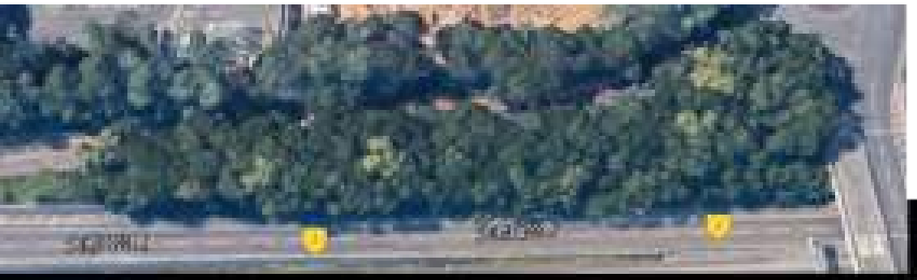
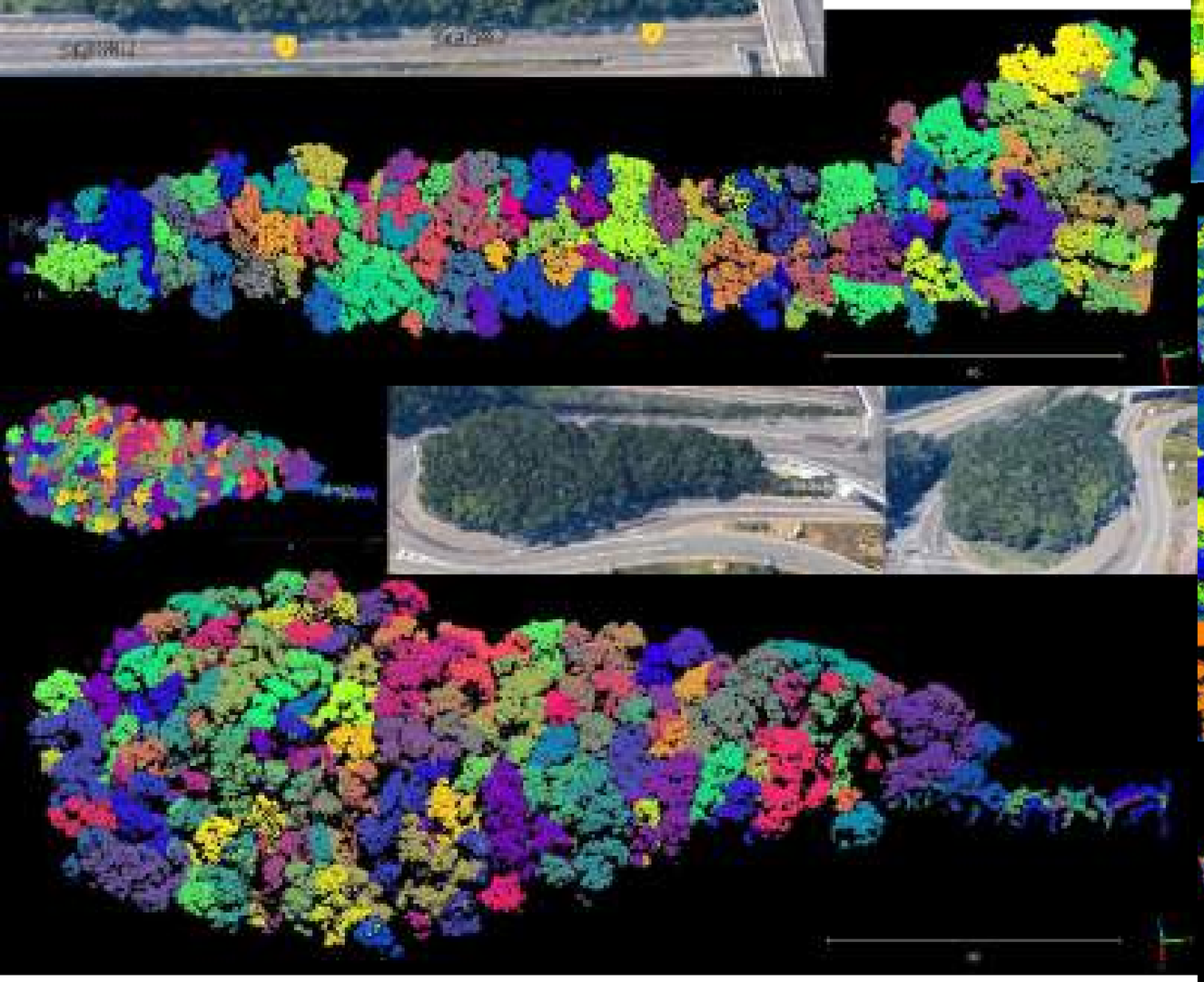
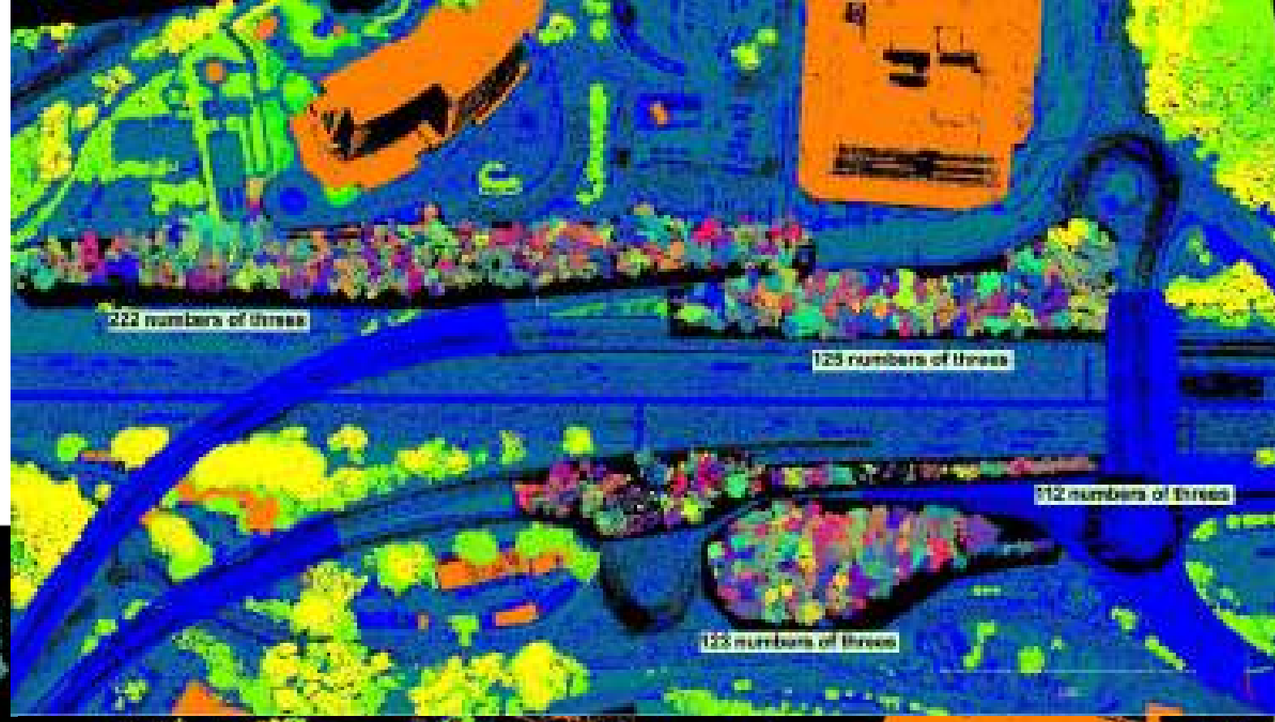
Forestree
Remote sensing and Forestry

