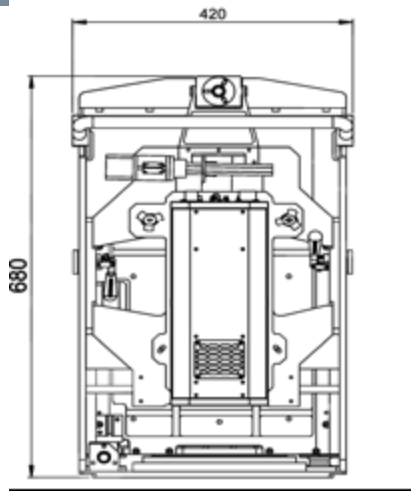
Hyper-spectral Imaging (HSI) Data

- **AISA DUAL HSI Sensor Spectral Imaging Ltd. Finland**
  - **Simultaneous acquisition of VNIR and SWIR data**
  - **AisaEAGLE (VNIR)**
  - **AisaHawk (SWIR)**
- **492 Band (400-2500 nm)**
  - **VNIR (400-970nm, 2.44 nm)**
  - **SWIR (970-2500nm, 6.28 nm)**
- **Spatial Resolution**
  - **9/23/2008: 1.2 m**
  - **9/24/2008: 1.6 m**
- **Sidelap: 22%**





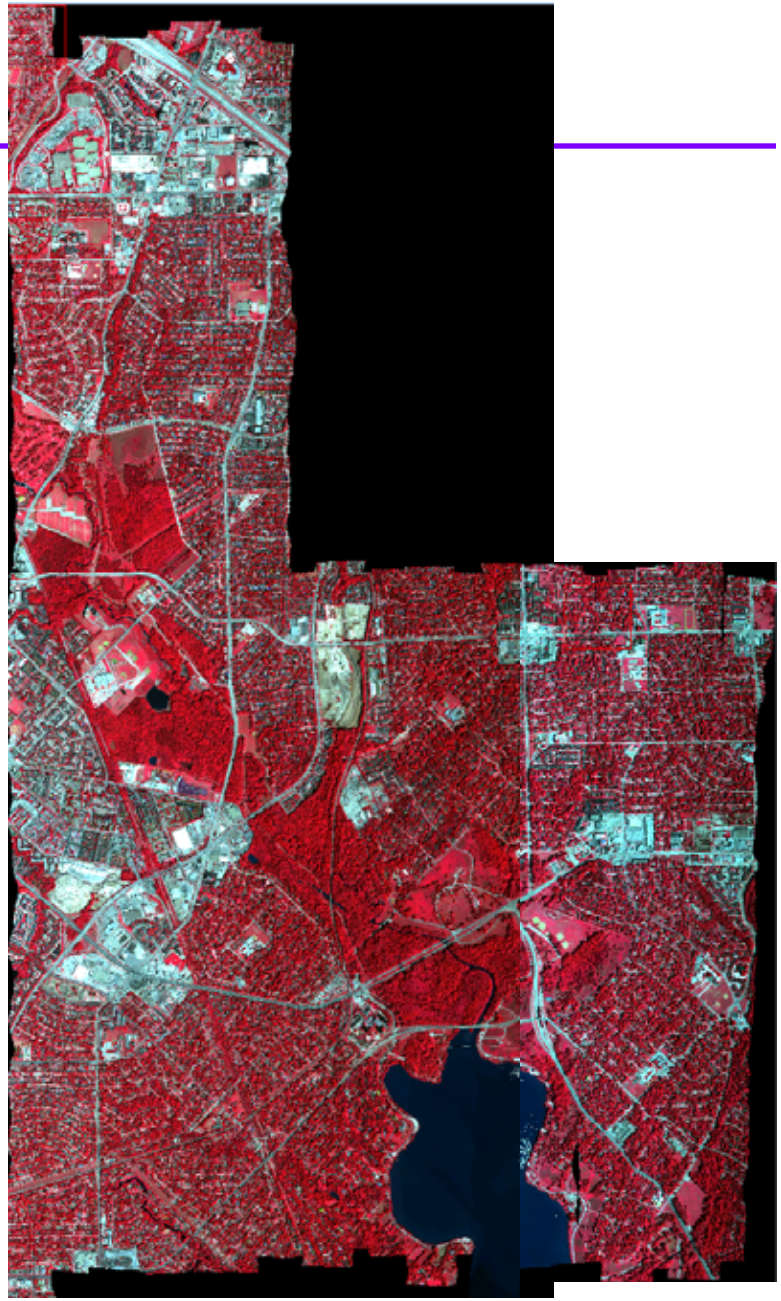
AisaDUAL sensor assembly, side view (AisaEAGLE on the right, AisaHAWK on the left)



AisaDUAL sensor assembly, back view

Mosaic of HSI

- Color Infrared Composite Image
  - Red: 841.13 nm
  - Green: 677.11 nm
  - Blue: 561.66 nm
- Typical Colors
  - Trees: Red
  - Buildings: Cyan
  - Water: Blue/black



In Situ Spectroradiometer Data Collection

- FieldSpec Pro ASD Spectroradiometer
  - Spectral Range from 350 – 2500 nm
  - Spectral Sampling of 1.4 nm in 350-1050 nm and 2nm in 1050-2050 nm range resulting in 2151 bands
  - Scan time of less than 3 seconds

