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

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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

Method 1

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

Method 2

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

Method 2

- 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

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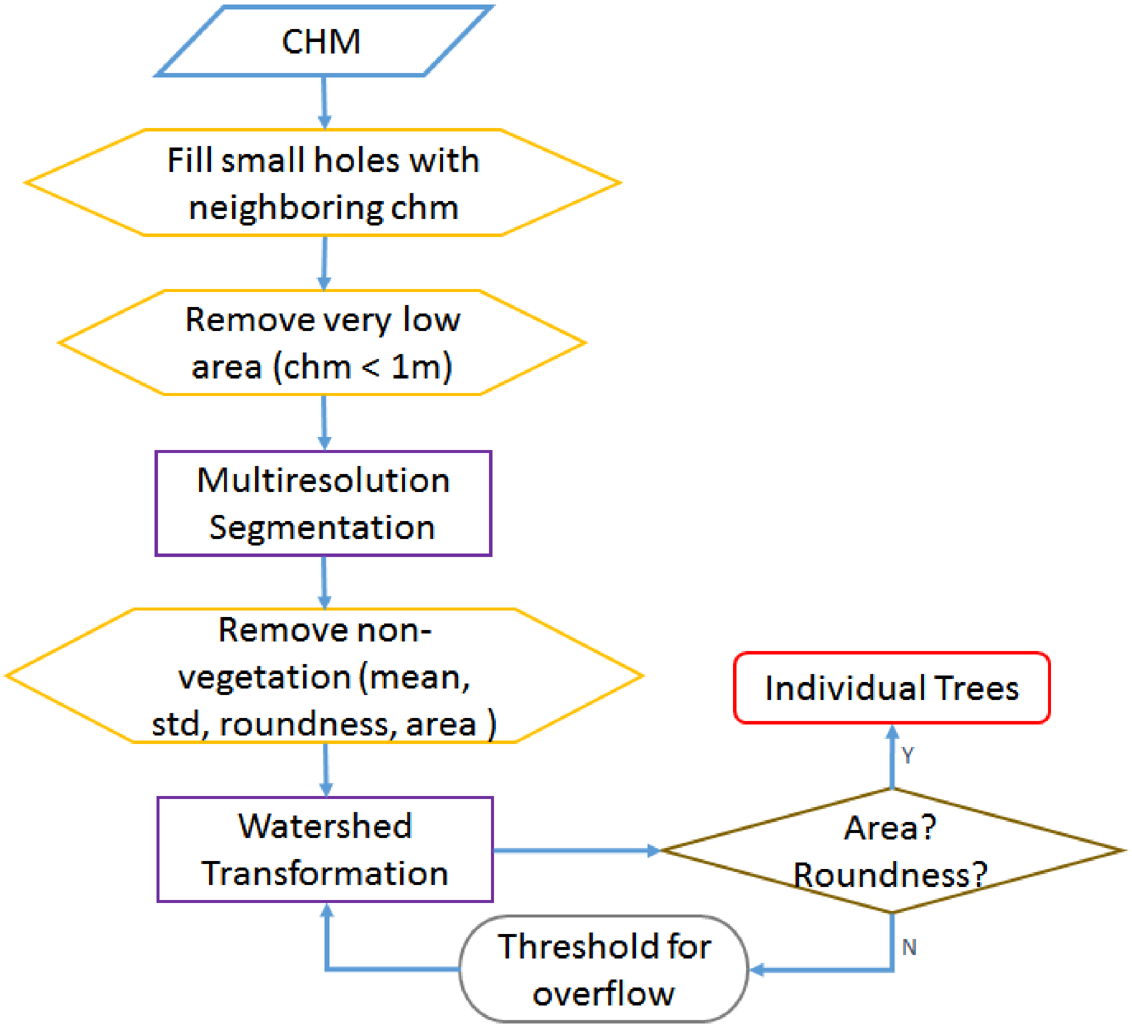
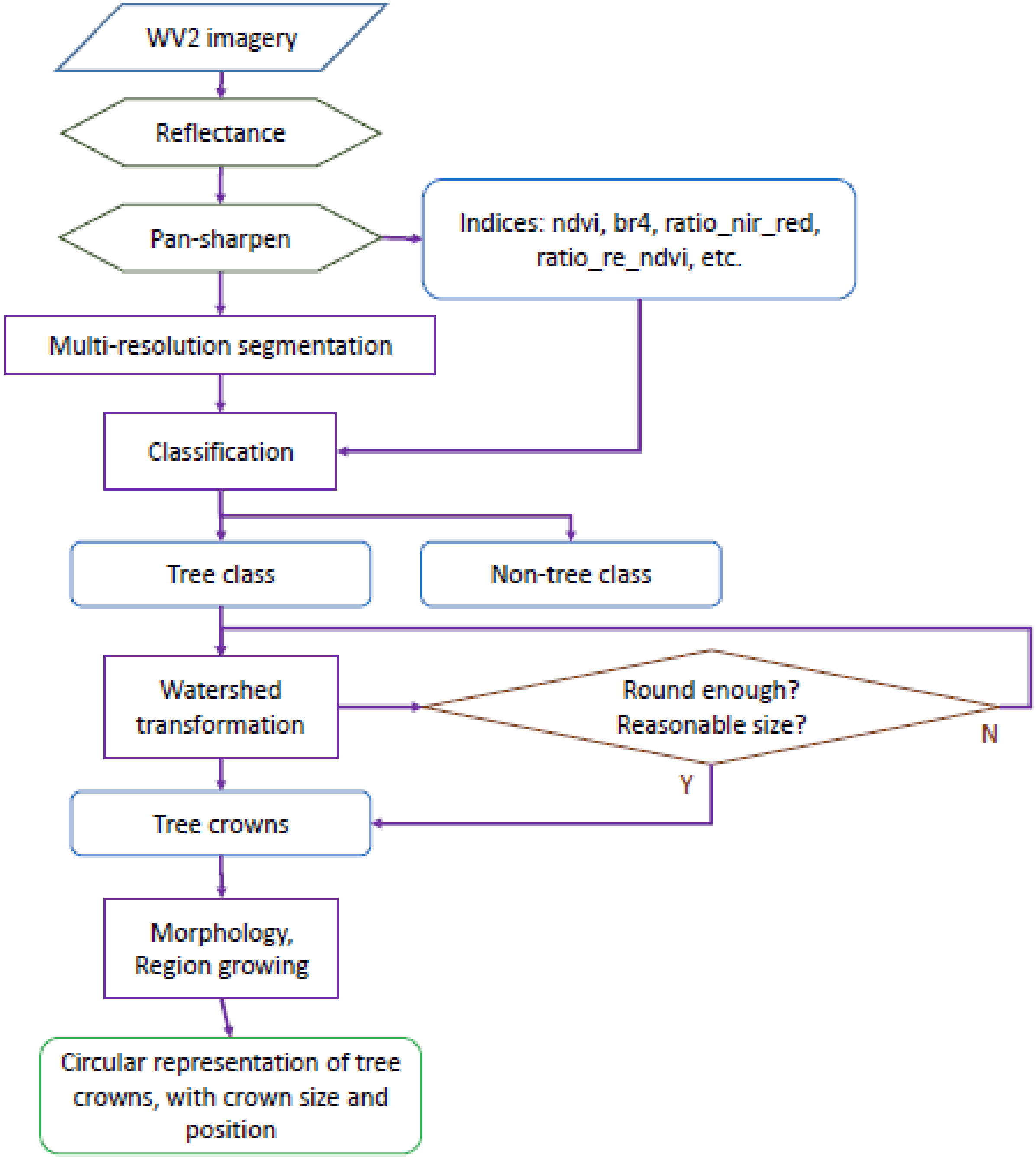
Tree crowns identification and delineation from CHM



