Extracting DBH Measurements from RGB Photo Images

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Contents

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Introduction

01 Introduction

01 Forest inventory

- Requires significant financial investment.
- Also labor intensive.
- Great importance

02 Tools

- Direct Measurements
- Indirect Measurements
  - ✓ Regression models
  - ✓ Laser technology
  - ✓ Photos with computer vision

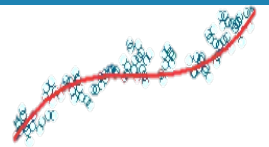
Direct measurement

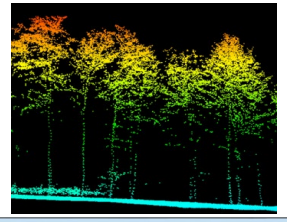
Diameter tapes

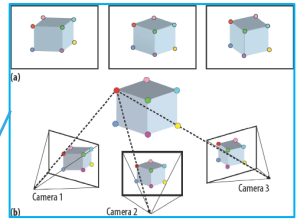
Calipers

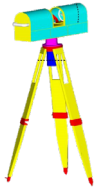
Biltmore stick

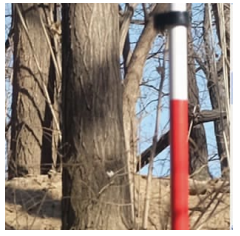
01 Introduction









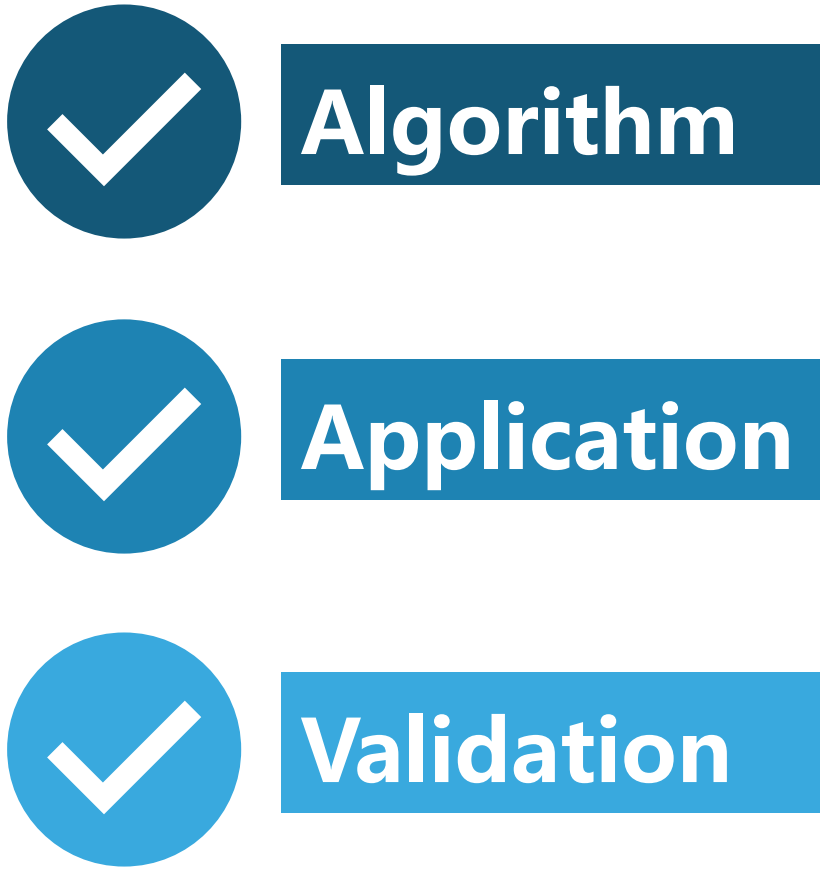


- Indirect Measurements
  - Regression model
  - Laser technology
    - Direct measuring
      - Laser dendrometers
      - Hand-held laser survey instrument
    - LiDAR (3D)
      - Ground-based
      - Airborne laser scanner
    - 2D laser scanner
  - Photos with computer vision
    - Structure from motion (SfM)
    - Estimate scale
      - Benchmark assist
      - Laser point assist

01 Introduction

Our work

- Designed an **algorithm** based on **vanishing point horizon** to extract and calculate DBH from photos.
- Made an open source **software** called ImageDBH in Python3.5.
- **Validated** the calculated results by field measurements.