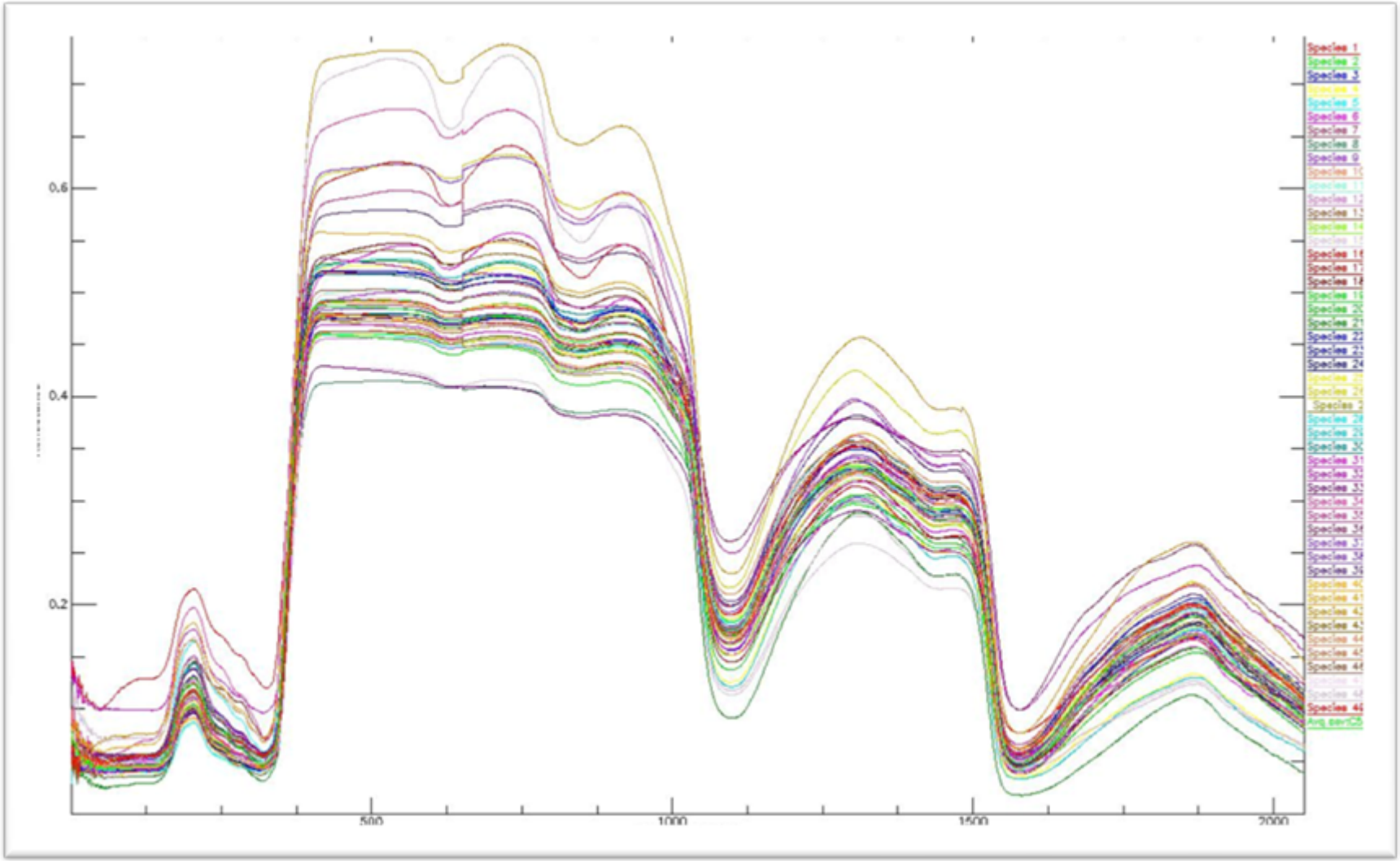
Spectroradiometer

High Intensity Contact Probe

In Situ Spectroradiometer Data Collection

- Sampling areas
  - Reverchon park
  - Turtle Creek area

Reflectance Spectral Signature for 50 species



Mean Spectral Profile for each species used as Reference Spectra

Species Spectral Seperability analysis

Using GFLVQ approach (50 Testing Samples)

- About 60-72% of accuracy was achieved
- Double the % accuracy of the spectral angle mapping

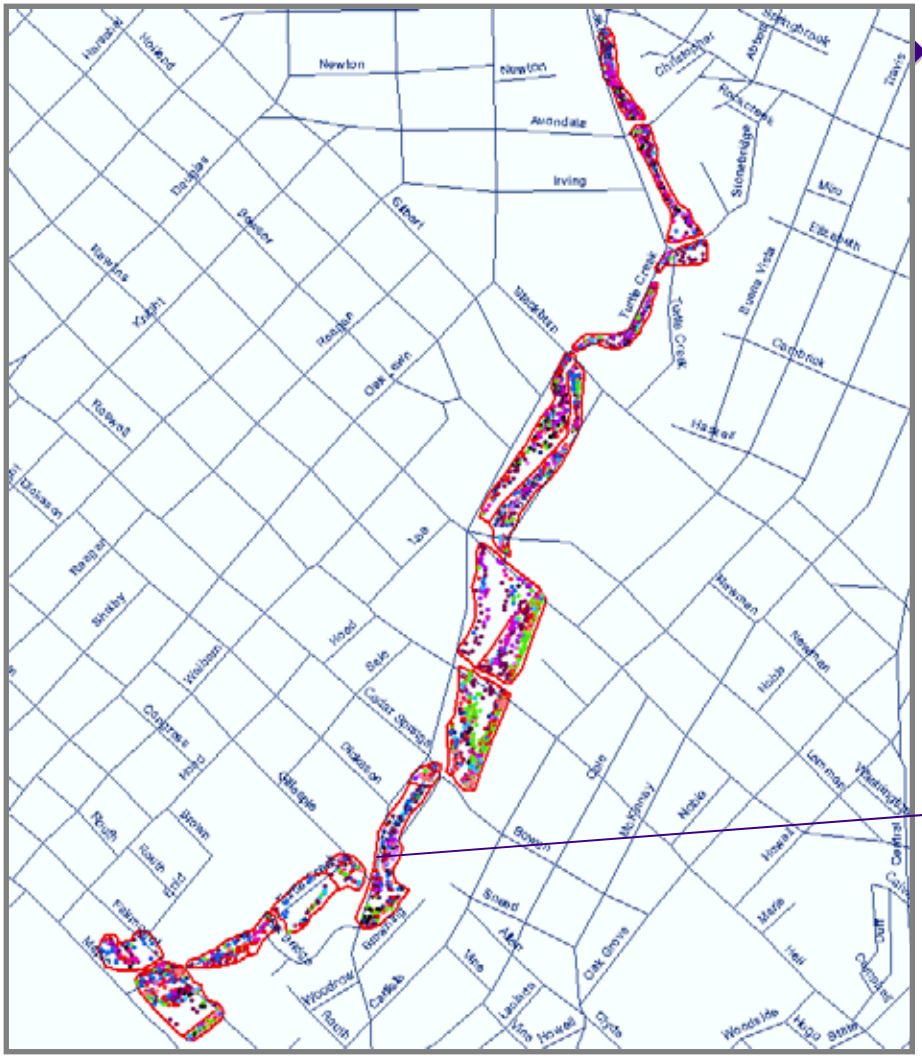
Trial	Accuracy
1	64%
2	62%
3	62%
4	68%
5	64%
6	60%
7	70%
8	72%
9	68%
10	70%

GFLVQ

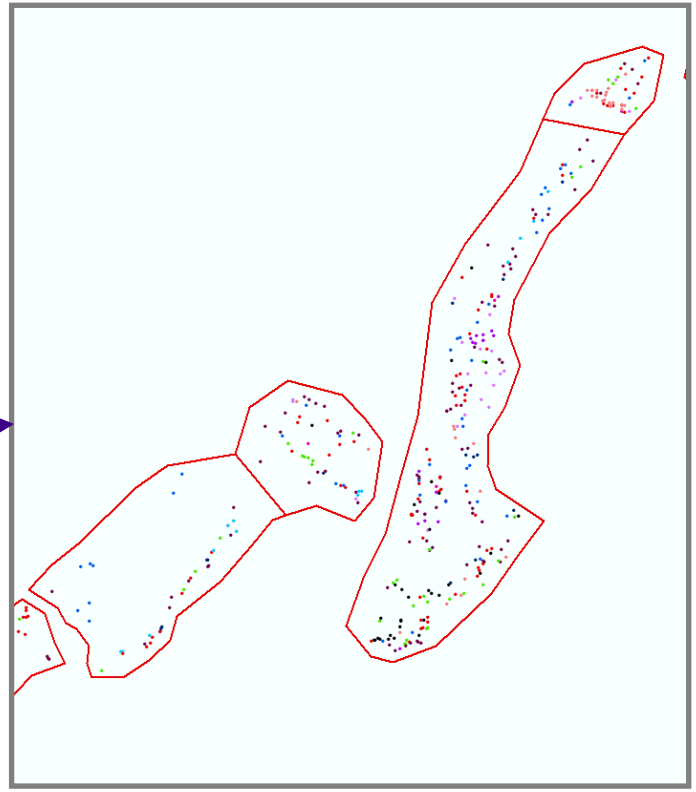
Trial	Accuracy
1	34%
2	30%
3	34%
4	42%
5	42%
6	36%
7	40%
8	42%
9	40%
10	42%