back

Methodology - Tree crowns identification and delineation from WV



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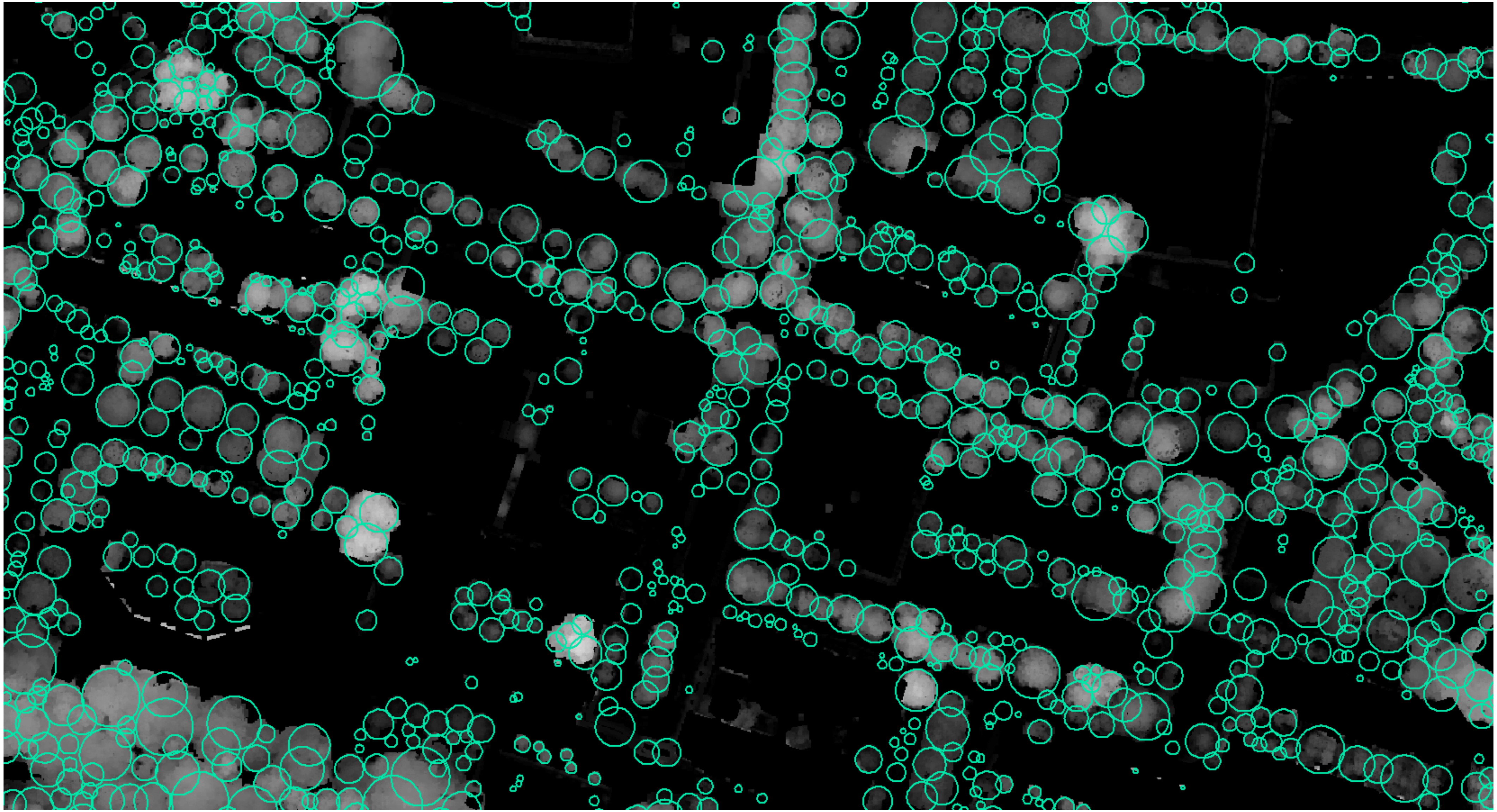
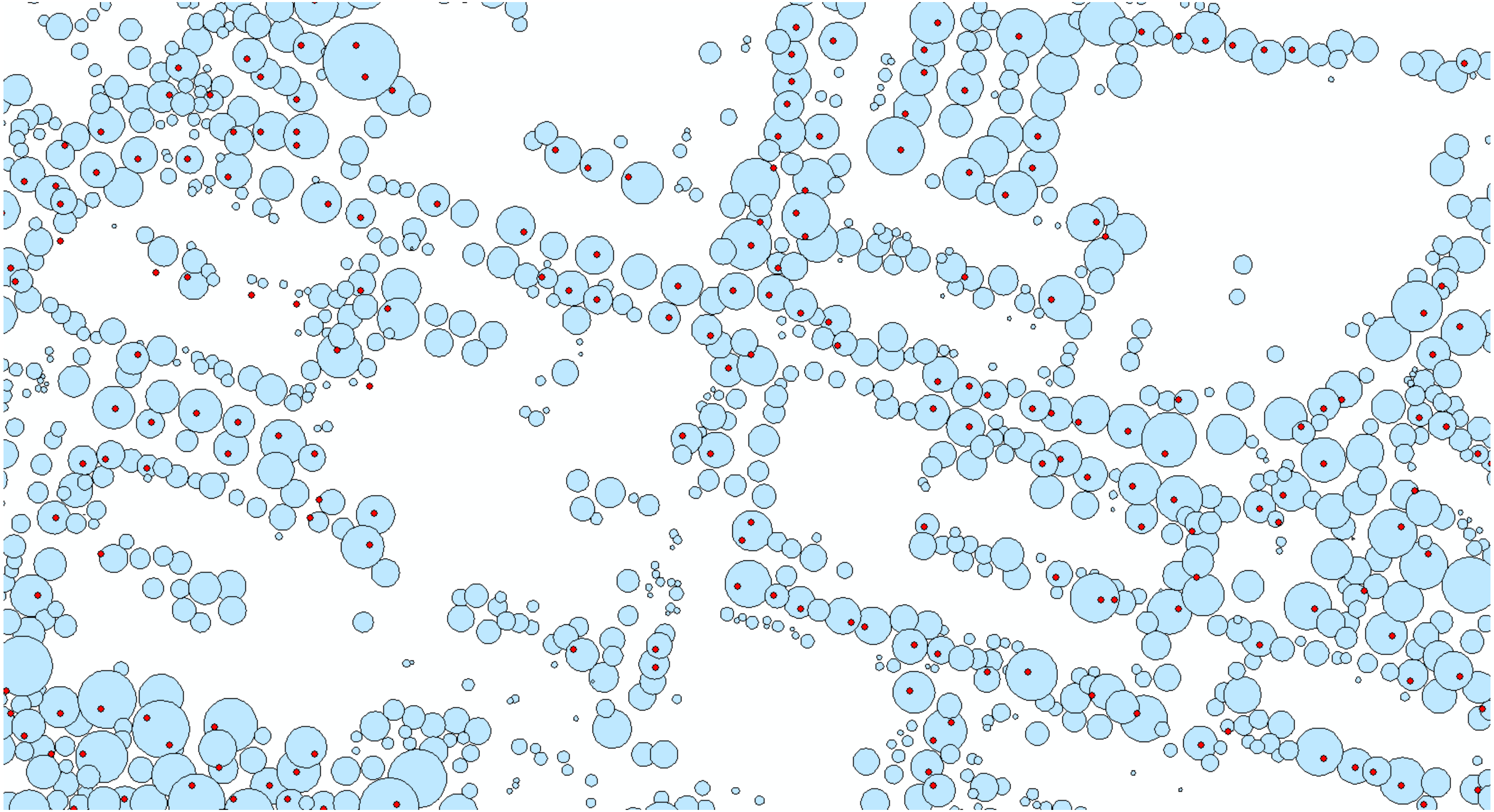