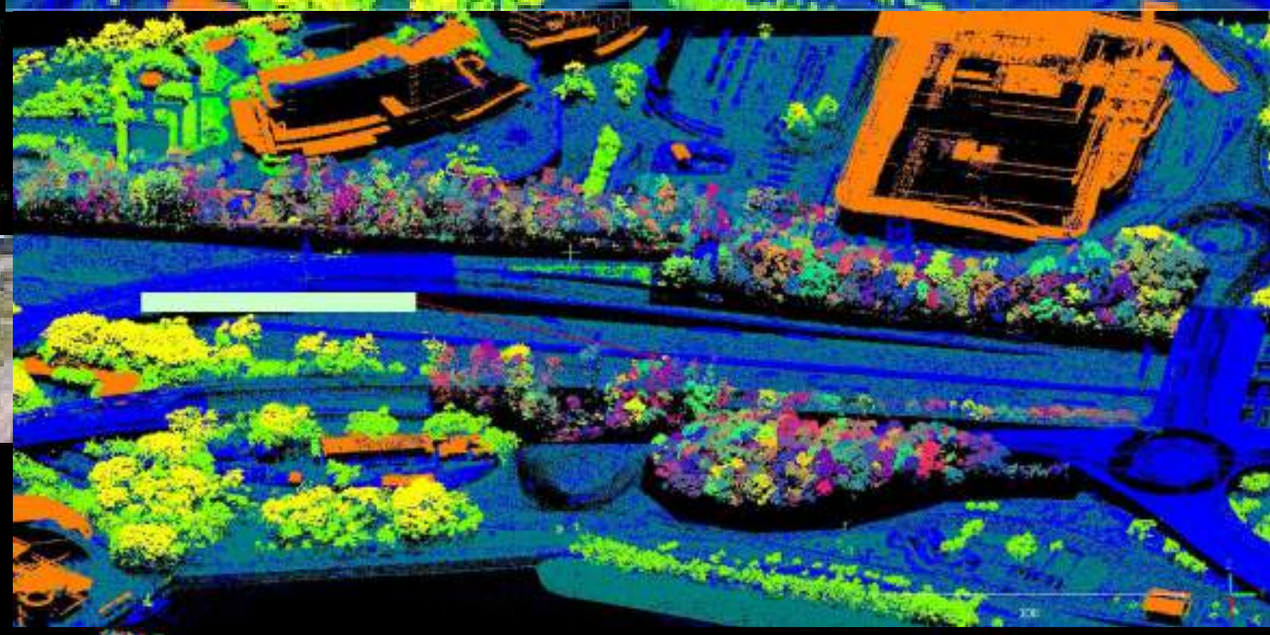
Our application and Pilot study

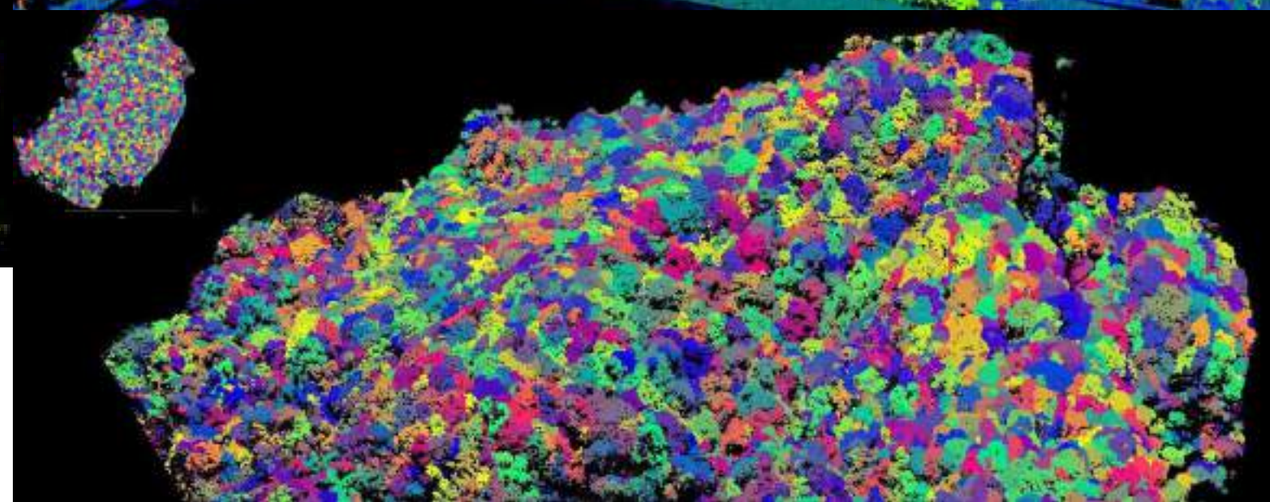
Tree inventory with Point Cloud











The extracted tree map from CEDD LiDAR (airborne survey) is available on the QR code.

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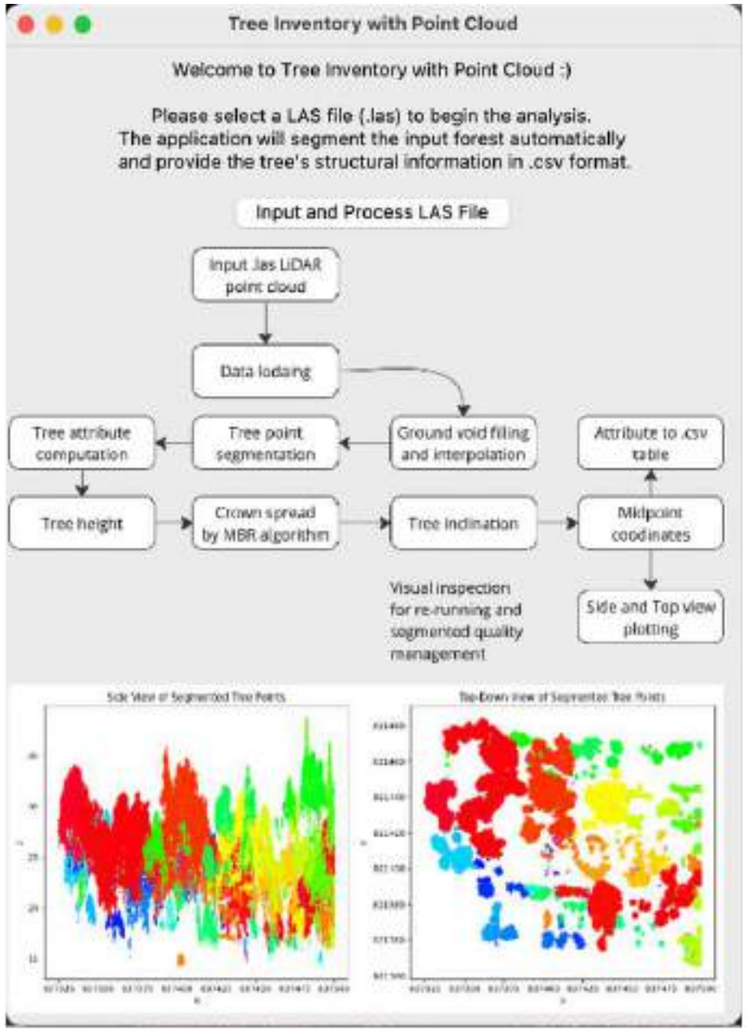
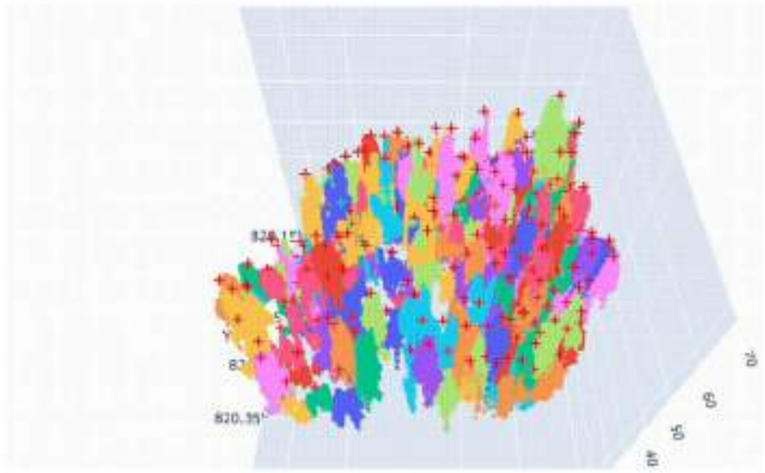
Our application and Pilot study

Tree inventory with Point Cloud
The tree inventory is based on the input .las, and then divides the point cloud to calculate the attributes and structural parameters of each tree. Then, after the calculation process, we can perform a visual inspection from side and top views. Tree records will eventually be output in .csv format.

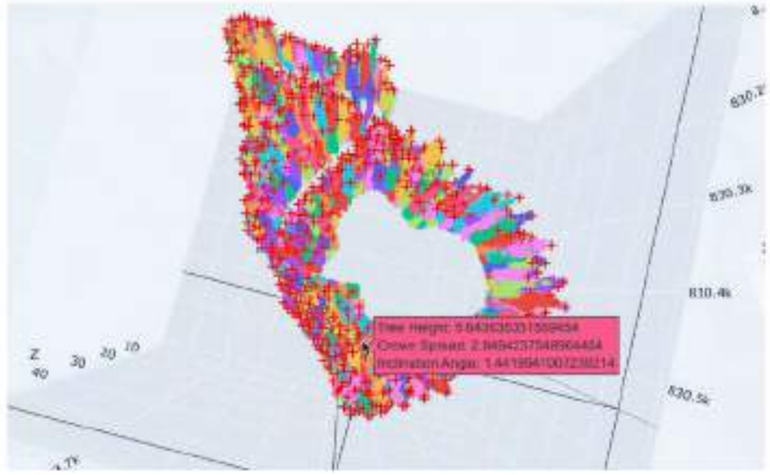
Segmented model from the point cloud was re-rendered into tree models.



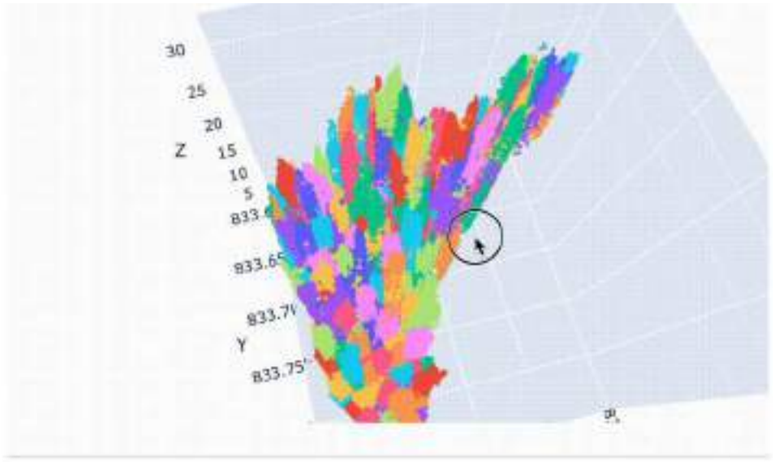
Tree Invertory with Point Cloud GUI



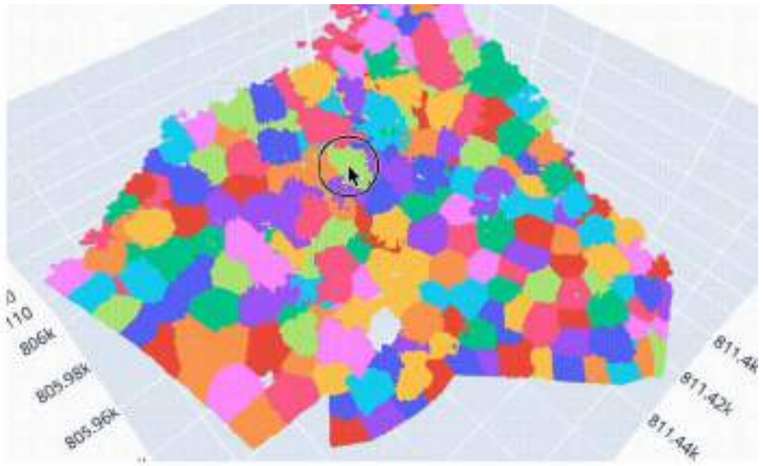
Plantation and private garden, Kadoorie hill segmented tree model



Reforested Park after landfill, Kwai Chung Park



Fung Shui Wood, Tai Om SSSI



Secondary forest, Tai O Road hillside

Extracted tree map from LiDAR (2020)

The extracted tree map from CEDD LiDAR (airborne survey) is available on the QR code.