SAM

Urban Tree Field Survey Data by Halff Association

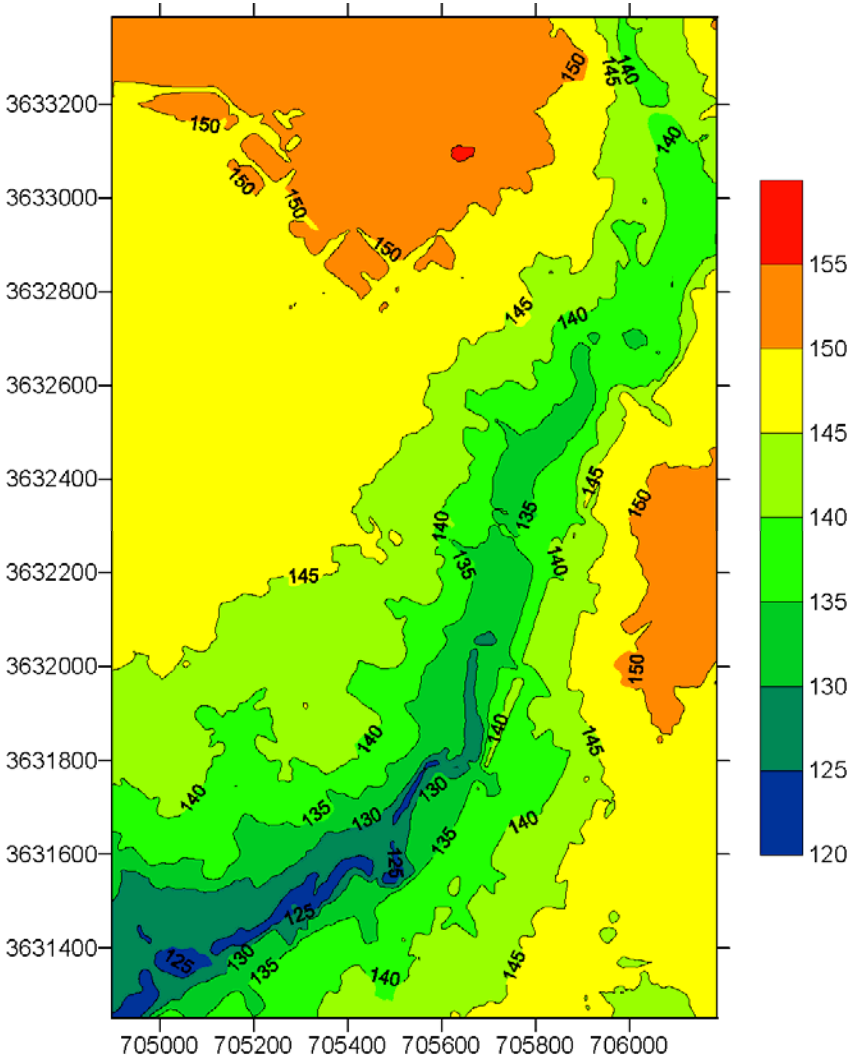


- **Turtle Creek Corridor**
  - **Total 2602 trees surveyed.**
  - **Total 46 species found**
  - **10 most frequently occurring species identified.**