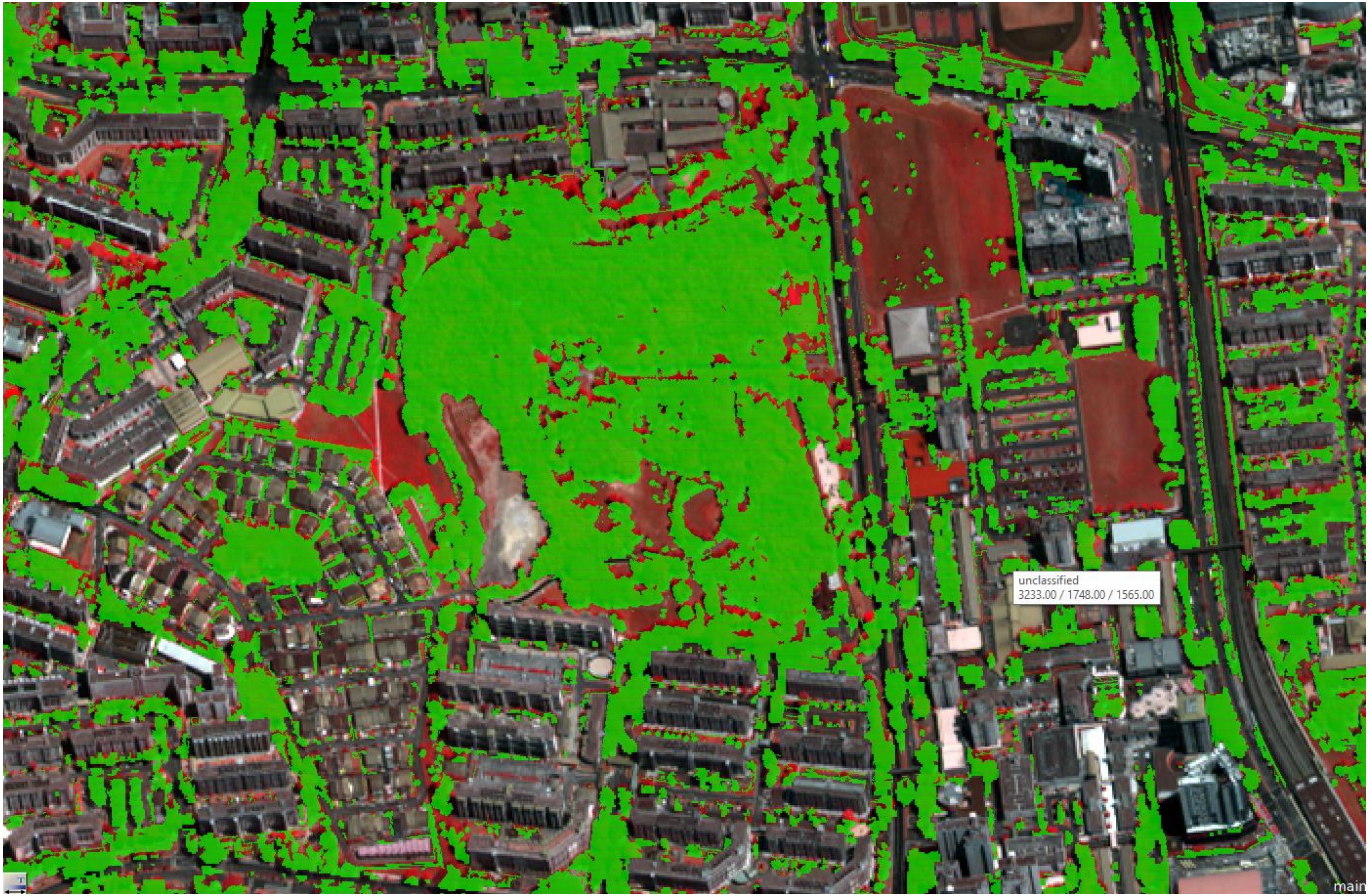
Tree crowns (cyan) detected from CHM (grey)