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Methods to enhance the tree care and management

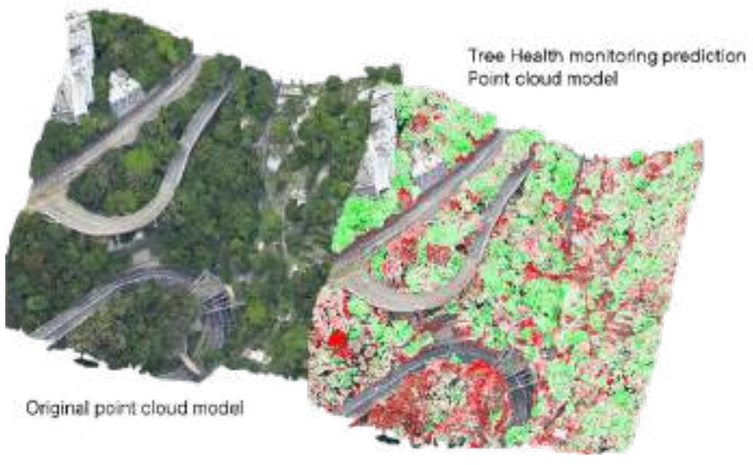
Automatically Tree inventory

Airborne LiDAR data, includes the followings:
1) Geometry of the structure
2) Intensity (surface return)
3) Height based classification (classification code)
4) GPS time, scan angle and more

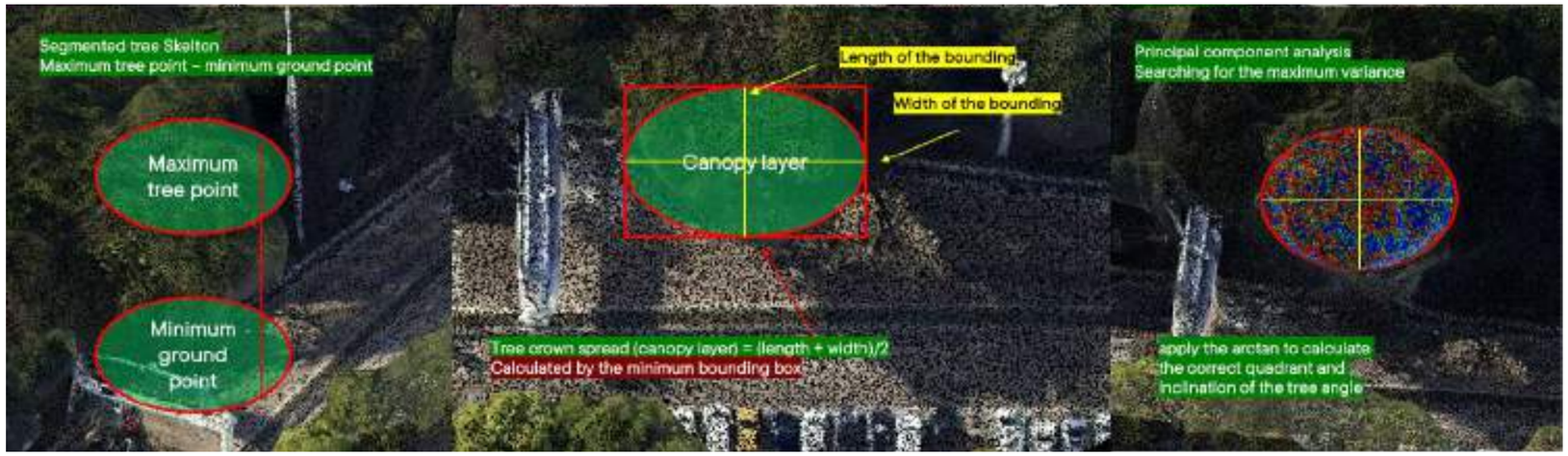
Load the data from .las to array (use pylas, numpy or pandas package to read the file
Use the default .las classification code to filter the ground and non-ground points
The non-ground vegetation point is the canopy height mode
CHM(x,y) = max(Z(x,y)) - DTM(x,y)

Run the tree point segmentation by the watershed segmentation algorithm of Vincent and Soille (1991) to identify the individual trees

The processed CHM will be treated as a topographic surface and identify the ridges and valleys that separate the watersheds of each tree.



For each of the segmented trees, computed the height, crown spread, inclination and extract the mid-point coordinates.



Height is determined by the maximum z point of the segmented tree minus the averaged height of the interpolated digital terrain model from classification code 2.

Crown spread is estimated by the Minimum bounding rectangle (MBR), the maximum and minimum x and y coordinate of the segmented crown, it is used to define the corners of the MBR, apply the distance formula to the resulted length and width of the bounding box will be the estimated crown spread.

Tree inclination is computated by the Principal component analysis (PCA), by computing the principal components of the tree points, this code is essentially finding the direction of maximum variance in the x and y coordinates of the tree points. Then, apply the arctan to calculate the correct quadrant and inclination of the tree angle.

Health monitoring and prediction

LandsD has been continuously capturing aerial imagery of trees, which can be used to compute various vegetation indices such as the Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), and Green Chlorophyll Index (GCI). These indices can be used to evaluate changes in the canopy and tree growth over time.

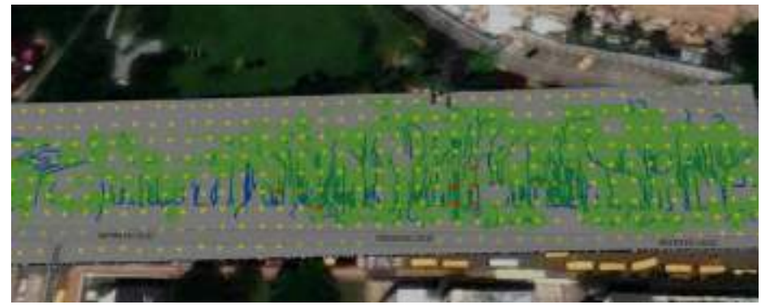
Based on the reflection and plant nature itself, the dead leaf has very low chlorophyll, anthocyanin content and reduced photosynthetic activity, stressed leaf compare has a relative higher content than the deadwood, the healthy leaf has the highest reflectance to the sensing platforms.

Canopy-slope intergrate simulation

Digital Terrain model and surface model was created and result by the Airborne LiDAR survey, the DTM shows the original terrain profile (included) the cutted and filled slopes and the DSM shows the canopy layers among the man-made slopes. Therefore, we can adopt both of them do eveulated the flow direction and simulate the flow accumulation areas.

Compute the CHM model and the flow directions from DTM and DSM. Then the DSM and result from the Auto-tree inventory can help us to plot the trees along the slope for referencing.
Calculate the flow direction and accumulation raster by the DTM, create a fishnet plotting for the data visulisation.

Then, we can make use of the flow raster to eveulate the protential root decays and damage areas that will higher flow accumulation rate.



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Recent updates and development

Spatial data are important for the smart city development, but they were not limited to the airborne and spaceborne, but also include various methods, such as the close-ranging data capture (from mobile and 360 degrees pano images).

Forestree now embrace with the *close-ranging data* that were captured with *Mobile Mapping System (MMS)* and cameras, in order to **make our urban tree safer and more resistance** during the adverse weather, such as typhoon and rainstorm.

We have recently updated and continued developing three key topics: (1) Tree Defects Diagnosis with AI, (2) Tree structural skeletonization, and (3) Leaf area index estimation with close-ranging panoramic imageries.

By deriving the tree's structure through skeletonization and estimating the leaf area index (LAI), we gain a better understanding of the tree's topology, structure, and its relationship with the urban environment. Utilizing these skeletons, we can further investigate the impact of phototropism on tree growth and identify tree species that thrive in urban conditions.

Additionally, estimating the leaf area index from panoramic images provides a valuable source of data for forest management and city development. In the past, measuring leaf area index required specialized camera tools in the field. Now we can use 360-degree panoramic images as a faster and alternative method for urban forestry and tree care.