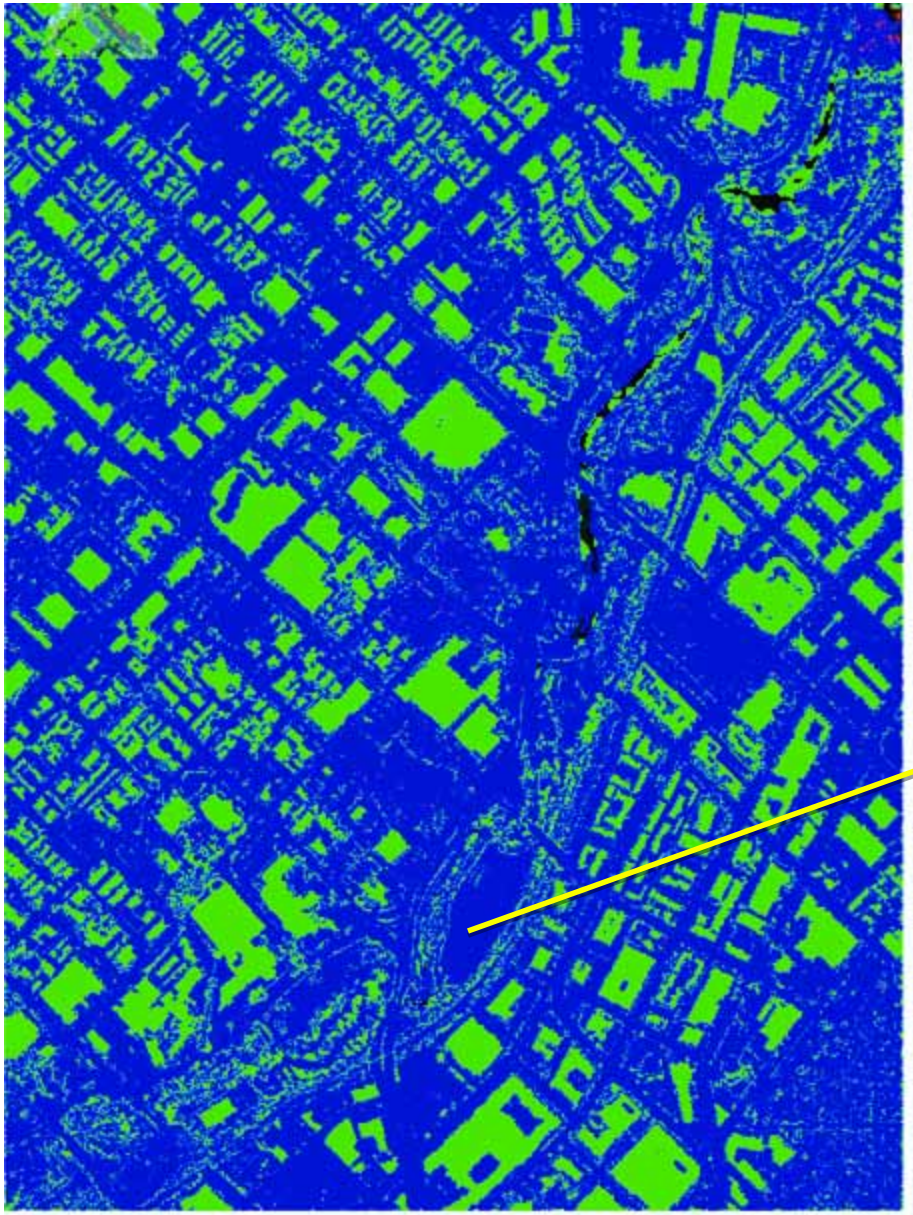


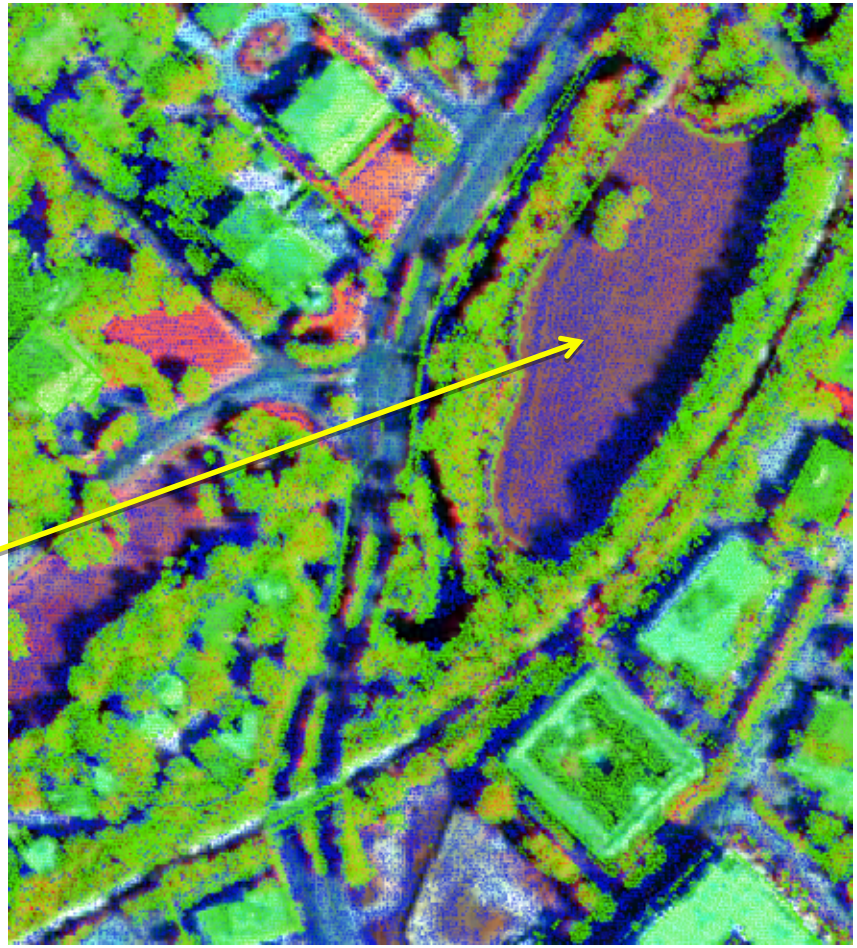
LiDAR Data Filtering

- Segmentation using MNN
- Ground and non-ground separation
- Digital Terrain Model generation