02

Methods

02 Methods

2.1 Site

Noonan plot, Fredericton,
New Brunswick, Canada.

2.2 Instrument

DIY laser scanner

2.3 Algorithm

Triangular similarity
Analytic geometry

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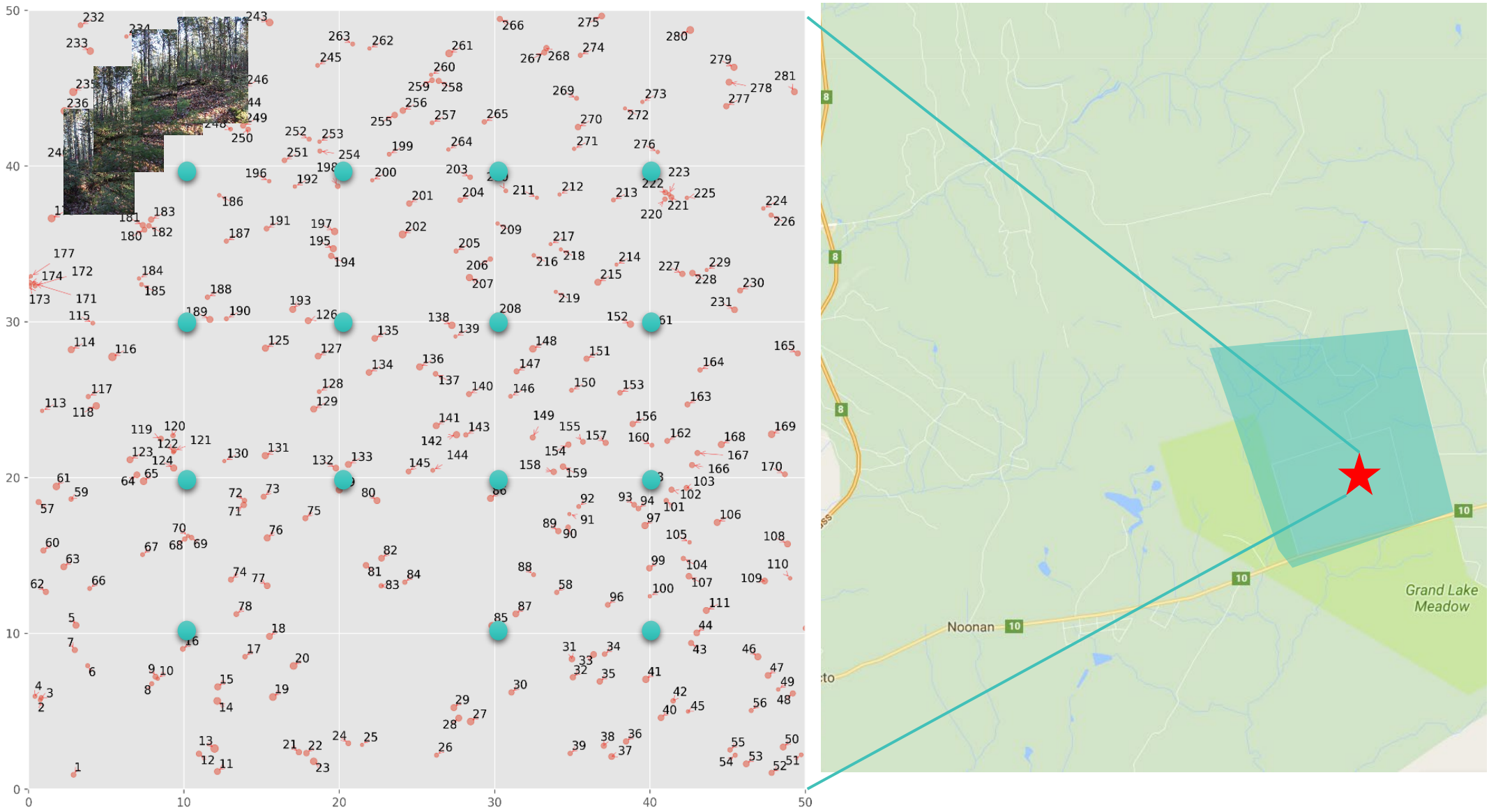