Tree Defects Diagnosis with AI

Codeless, fast and simple
with our developed package

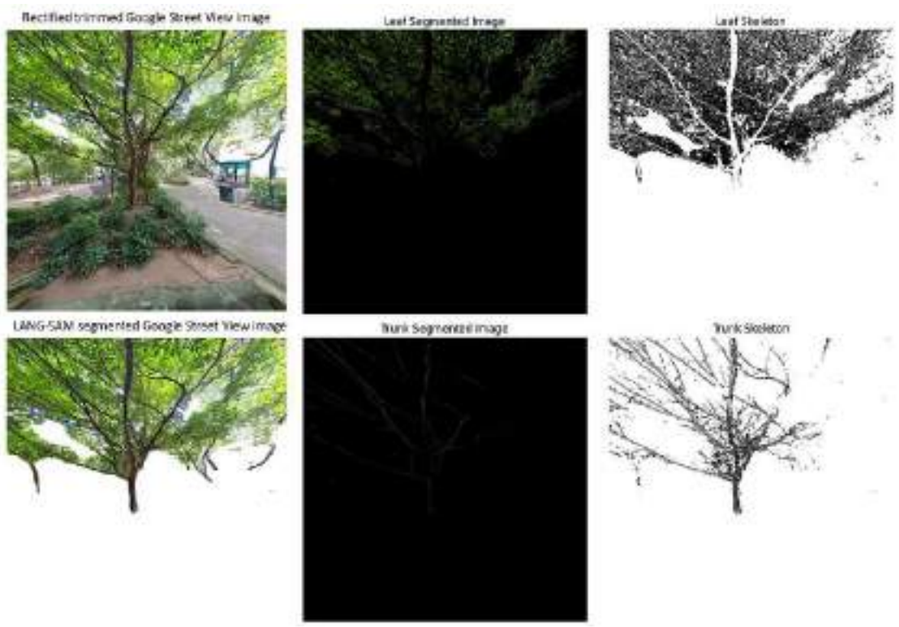
```
[ ]   image_path = "/content/Sample1.png"
      TreeAI(image_path)
```

```
Prediction: Co-dominant branches 等势枝 , 0.9375607371330261 %
Prediction: Cross branches 叠枝 , 0.02083328180015087 %
Prediction: Heavy lateral limb 重侧枝 , 0.010421091690659523 %
Prediction: Asymmetric tree canopy 树冠不对称 , 0.007757129613310099 %
Prediction: Epicormics 水横枝 , 0.0051670074462890625 %
```

Implementing an AI-based tree defect diagnosis tool can help enhance tree management services for the public. After storms, trees often become unstable due to structural issues like decay and pests/diseases. However, people may not report defects to TMO and the officials due to lack of expertise in professional terminology. While global AI models exist, but they do not align with standards set by the local Tree Management Office (TMO).

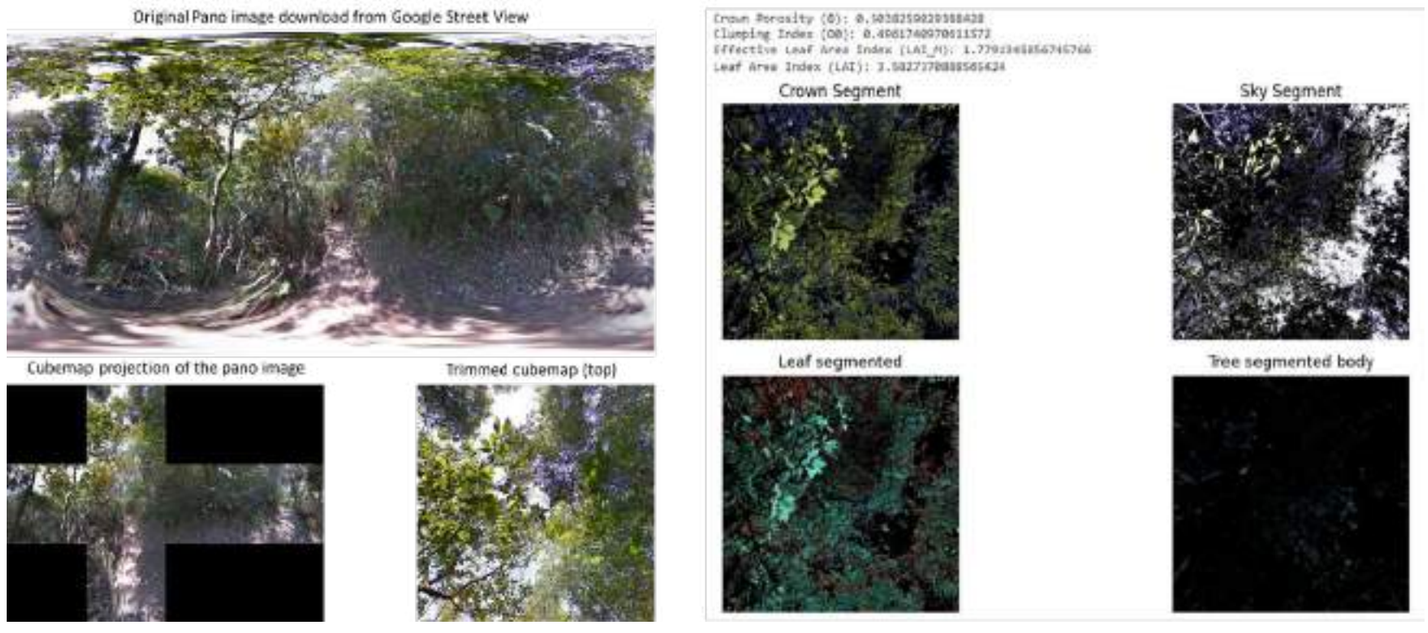
Therefore, Forestree is developing **a predictive system** to accurately scan trees, identify defects based on TMO standards, and report issues. This user-friendly AI tool will empower the public to effectively monitor tree conditions.

Tree Structural Skeletonization with Close-ranging Panoramic imagery



Forestree (2023, September). Tree Structural Skeletonization with Close-ranging Panoramic imagery. Forestree. Medium. Retrieved from https://medium.com/forestree/tree-structural-skeletonization-with-close-ranging-panoramic-imagery-d858db151efc

Leaf area index estimation with Panoramic imagery



Forestree (2023, September). Estimating Leaf area index with Polarised Pano imaging. Forestree. Medium. Retrieved from https://medium.com/forestree/estimating-leaf-area-index-with-polarised-pano-imaging-fb4a632ea839

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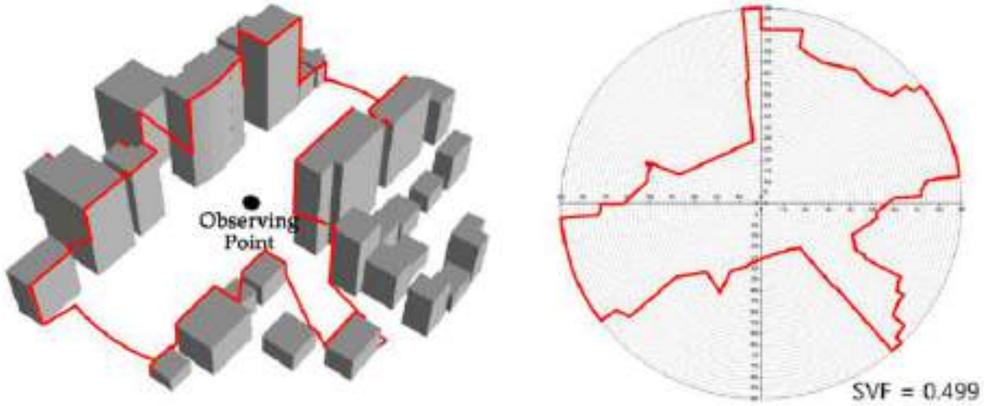
Concepts of sky view factor and leaf area index

Sky view factor

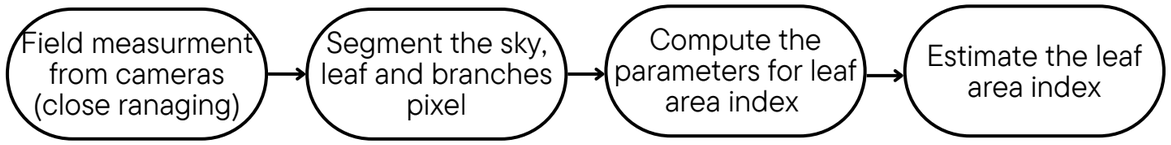
Applied commonly in urban environment
Sky view factor is a index to know the sky and surrounding coverage
If there are blocked views, the SVF will be nearly 0 and
Else if there are open sky view, the SVF will be nearly toward 1
The range of the SVF is from 0 to 1.
It assumed to be single layer determination
The way to compute the SVF, is just determine the sky pixel verse the captured total pixel
Normally, the SVF was captured from the hemispheric cameras from the urban design and urban sensing



Potential problems of the image based method to determine the leaf area index

It is about the **single and multilayering difference**
Since the image is single layer, two dimensional will not enough for leaf area computation
Establishing the Empirical coefficient and relationship will not be a "correct" solutions, since the coefficient will be changes in various forest environment (such as broad leaf, needle-like leafs and pan-like)

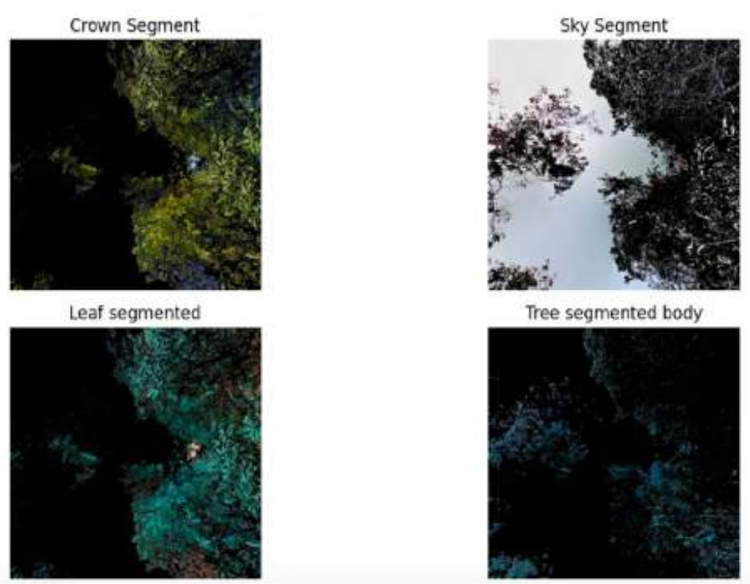
Implentation
(1) Determine the sky, branches and leaf pixel with color based segmentation
(2) Compute the fractions of foliage cover and crown cover, crown porosity, clumping index, light extinction coefficient
Here we assumed that those index can help us to determine the multilayering of the leaf areas
(3) Estimate the effective leaf area index by those paramters



Leaf area index

applied in forestry and remote sensing
Leaf area index is a index to know the leafs total area within a particular area
It was not simply compute the coverage of the sky and the leaf
Since the leaf area will be multi-layered among the forest
Therefore simple single layer determination will not be enough
If there are dense and complex forest, the LAI will around 5+,
If there are less dense and simple forest, the LAI will be around 0 and <1
The LAI can be determined with close ranging images with Empirical formulas

More Empirical coefficient are still developing for the LAI with images
The way to compute the LAI, is to determine the sky pixel verse the captured leaf pixels, ignored the trunk and branches pixels
Normally, the LAI need to apply the empirical formulas to compute the fractions of foliage cover and crown cover, crown porosity, clumping index, light extinction coefficient, effective leaf area index and estimated leaf area index.