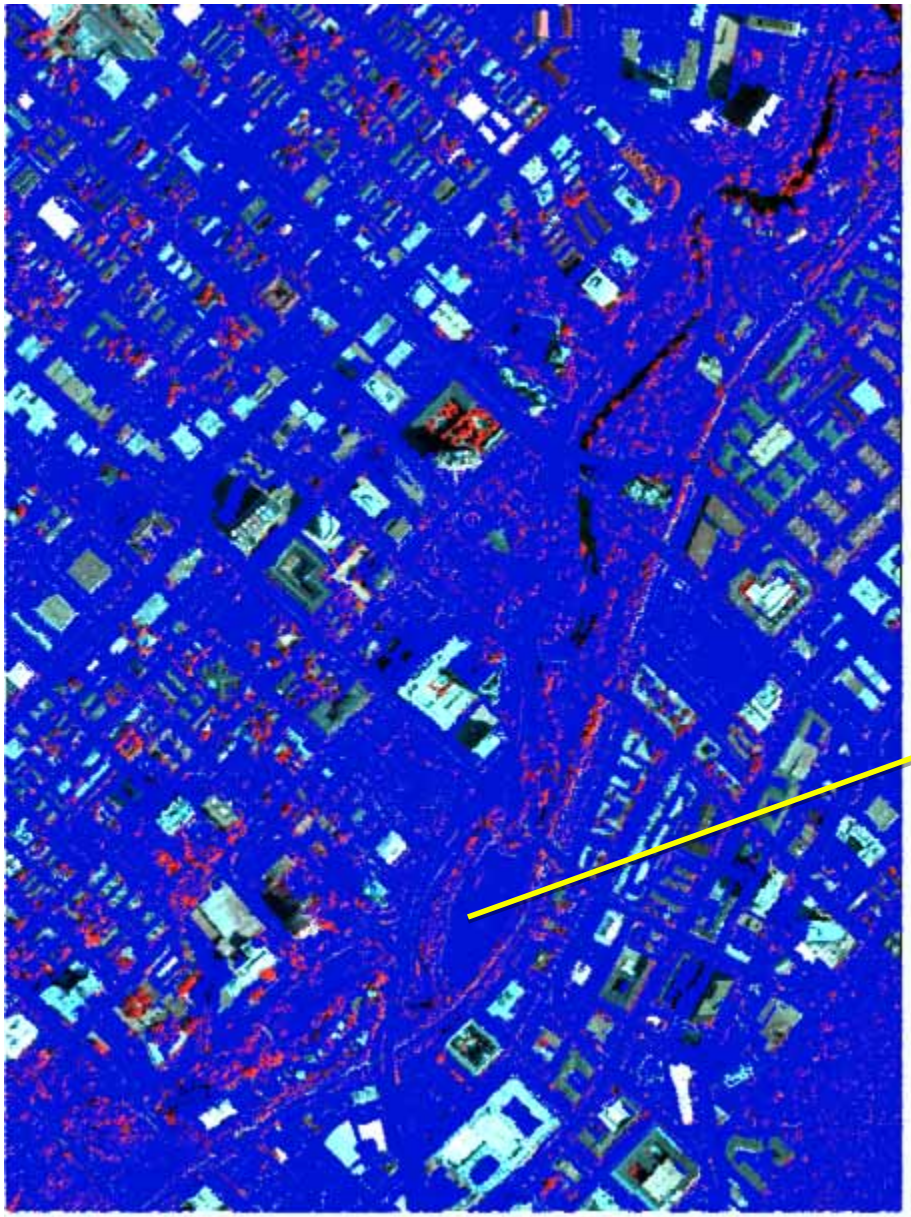


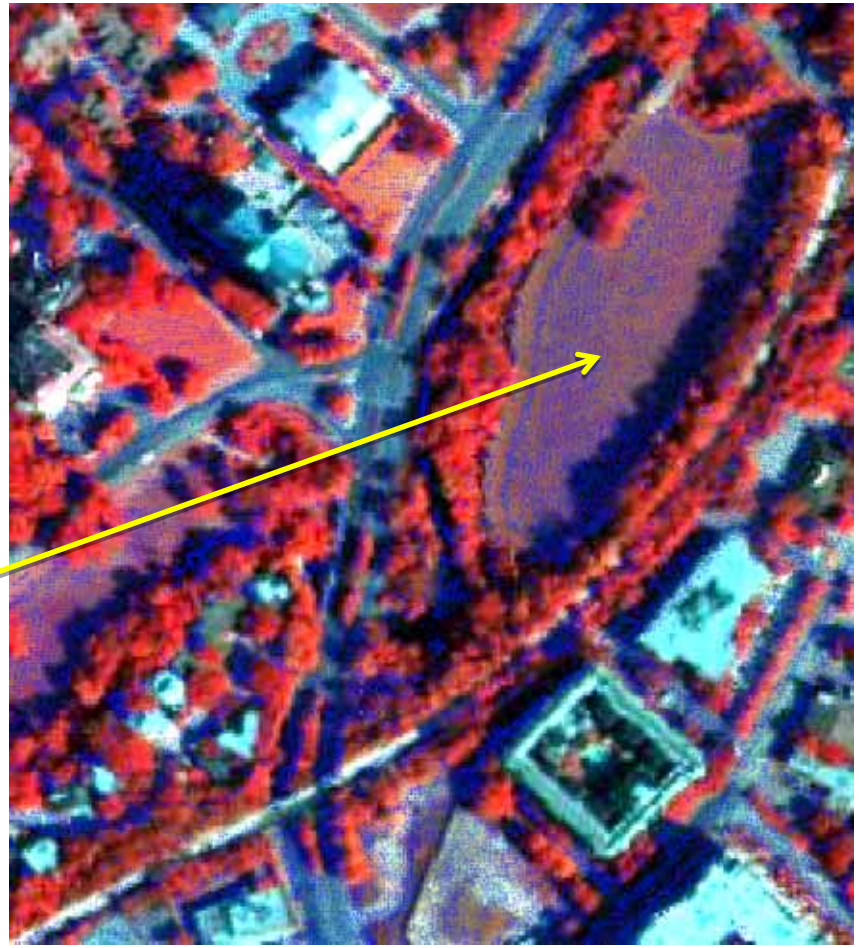
Lidar Filtring



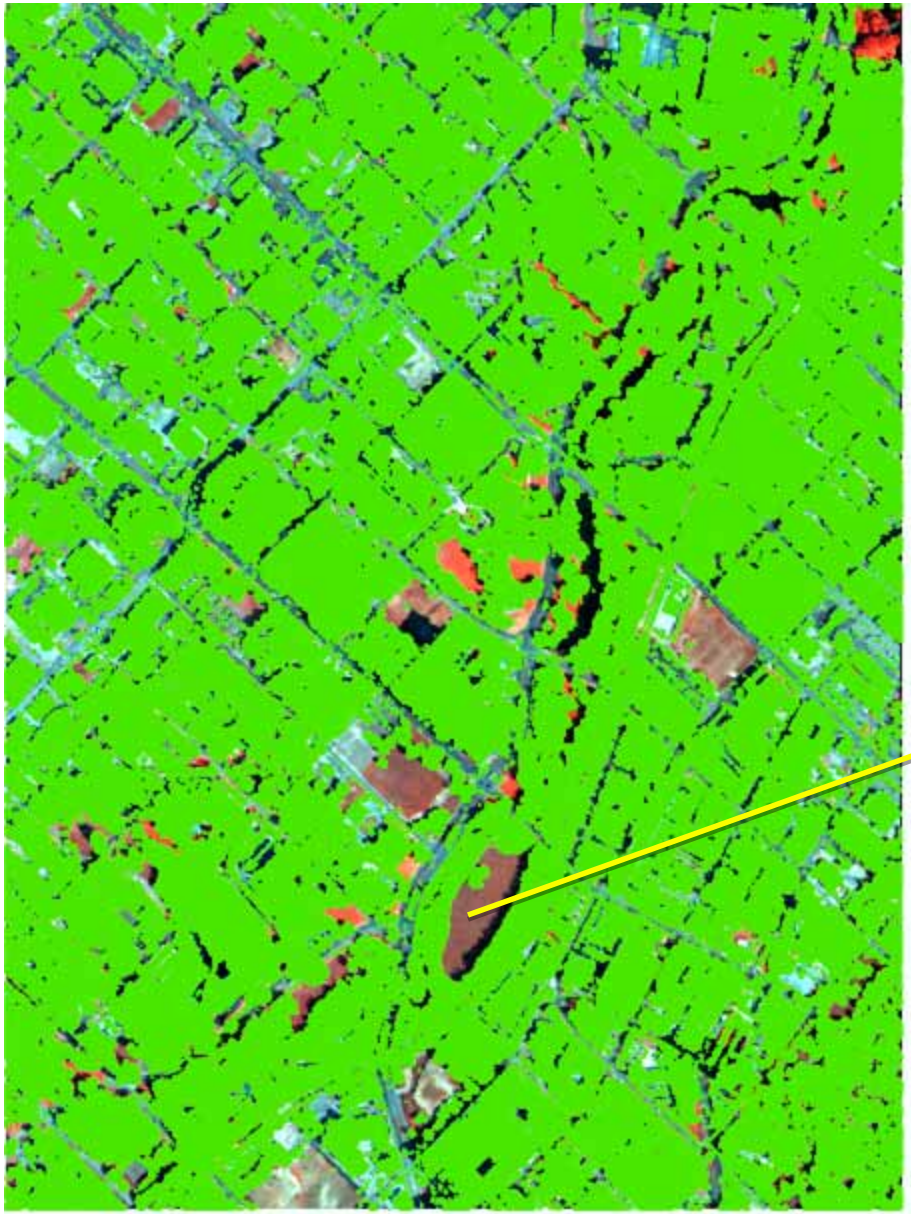


Ground points

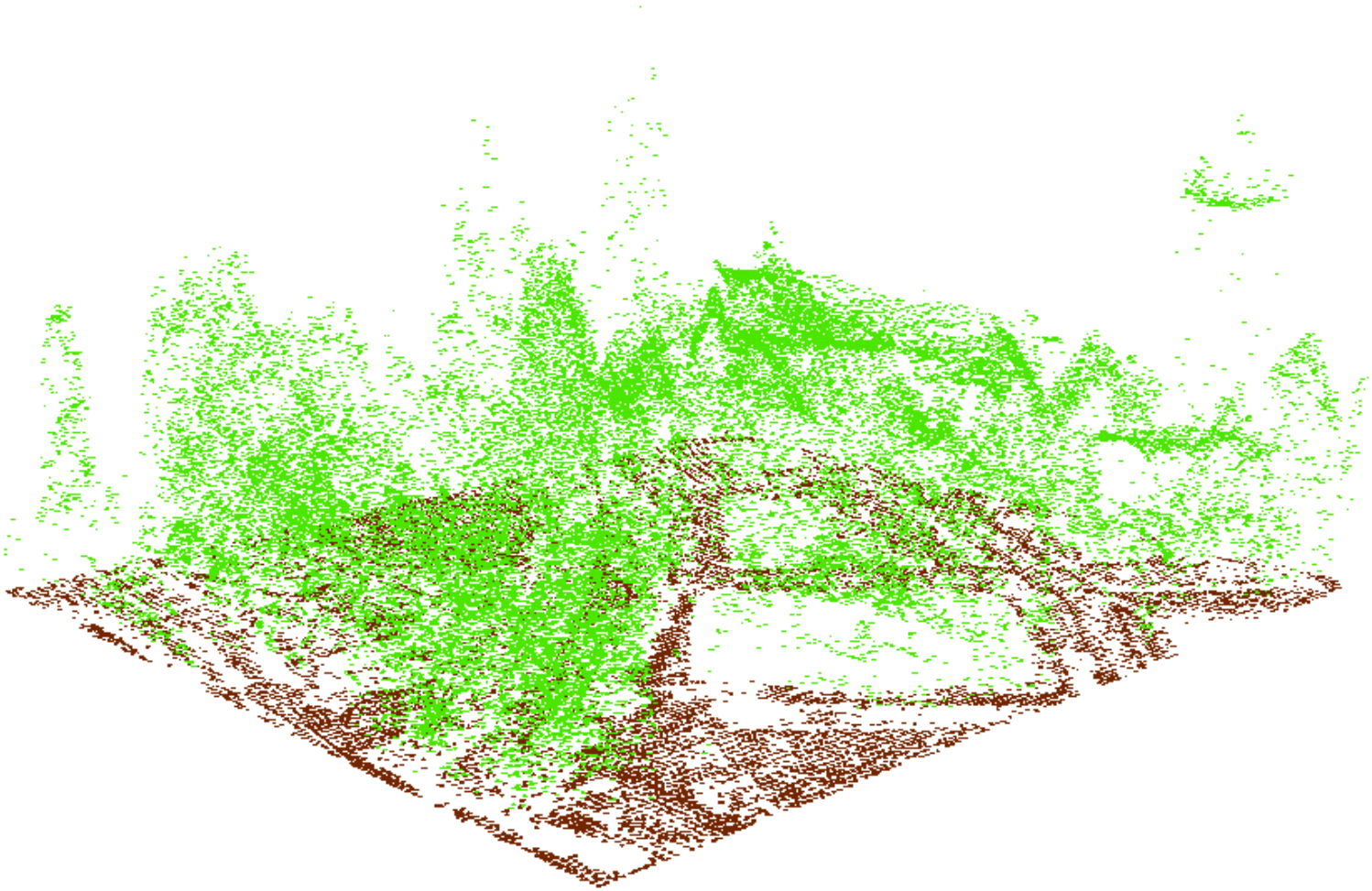




Non-ground points



Lidar filtering of ground and non-ground points



LiDAR Data Filtering: Ground points