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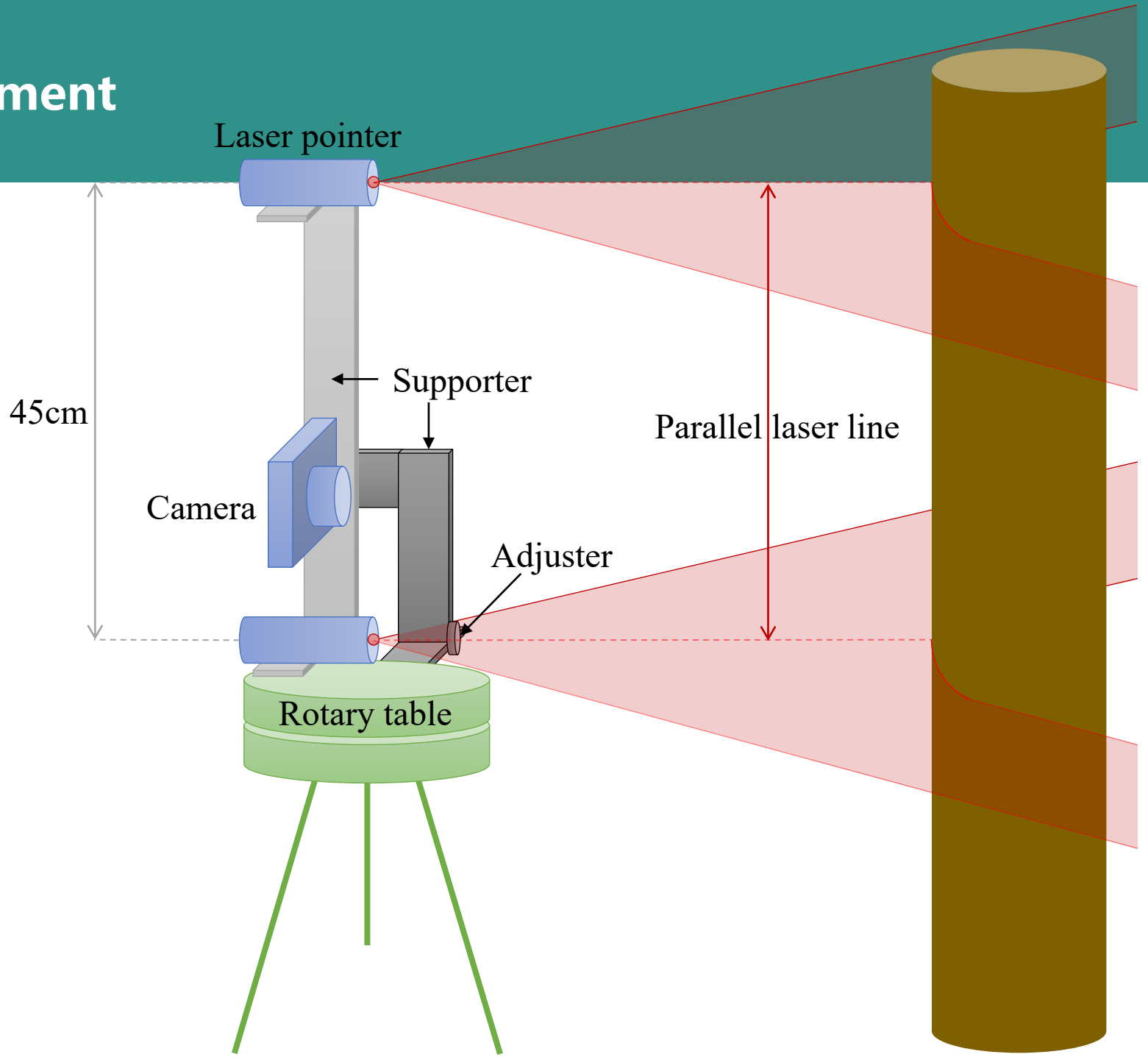