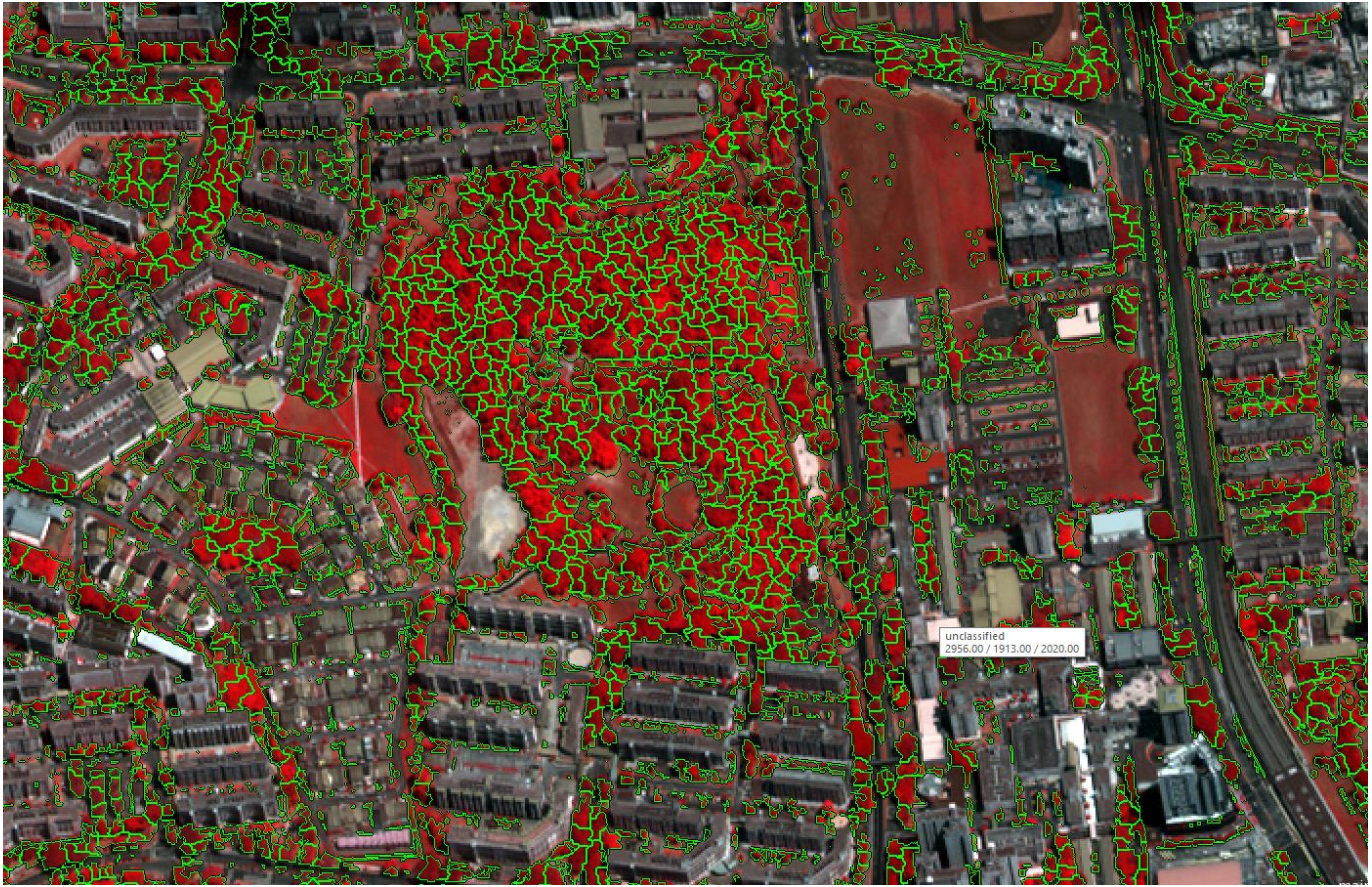
Tree crowns from CHM + Tree Database (NParks, red dots)