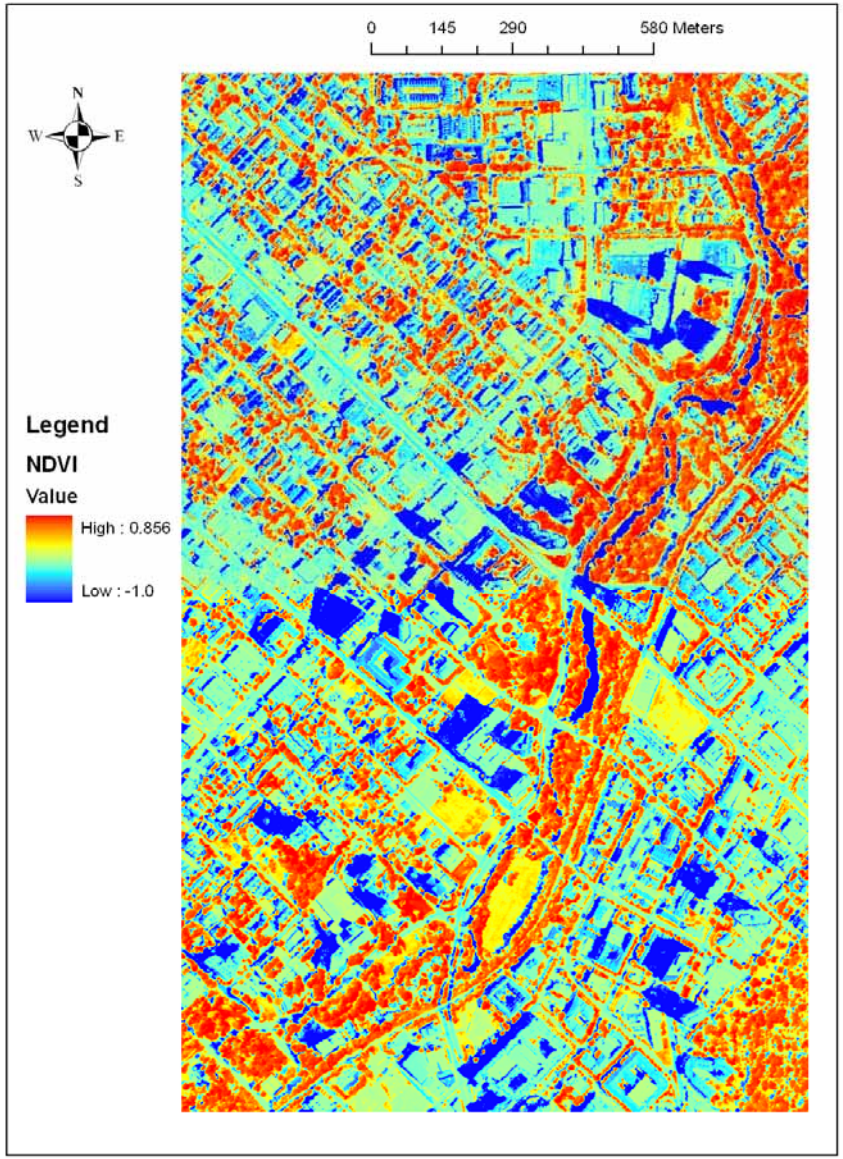
LiDAR Data Filtering: Non-ground

LiDAR Tree Mass Point Extraction

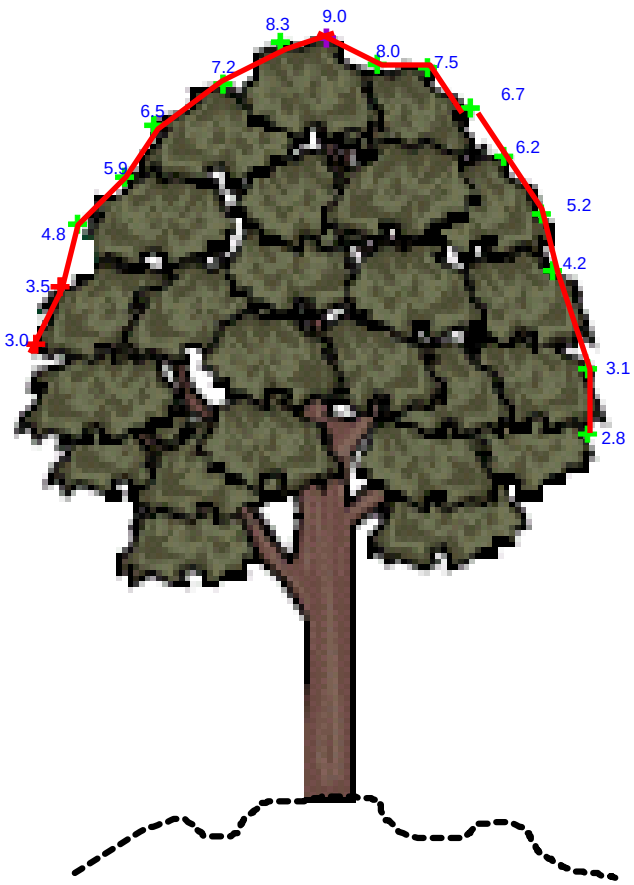
- **Normalized Difference Vegetation Index (NDVI)**

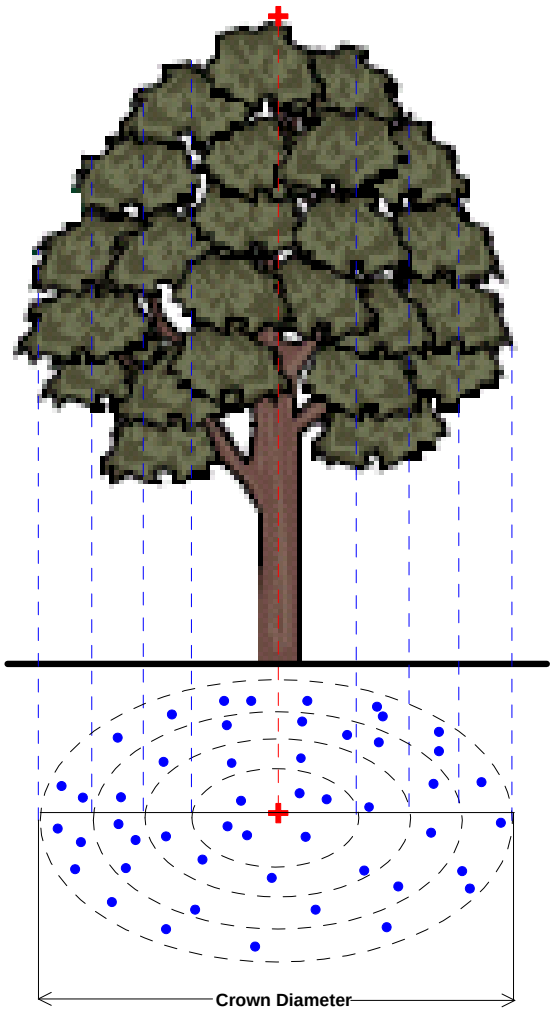
$$NDVI = \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + \rho_{red}}$$