Still the process and formula will not works well when there are too many overlapping tree leafs in the sample areas, therefore the LiDAR and active remote sensing is more accurate and efficient to determine the leaf area index

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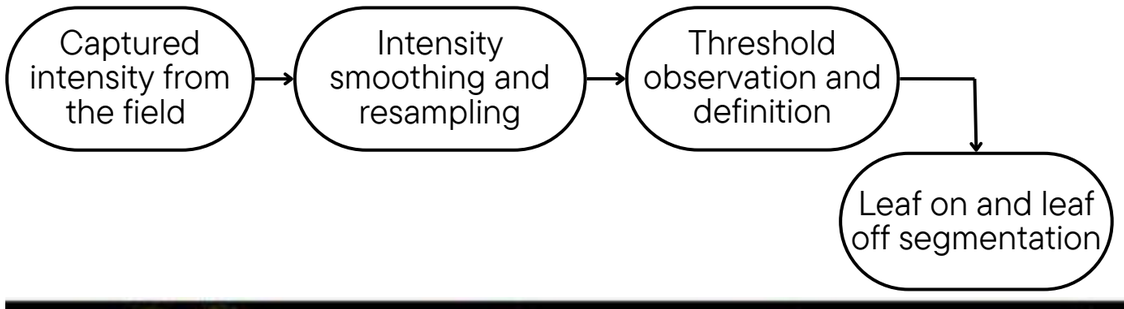
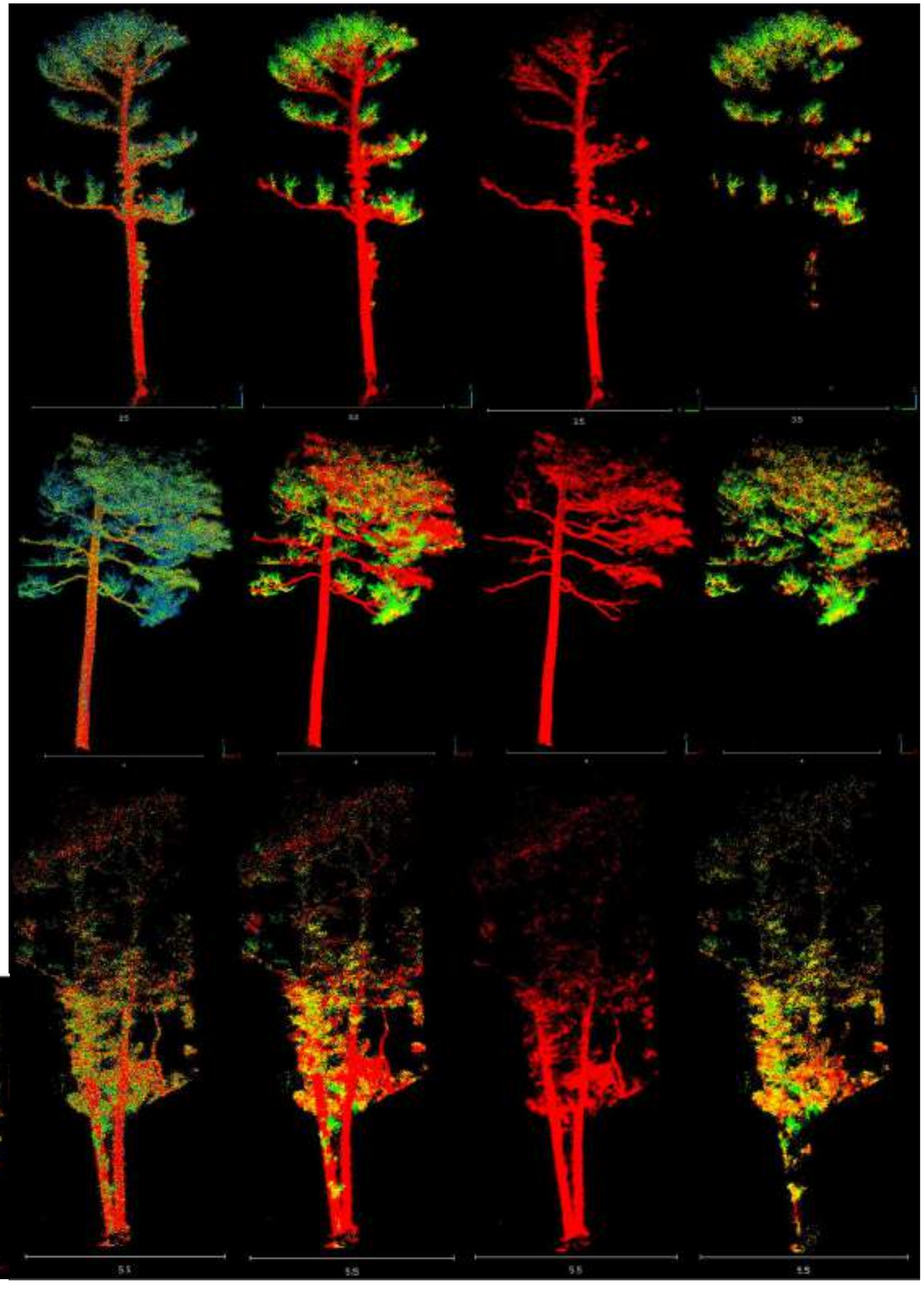
Intensity based leaf on and leaf off segmentation

Assumption
- Intensity is the captured surface reflectance from the returned light beam
- Trunk and leafs should have a distant difference among the intensity

Implementation
- Remove the noise from the LiDAR
- Apply intensity resampling and smoothing
- Segment the leaf and trunk by an observed threshold

Problems, validation and improvement
- Observed threshold will be various across different sensing platform
- The boundary between the leaf and branch may not be clearly differentiated -> smoothing leading some of the leaf/ trunk points is wrongly depicted
- Weighting and geometric parameters should be add together to evaluate the edge of the leaf and branches
- Such as the planarity, surface variance, curvature and more geometric characteristics of that point can be a weighted field for the detail edge determination of the leaf on and off point cloud segmentation
- Threshold of the intensity should be corrected to the sensor, similar value of threshold are more preferable within the same species of trees -> the threshold may be different depending the species, but same species should be similar and close to each other