- 866 trees from CHM, 182 in database (174 detected, 8 undetected)
- Match well for locations
- More trees from CHM

Classification - Trees detected from WV2



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

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Accuracy assessment for trees extraction from WV2 satellite imagery

Actual trees	815
Detected trees	844
Falsely detected trees	51
Undetected trees	22
Omission error	3 %
Commission error	6 %
Producer's accuracy	97 %
User's accuracy	94 %

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 = (Latitude - LAT_OFF) / LAT_SCALE
- L = (Longitude - LONG_OFF) / LONG_SCALE
- H = (Height - HEIGHT_OFF) / HEIGHT_SCALE
- r_n = (ROW - LINE_OFF) / LINE_SCALE
- c_n = (Column - SAMP_OFF) / SAMP_SCALE

$$r_n = \frac{\sum_{i=1}^{20} LINE\_NUM\_COEF_i \bullet p_i(P,L,H)}{\sum_{i=1}^{20} LINE\_DEN\_COEF_i \bullet p_i(P,L,H)} \quad and \quad c_n = \frac{\sum_{i=1}^{20} SAMP\_NUM\_COEF_i \bullet p_i(P,L,H)}{\sum_{i=1}^{20} SAMP\_DEN\_COEF_i \bullet p_i(P,L,H)}$$

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

Map (L, P, H) → Image (c, r)

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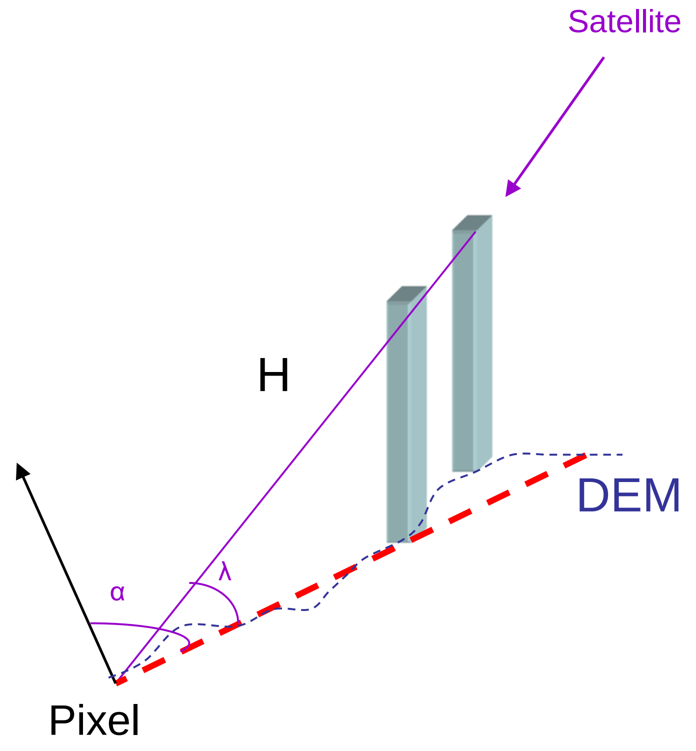
Camera Model (RPC) of WV-2

- Map coordinates to image coordinates for top and base points

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

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

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



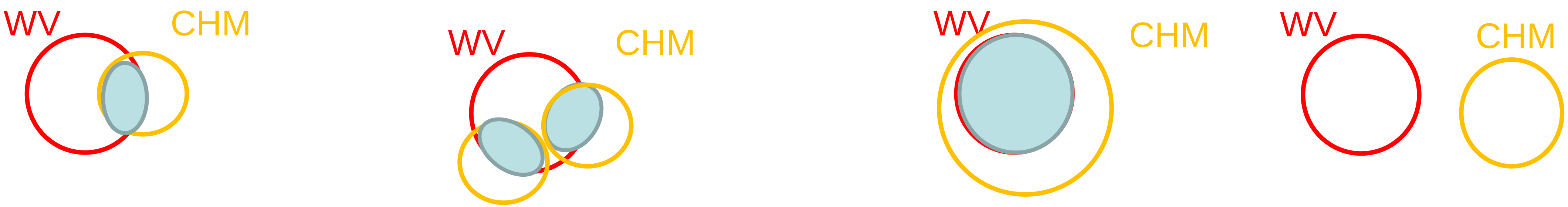
- Any point in the ray of light shares the same pixel in the image
  - For crown top of WV, the base can't be derived as height is unknown.
  - For crown of CHM, the pixel position for tree top in the satellite image can be derived using RPC.

back

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



$H_{wv} = H_{chm}$ $H_{wv} = (H_{1chm} * A_1 + H_{2chm} * A_2) / (A_1 + A_2)$ $H_{wv} = H_{chm}$ $H_{wv} = 0$

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)

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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!