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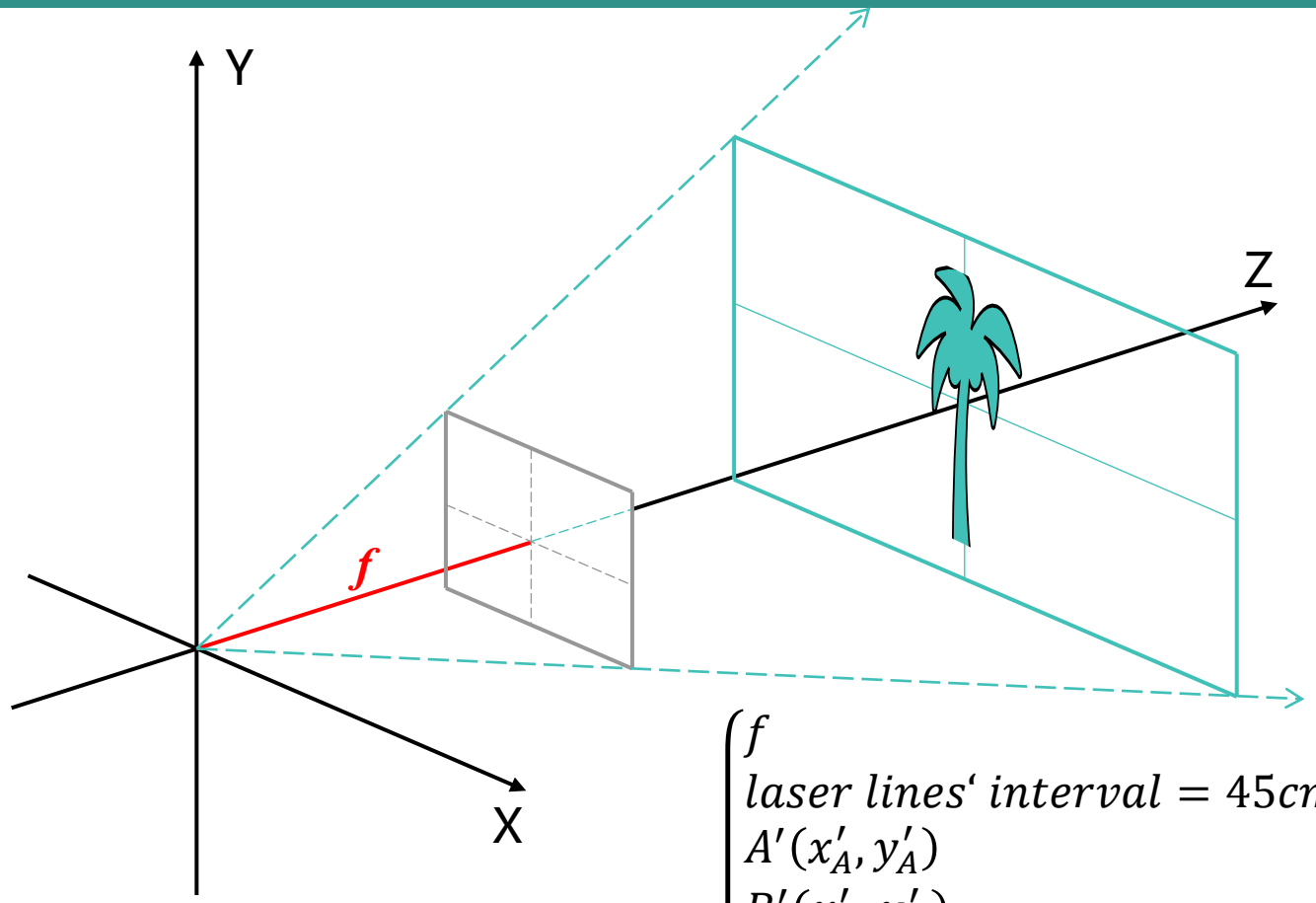