- **Red: 660nm (band 113)**
- **Near-infrared: 860nm (band 198)**



Urban Tree Top Identification & Canopy Delineation

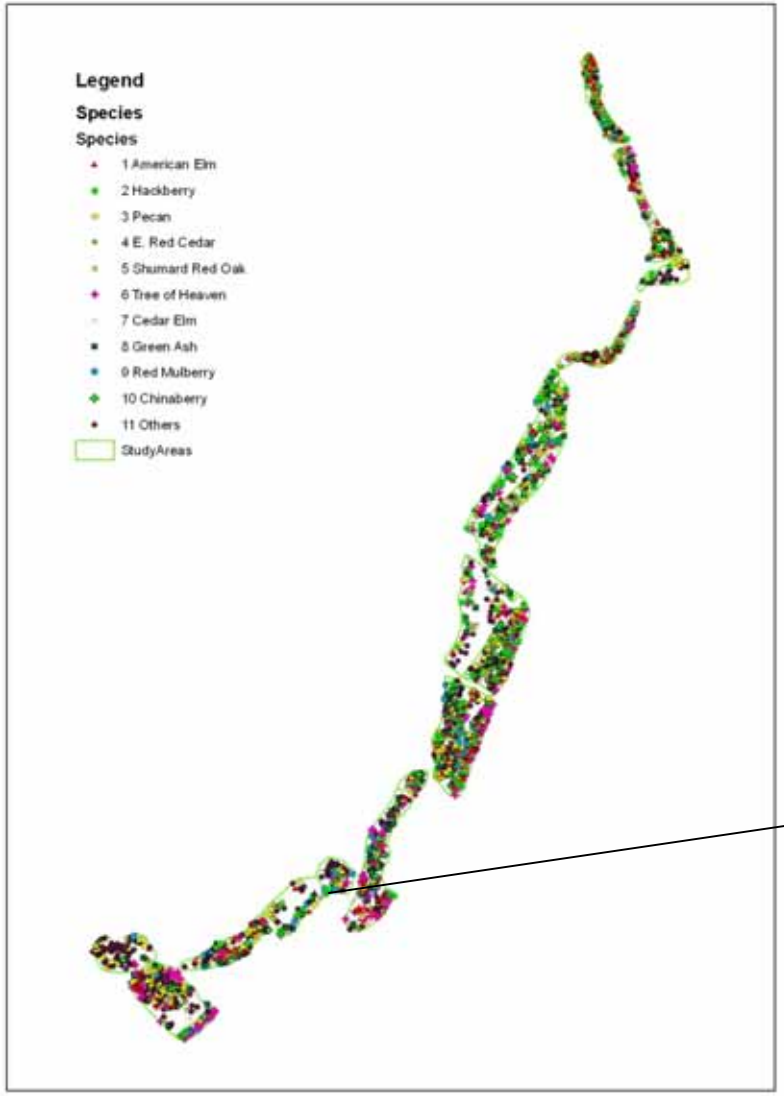


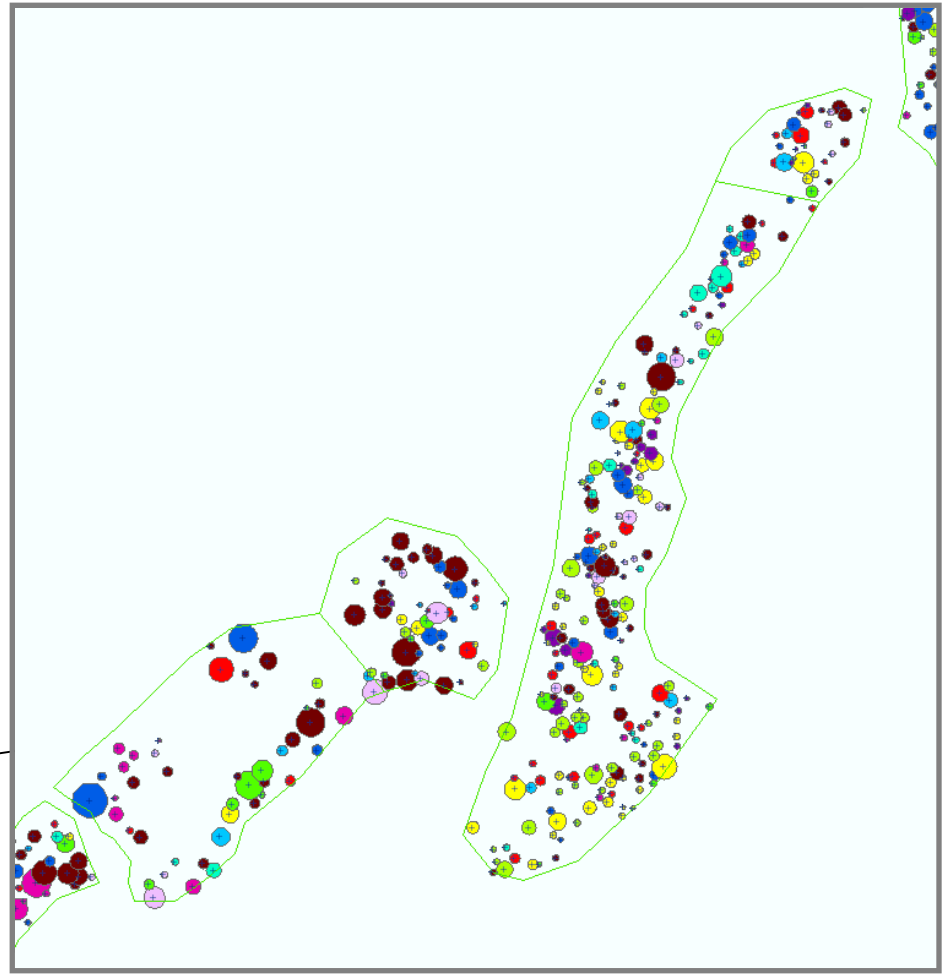


Urban Tree Top: Results

Urban Tree Canopy (UTC) Delineation : Results

Urban Tree Species (UTS) Identification: Results



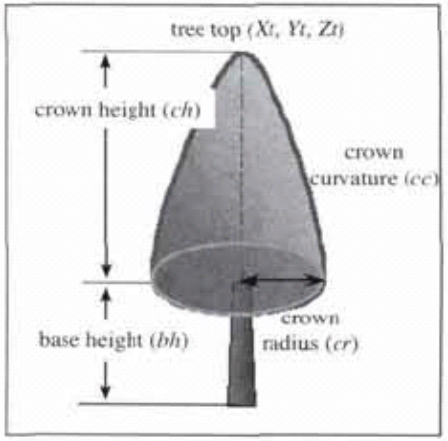


Accuracy Assessment

Species Name	Accuracy	Species Name	Accuracy
American Elm	39.39%	Bois d'arc	91.67%
Hackberry	47.89%	Sycamore	72.73%
Pecan	65.55%	Black Locust	87.50%
E. Red Cedar	62.93%	Redbud	100.00%
Shumard Red Oak	77.27%	Persimmon	100.00%
Tree of Heaven	76.36%	Slash pine	100.00%
Cedar Elm	83.54%	Gingko	100.00%
Green Ash	87.23%	Southern Magnolia	100.00%
Red Mulberry	84.62%	Dogwood	100.00%
Chinaberry	78.79%	White Ash	100.00%
Gum Bumelia	88.89%	Pear	100.00%
Baldcypress	84.00%	Chinese Pistache	100.00%
Cherry Laurel	95.00%	Chinese Tallow	100.00%
Boxelder	90.00%	Southern Catalpa	100.00%
Post Oak	100.00%	Sweetgum	100.00%
Live Oak	89.47%	Golden Raintree	100.00%
Bur Oak	94.12%	Black Walnut	100.00%
	94.12%	Honey Locust	100.00%
Crepe Myrtle	100.00%	Western Soapberry	100.00%
Black	93.75%	Catalpa	66.67%
Kappa	64.4%	Total Accuracy:	68.8%