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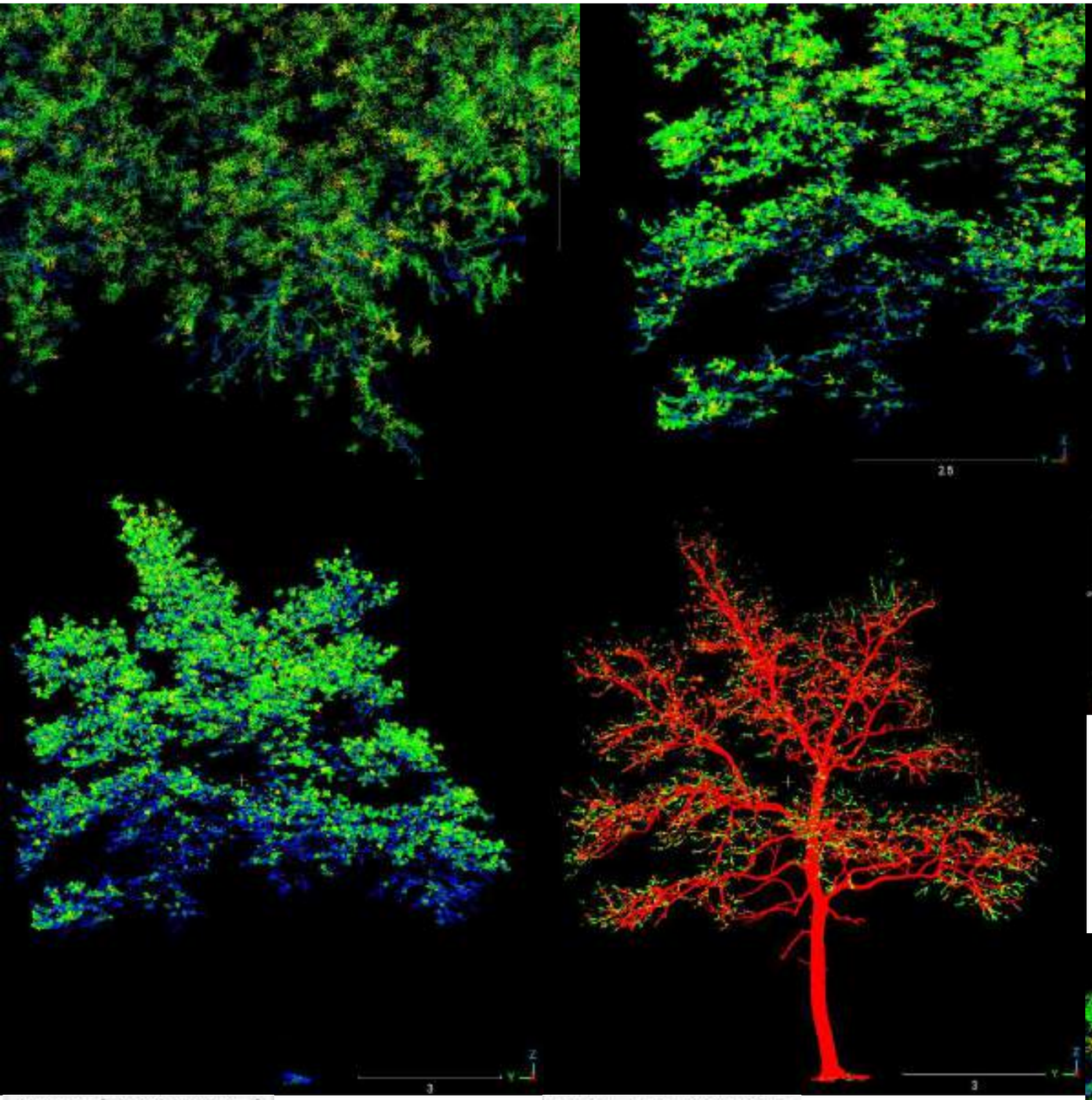
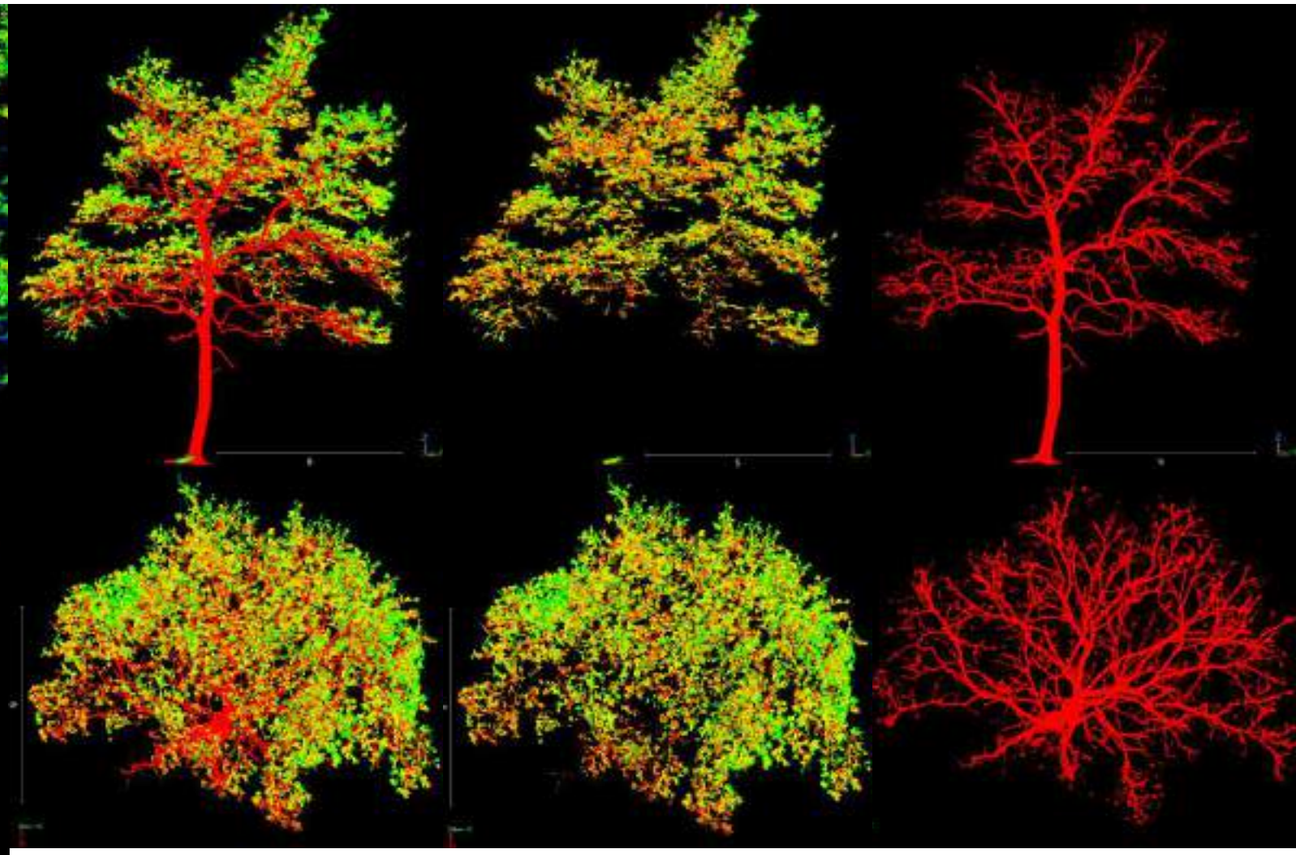
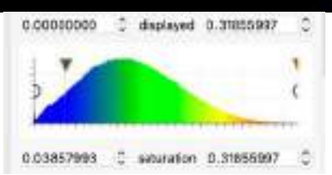
Intensity based leaf on and leaf off segmentation validations and enhancement





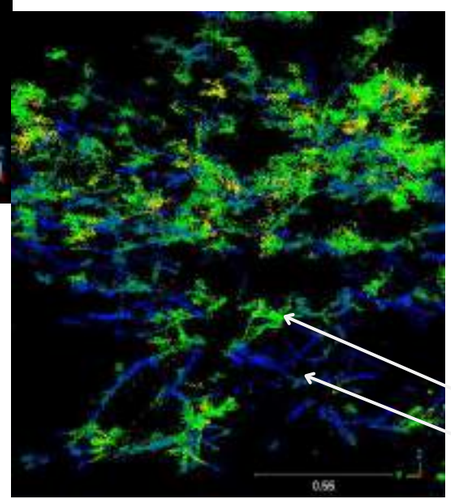
Original Tree point cloud, Leaf-on and Leaf-off segmentation result

Threshold observation and definition → Leaf on and leaf off segmentation → Curvature segmentation → Finalised segmented tree



Scaler field: curvature of the leafs

Scaler field: smoothed intensity
with post-processed curvature segmentation



Curvature is the rate of change of the surface normal vector. Leaves tend to have different shapes and curvatures compared to branches. On the other hand, branches tend to have lower curvature values compared to leaves. The main trunk and larger branches generally has smoother and less curved surfaces.
By analyzing the curvature values in the point cloud, we can identify regions with relatively low curvature, which correspond to smoother parts of the tree structure. These areas represent branches or trunks.

Leaf

Branches

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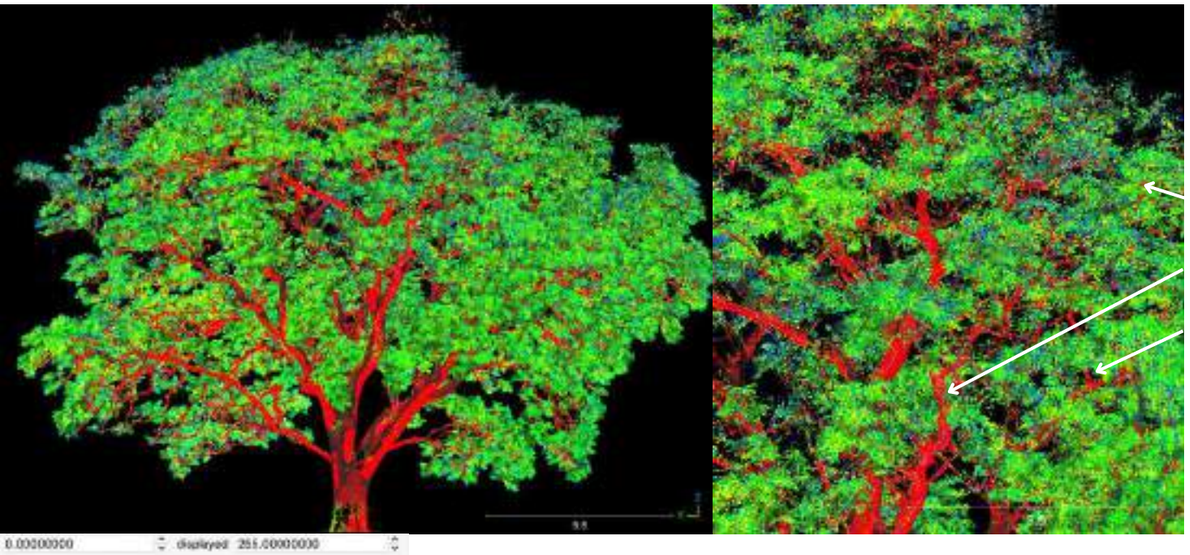
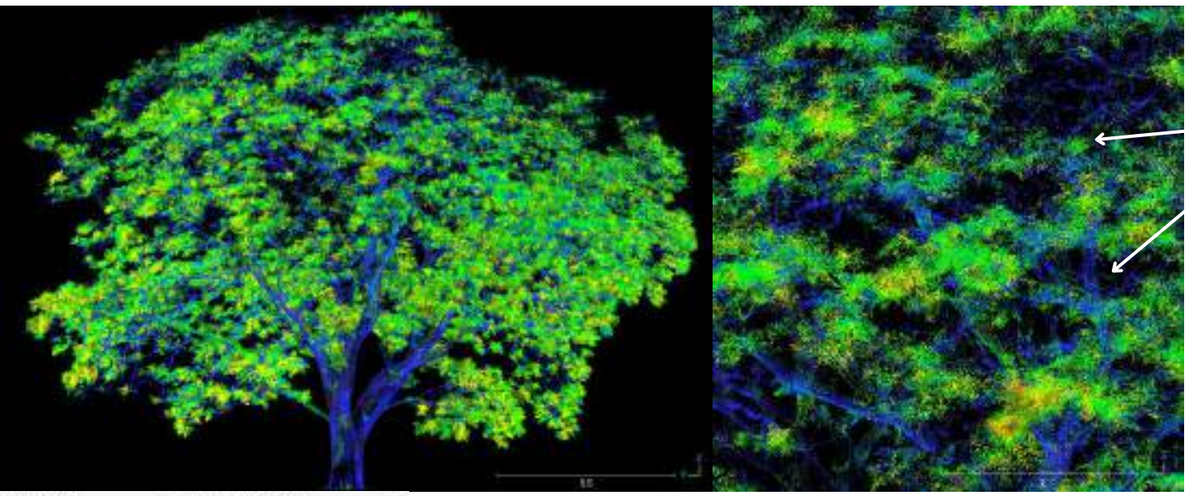
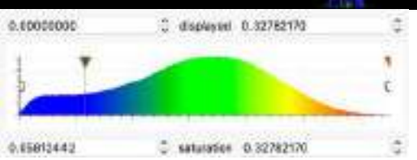
Intensity based leaf on and leaf off segmentation validations and enhancement

Threshold observation and definition → Leaf on and leaf off segmentation → Curvature segmentation → Finalised segmented tree



Intensity based method
The leaf and trunks should have a distant differences in terms of the reflectance.