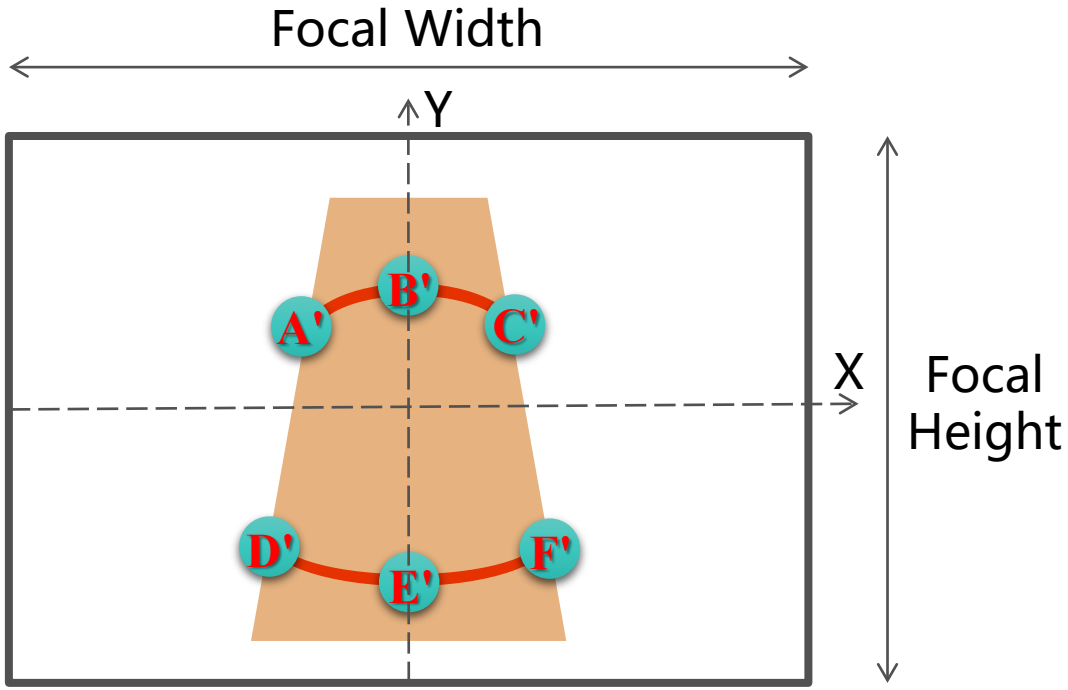
2.3 Algorithm - Overview