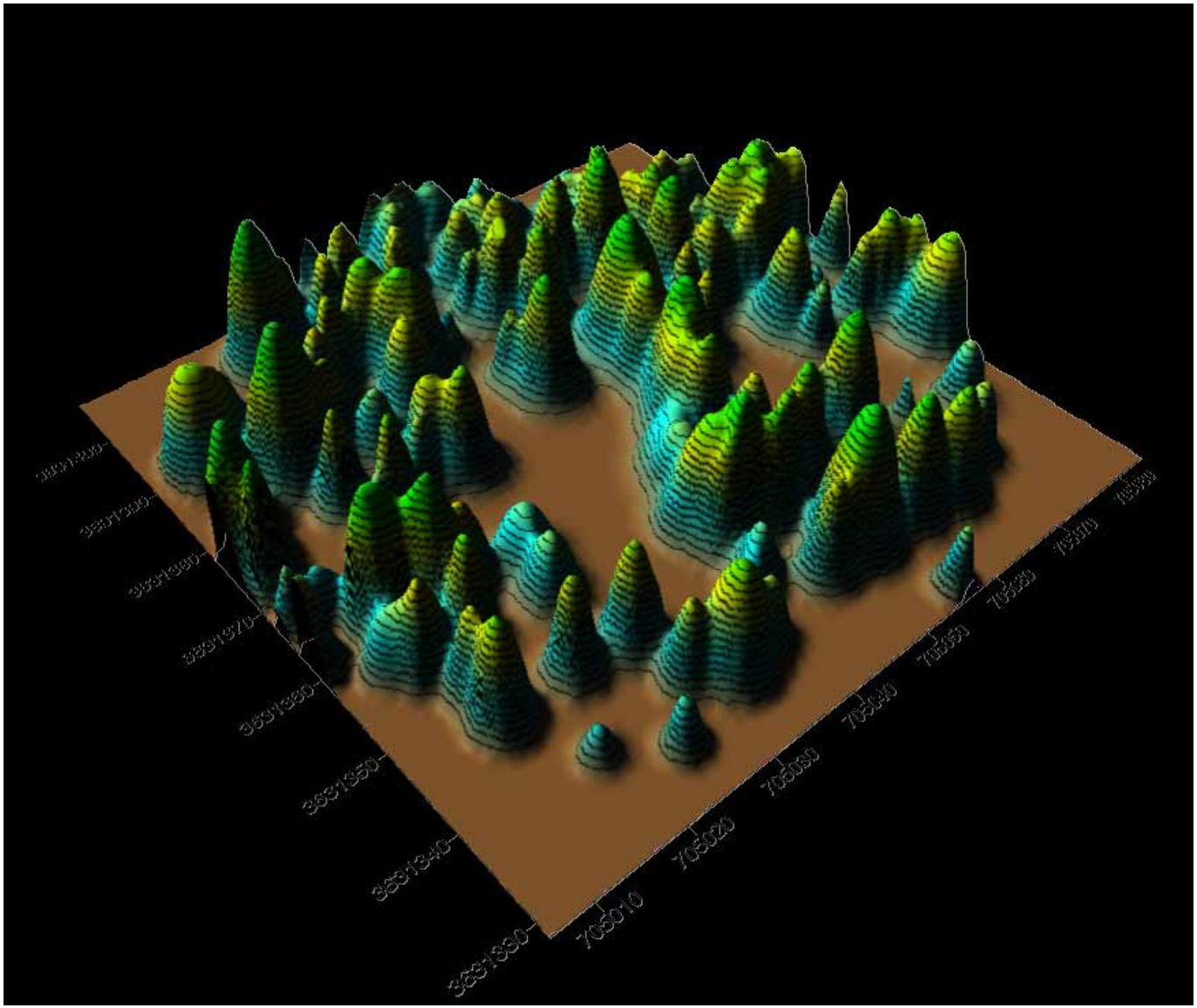
Digital 3D Tree Canopy Model Construction

- **Tree top locations (x_t,y_t)**
- **Tree heights (*z*)**
- **Tree base heights(*bh*)**
- **Tree crown depths (*ch*)**
- **Tree crown radius (cr)**

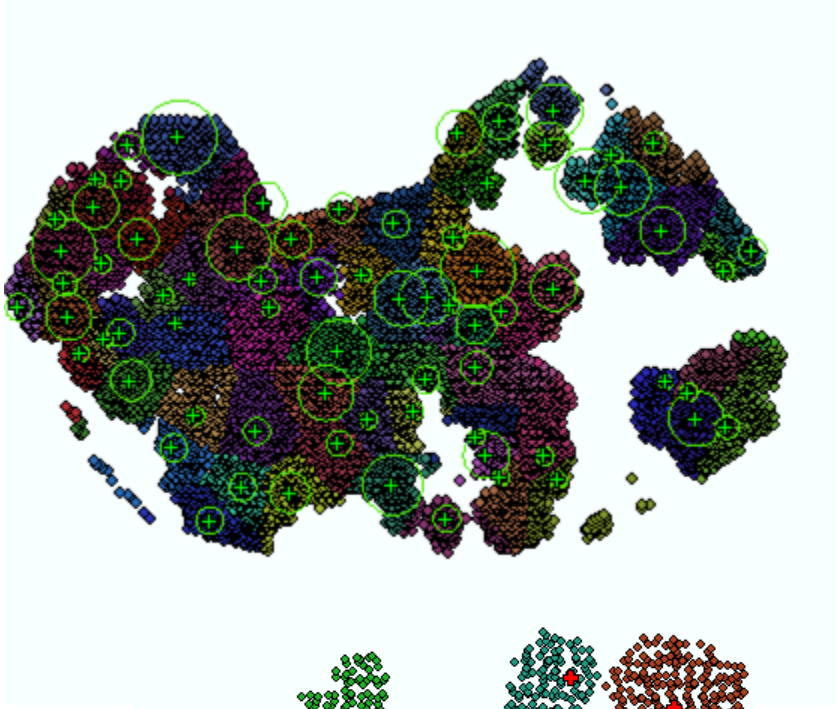


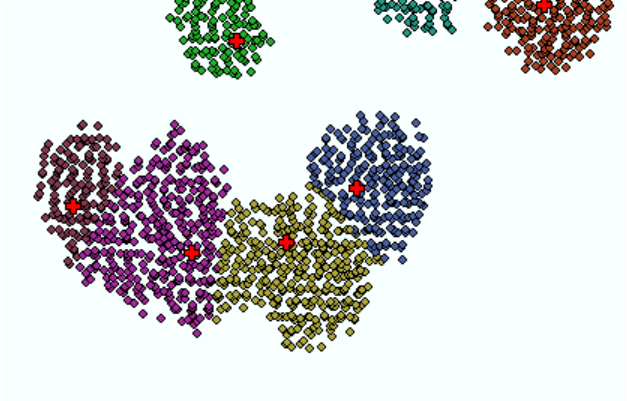
$$\frac{(z-bh)^n}{ch^n}+\frac{(x-x_t)^n+(y-y_t)^n}{cr^n}=1 \qquad \begin{cases} n=1: conical \quad shape \\ n=2: elliptical \quad shape \end{cases}$$

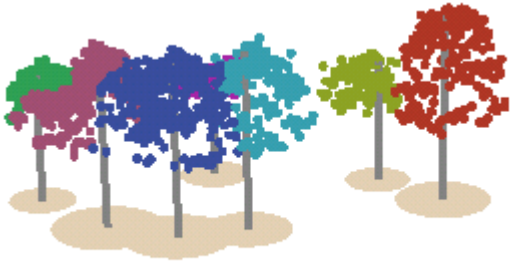
Tree model: Results



Individual Tree Extraction and Visualization







Individual Tree Structure Model