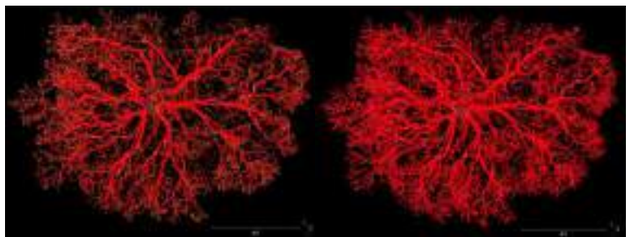


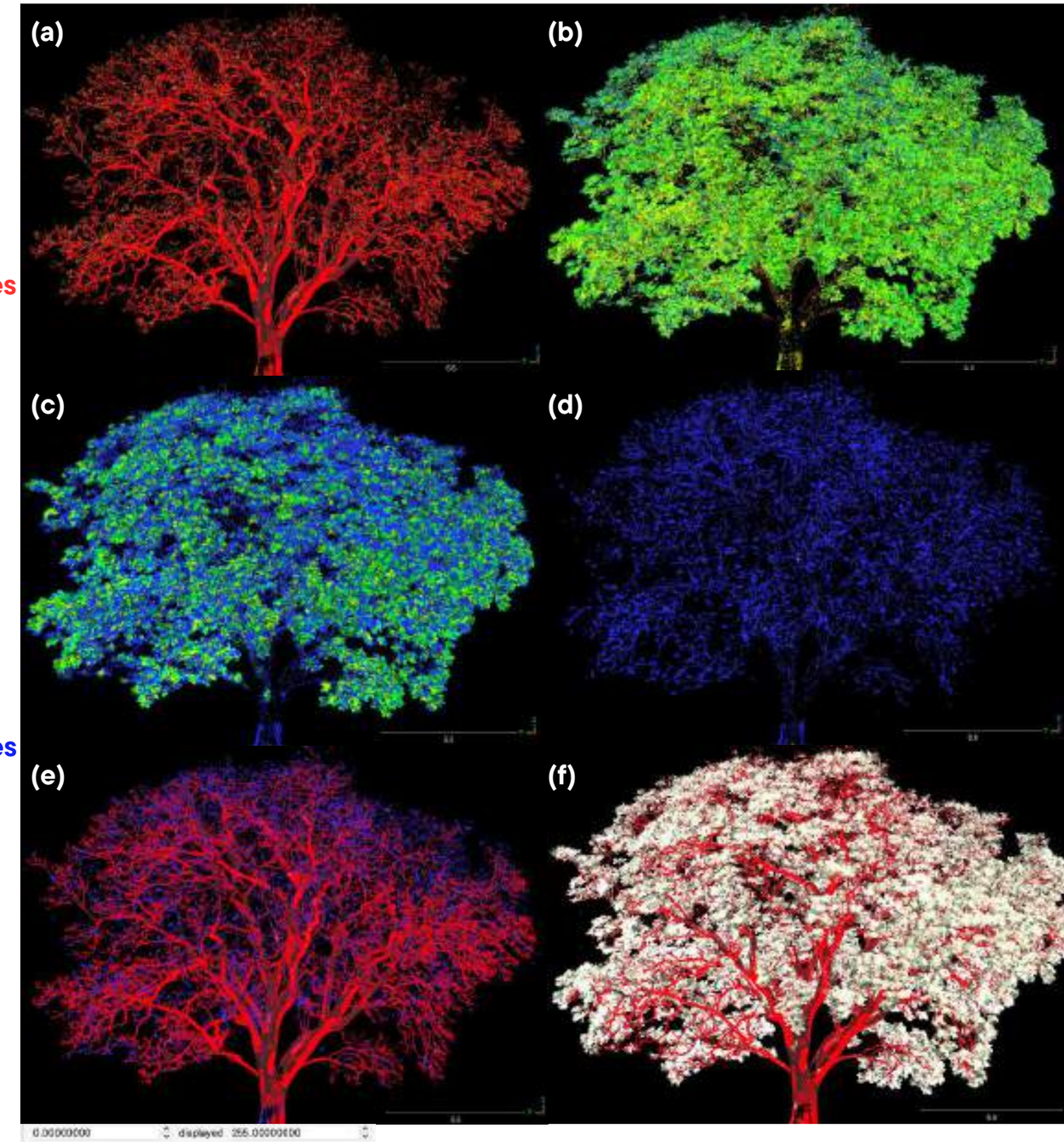


Geometric (curvature) based method
The leaf will have a higher curvature than the trunk and most of the branches will has lower curvature, since the trunk and branches are smoother and less curved surfaces.

Fusion approches
Since intensity based approches will not hunderd percent segment all the trunk and branches, so after intensity based method, the we can apply the curvature approches to segment the trunk and branches finner.

Intensity based (left) and fusion approches (right)





(a) intensity based segmented trunk and branches
(b) intensity based segmented leafs
(c) curvature based scaler field after intensity segmentation
(d) curvature based refined segmented trunk and branches
(e) finalised intensity and curvature based segmented branches and trunk
(f) finalised segmented leaf-on and leaf-off point cloud

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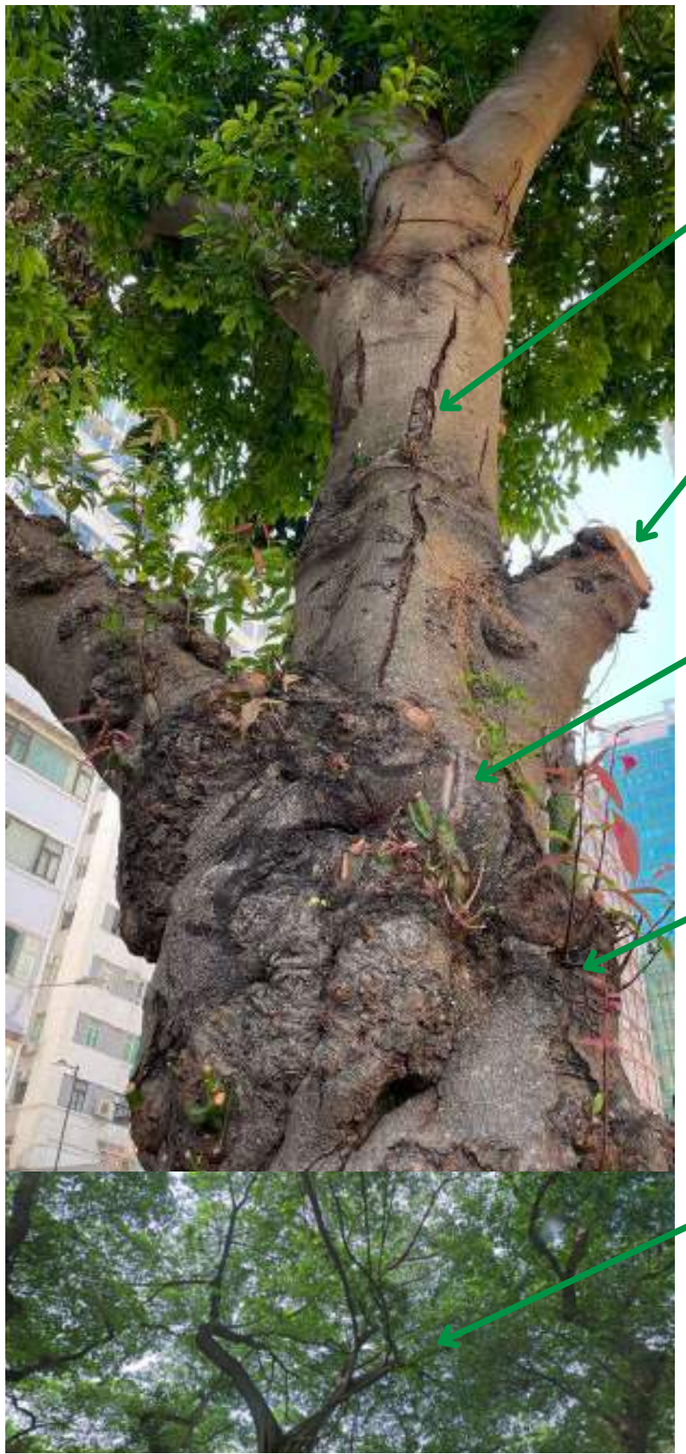
More information about tree structure signals and their body language



Trees have ways of communicating and interacting with their environment through their structure and behavior.

Cavity in trunk
When a branch is injured during typhoon, it will expose the inner wood to the elements and create entry points for pathogens

Cracks or Fissures on the trunk
Those cracks will implies the force and protential leading direction, crown thinning is need to balance the and avoiding futher leading and structural imbalance.

Topping
Tree topping is a common tree cutting approches, to removes a significant portion of a tree's foliage

Swelling trunk
It was casued by certain diseases and infections can cause swelling in tree trunk.