What we known:

$$\begin{cases} f \\ laser\ lines'\ interval = 45cm \\ A'(x'_A, y'_A) \\ B'(x'_B, y'_B) \\ C'(x'_C, y'_C) \\ D'(x'_D, y'_D) \\ E'(x'_E, y'_E) \\ F'(x'_F, y'_F) \end{cases}$$

What we want to be represented:

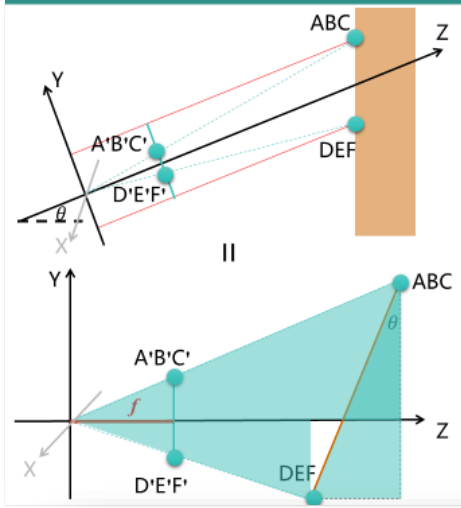
$$\begin{cases} tan\theta\ (camera\ elevation) \\ Distance \\ DBH = 2 * r \end{cases}$$

* f = Focal length
  Points on real tree: A
  Points on photo: A'

2.3 Algorithm - Overview

2.3 Algorithm - Side View

$$* \; z'_{A|B|C|D|E|F} = z'_A \; OR \; z'_B \; OR \; z'_C \; OR \; z'_D \; OR \; z'_E \; OR \; z'_F$$

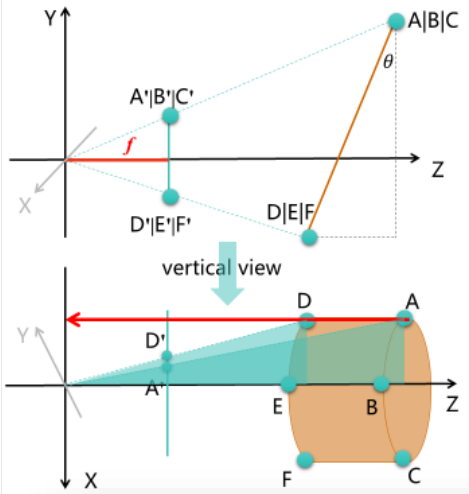


$$\begin{cases} z'_{A|B|C|D|E|F} = f \\ y'_{A|B|C|D|E|F} = \dfrac{y_{A|B|C|D|E|F} \times f}{z_{A|B|C|D|E|F}} \end{cases} \Rightarrow z_{A|B|C|D|E|F} = \frac{y_{A|B|C|D|E|F} \times f}{y'_{A|B|C|D|E|F}} \quad (1\text{-}1)$$

$$\begin{cases} tan\theta_{l|c|r} = \dfrac{z_{A|B|C} - z_{D|E|F}}{y_{A|B|C} - y_{D|E|F}} \\ 45\ cm = y_{A|B|C} - y_{D|E|F} \end{cases} \Rightarrow \begin{cases} z_{A|B|C} - z_{D|E|F} = 45\ tan\theta_{l|c|r} & (2) \\ y_{A|B|C} - y_{D|E|F} = 45 & (3) \end{cases}$$

$(laser\ line\ interval)$

2.3 Algorithm - Vertical View



$$z_{A|B|C|D|E|F} = \frac{y_{A|B|C|D|E|F} \times f}{y'_{A|B|C|D|E|F}} \quad (1\text{-}1)$$

$$\begin{cases} z_{A|B|C} - z_{D|E|F} = 45\ tan\theta_{l|c|r} & (2) \\ y_{A|B|C} - y_{D|E|F} = 45 & (3) \end{cases}$$

$$\begin{cases} x_{A|B|C} = x_{D|E|F} & (4) \\ x'_{A|B|C|D|E|F} = \dfrac{x_{A|B|C|D|E|F} \times f}{z_{A|B|C|D|E|F}} \end{cases} \Rightarrow z_{A|B|C|D|E|F} = \frac{x_{A|B|C|D|E|F} \times f}{x'_{A|B|C|D|E|F}} \quad (1-2)$$

$$(1\text{-}1) + (1\text{-}2) \Rightarrow y_{A|B|C|D|E|F} = \frac{y'_{A|B|C|D|E|F}}{x'_{A|B|C|D|E|F}} \cdot x_{A|B|C|D|E|F} \quad (5)$$