Epicormic shoot
These epicormic are those arise from dormant buds located along the trunk. It can provide new growth and rejuvenation in trees, they often grow rapidly and can be weakly attached to the tree

Co-dominated trunk
Co-dominant trunks can pose structural risks to trees. The attachment between the trunks tends to be weak, with included bark between them.

Pests and Diseases
Termite cause damage to the wood and weaken the structural integrity of the trees

Diebacks
Diebacks is the progressive deterioration and death of branches or the entire crown of a tree

Strangler fig
Strangler figs begin their lives as epiphytes, meaning they sprout in the branches of other trees. Over time, the roots of the strangler fig will fuse together to form a trellis-like structure that may cause the host tree to weaken and die.

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Tree care and managment in action

Case study of the epicormics and improper tree trimming

Upper left : 2008 after tree topping, bottom left: 2014
Right: 2018, These images is from Noel Lau

Before typhoon “Koinu” 2023

After the typhoon “Koinu” 2023

Improper tree trimming and topping
Only some of the tree's branches on the left side have been left untouched, while the majority of branches have been severely topped, likely due to damage from a typhoon. This approach results in several issues, primarily centered around the imbalance and structural integrity of the tree.

After topping and epicormics competition
Epicormic shoots have sprouted from Latent buds after tree was topped. When epicormic growth is not actively pruned, it competes with the existing branches and the main stem for sunlight, nutrients, and water. This competition can weaken the tree, alter its structure, and potentially lead to health issues.

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Tree care and common disease in Hong Kong

Tilting sensors are not available to determine the tree defects below, so the image-based method with mobile mapping system can effectively delineate the tree structure defects for a large scale application.

Powdery mildew
Powdery mildew is a fungal disease that creates a white or gray powdery growth on the leaves, stems, and fruits of infected trees.

Phauda flammans
Phauda flammans larvae (larvae) feed on leaves to survive and are commonly found on Ficus trees.

Termite
Termites are insects that eat wood. They can cause significant damage to trees by tunneling through the wood and weakening the tree's structure and depleting its nutrients.

Lignotuber
Wood tubers are woody swellings or structures found on or below the surface of certain plant species, mainly woody perennials.

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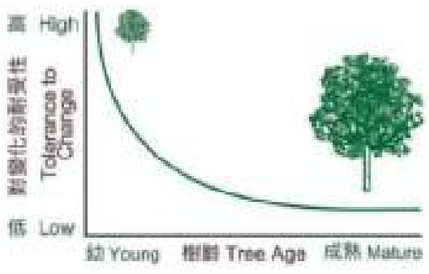
Background and story behind

Trees go through a natural cycle of growth, aging, and death, and many of the trees planted in Hong Kong during the 1950s and 60s are now reaching the end of their lifespan.

Tree collapse occurs in their senescence and death period



Video about about the Smarat city, Tree, You and I (in Cantonese) 智慧城市、樹木與你我

樹木管理混亂　業界倡優化架構

2023-01-30 00:47:49 香港

five bureau and nine departments involved in tree management

〔大公報記者 盛德文〕近年香港發生多宗塌樹傷亡事故，情況令人心痛。現時政府管理的樹木逾170萬棵，多年來政府一直以「綜合管理方式」管理樹木，由樹木所在地或設施的部門，同時負責護養管理該範圍內的樹木，部門不但涉及「五局九署」且互不隸屬，同一地段內的樹木，咫尺間可能已涉及多個不同的管理部門，出現灰色地帶而相互「推諉」。

申訴專員公署去年曾指出本港的樹木管理制度需要改善，支持訂立樹木法。有業界及立法會議員建議參考內地城市的園林局或新加坡的國家公園局，優化架構，建立樹養師註冊條例和制度，提升管理效能。

The major challage of the urban foresry is the

- Lack of Tree care professionals
- No complete forest statistics in Hong Kong

No inter-departmental cooperations

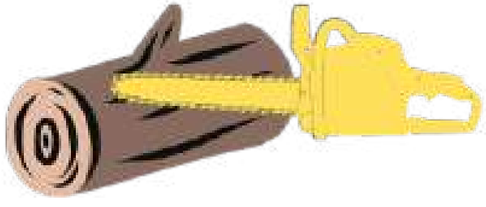
In our tree management workflow and process,
10,000-30,000 Trees per staff

How Forestree toward ESG win-win situation with CSDI Open data

Automatically Tree inventory application
Developers and policy makers can make use of our application to generate a **quantitative tree inventory report** for their final decision.

Data collected by CEDD LiDAR point cloud and colorized by LandsD aerial image

Deciding and Optimisation
If the lands development need to deforestated/ cut off some of the vegtatation covers, **optimisation and minimised the logging area** can be with Forestree.



Monitoring and management
From aerail imageries, we are avaliable to **retrive the tree health conditions** and manage with remote sensing techniques **to keep our forest safe**.

About our team

Group of student from Land surveying and Geo-informatics, PolyU
Keen on GIScience, Remote sensing, Photogrammetry and Forestry.

For Forestree project and application details, please contact kai-him-otto.yu@connect.polyu.hk (Otto Yu).

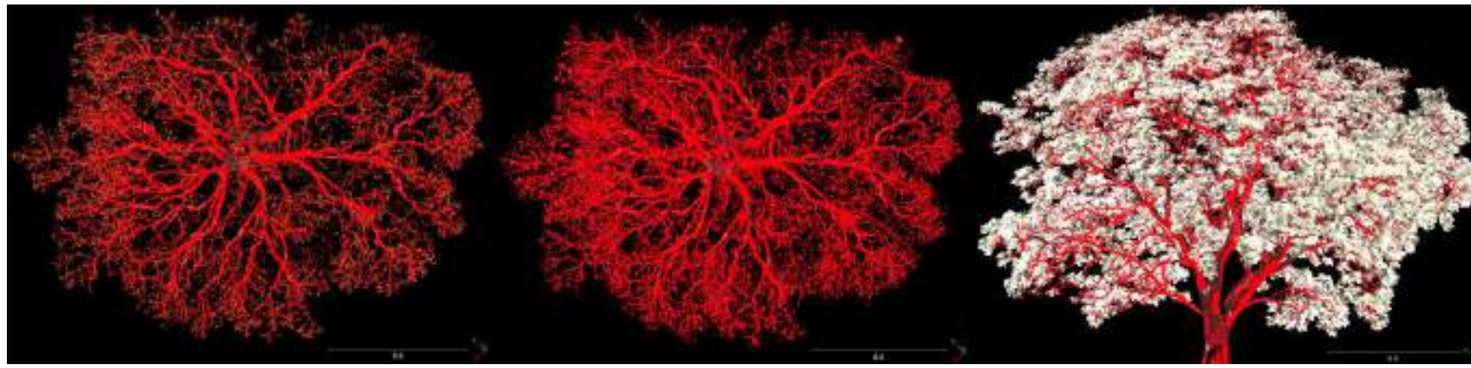
Forestree
Remote sensing and Forestry

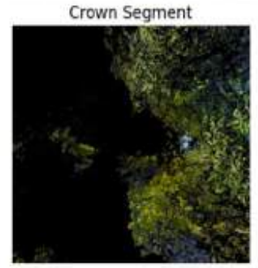
Support Us

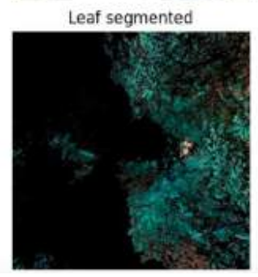
Data is very important for research and development
As a student orientated research team, we are looking for large geospatial company and government are willing to send us data for further development on the segmentation, health detections and more ground validations.

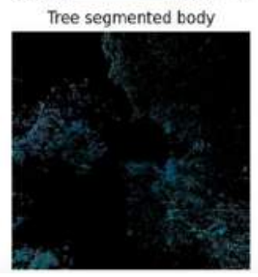
Your data will be enhancing the forestry and remote sensing development in Hong Kong, no matter it is airborne, handheld, Mobile Mapping system or backpack. We will only use them for research purpose and keep it confidentially.

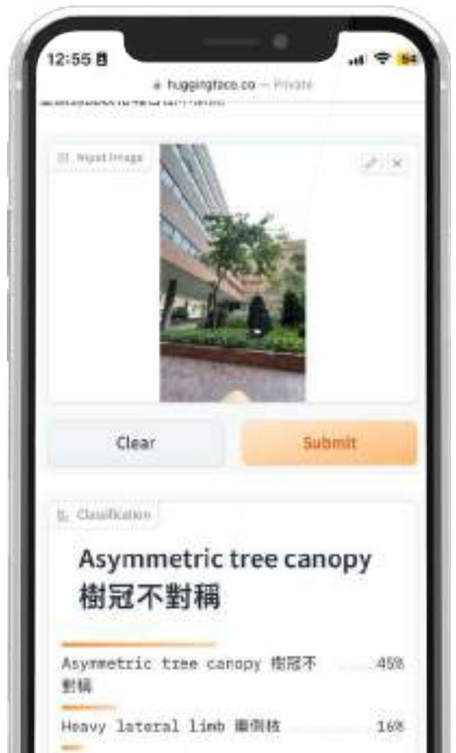
We are not aiming for startup or commercialization those research output, **Forestree is a volunteering campaign** to study and development innovation solution for the urban and rural forestry with remote sensing.











Codeless, fast and simple
with our developed package

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```

```
Prediction: Co-dominant branches 等勢枝 , 0.9375607371330261 %
Prediction: Cross branches 叉枝 , 0.02083328180015087 %
Prediction: Heavy lateral limb 重側枝 , 0.010421091690659523 %
Prediction: Asymmetric tree canopy 樹冠不對稱 , 0.007757129613310099 %
Prediction: Epicormics 水橫枝 , 0.0051670074462890625 %
```

About us:

Contact Us with
otto-kh.yu@connect.polyu.hk (Otto Yu, Student from LSGI)