$$(3) + (5) \Rightarrow \frac{y'_{A|B|C}}{x'_{A|B|C}} \cdot x_{A|B|C} - \frac{y'_{D|E|F}}{x'_{D|E|F}} \cdot x_{D|E|F} = 45$$

$$+ (4) \Rightarrow \left(\frac{y'_{A|B|C}}{x'_{A|B|C}} - \frac{y'_{D|E|F}}{x'_{D|E|F}}\right) \cdot x_{A|B|C} = 45$$

$$\Rightarrow x_{A|B|C} = x_{D|E|F} = \frac{45}{\left(\frac{y'_{A|B|C}}{x'_{A|B|C}} - \frac{y'_{D|E|F}}{x'_{D|E|F}}\right)} \quad (6)$$

2.3 Algorithm - Deduction

(6) + (1-2) »

$$(7) \begin{cases} z_{A|B|C} = \dfrac{f}{x'_{A|B|C}} \times x_{A|B|C} = \dfrac{f}{x'_{A|B|C}} \times \dfrac{45}{\left(\frac{y'_{A|B|C}}{x'_{A|B|C}} - \frac{y'_{D|E|F}}{x'_{D|E|F}}\right)} \\ z_{D|E|F} = \dfrac{f}{x'_{D|E|F}} \times x_{D|E|F} = \dfrac{f}{x'_{D|E|F}} \times \dfrac{45}{\left(\frac{y'_{A|B|C}}{x'_{A|B|C}} - \frac{y'_{D|E|F}}{x'_{D|E|F}}\right)} \end{cases}$$

(2) + (7) »

$$45 \cdot tan\theta_{l|c|r} = \frac{f}{x'_{A|B|C}} \times \frac{45}{\left(\frac{y'_{A|B|C}}{x'_{A|B|C}} - \frac{y'_{D|E|F}}{x'_{D|E|F}}\right)} - \frac{f}{x'_{D|E|F}} \times \frac{45}{\left(\frac{y'_{A|B|C}}{x'_{A|B|C}} - \frac{y'_{D|E|F}}{x'_{D|E|F}}\right)}$$

$$tan\theta_{l|c|r} = f \cdot \frac{\frac{1}{x'_{A|B|C}} - \frac{1}{x'_{D|E|F}}}{\frac{y'_{A|B|C}}{x'_{A|B|C}} - \frac{y'_{D|E|F}}{x'_{D|E|F}}}$$

$$z_{A|B|C|D|E|F} = \frac{y_{A|B|C|D|E|F} \times f}{y'_{A|B|C|D|E|F}} \quad (1\text{-}1)$$

$$\begin{cases} z_{A|B|C} - z_{D|E|F} = 45\ tan\theta_{l|c|r} & (2) \\ y_{A|B|C} - y_{D|E|F} = 45 & (3) \end{cases}$$

$$\begin{cases} x_{A|B|C} = x_{D|E|F} & (4) \\ x'_{A|B|C|D|E|F} = \dfrac{x_{A|B|C|D|E|F} \times f}{z_{A|B|C|D|E|F}} \end{cases} \Rightarrow z_{A|B|C|D|E|F} = \frac{x_{A|B|C|D|E|F} \times f}{x'_{A|B|C|D|E|F}} \quad (1-2)$$

$$(1\text{-}1) + (1\text{-}2) \Rightarrow y_{A|B|C|D|E|F} = \frac{y'_{A|B|C|D|E|F}}{x'_{A|B|C|D|E|F}} \cdot x_{A|B|C|D|E|F} \quad (5)$$

$$(3) + (5) \Rightarrow \frac{y'_{A|B|C}}{x'_{A|B|C}} \cdot x_{A|B|C} - \frac{y'_{D|E|F}}{x'_{D|E|F}} \cdot x_{D|E|F} = 45$$

$$+ (4) \Rightarrow \left(\frac{y'_{A|B|C}}{x'_{A|B|C}} - \frac{y'_{D|E|F}}{x'_{D|E|F}}\right) \cdot x_{A|B|C} = 45$$

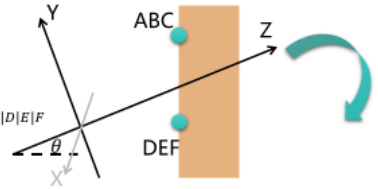
$$\Rightarrow x_{A|B|C} = x_{D|E|F} = \frac{45}{\left(\frac{y'_{A|B|C}}{x'_{A|B|C}} - \frac{y'_{D|E|F}}{x'_{D|E|F}}\right)} \quad (6)$$

2.3 Algorithm – Coordinate Rotation

$$(8) \begin{cases} x_{A|B|C} = x_{D|E|F} = \dfrac{45}{\left(\frac{y'_{A|B|C}}{x'_{A|B|C}} - \frac{y'_{D|E|F}}{x'_{D|E|F}}\right)} \\ y_{A|B|C|D|E|F} = \dfrac{y'_{A|B|C|D|E|F}}{x'_{A|B|C|D|E|F}} \cdot x_{A|B|C|D|E|F} \\ z_{A|B|C|D|E|F} = \dfrac{y_{A|B|C|D|E|F} \times f}{y'_{A|B|C|D|E|F}} \end{cases}$$

$$\theta_{l|c|r} = arctan\left(f \cdot \frac{\frac{1}{x'_{A|B|C}} - \frac{1}{x'_{D|E|F}}}{\frac{y'_{A|B|C}}{x'_{A|B|C}} - \frac{y'_{D|E|F}}{x'_{D|E|F}}}\right)$$

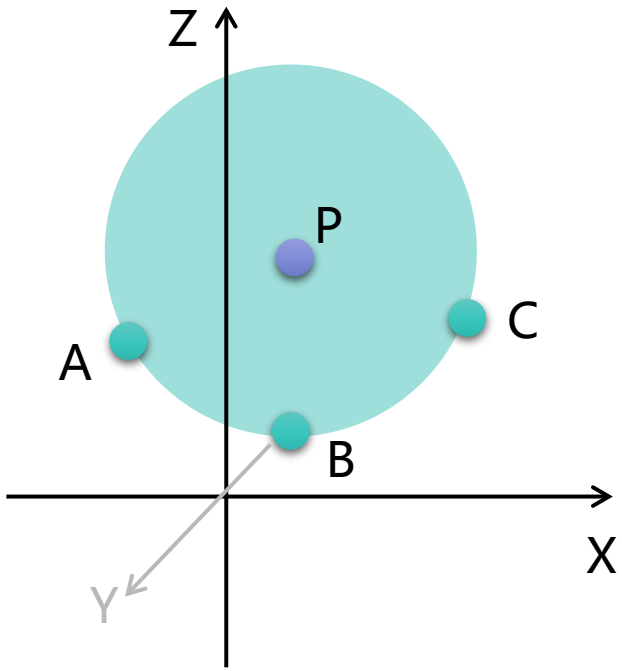
$$\theta_t = \frac{|\theta_l - \theta_c| + |\theta_r - \theta_c|}{2} \quad (9)$$



$$(10) \begin{cases} y' = zsin\theta_t + ycos\theta_t \\ z' = zcos\theta_t - ysin\theta_t \end{cases}$$

$$(8)+(9)+(10) \Rightarrow \begin{cases} A(x_A, y_A, z_A) \\ B(x_B, y_B, z_B) \\ C(x_C, y_C, z_C) \\ D(x_D, y_D, z_D) \\ E(x_E, y_E, z_E) \\ F(x_F, y_F, z_F) \end{cases} \text{ in new coordinate system XY'Z'}$$

2.3 Algorithm - Radius Calculation



$$\begin{cases} A(x_A, y_A, z_A) \\ B(x_B, y_B, z_B) \\ C(x_C, y_C, z_C) \\ D(x_D, y_D, z_D) \\ E(x_E, y_E, z_E) \\ F(x_F, y_F, z_F) \end{cases}$$

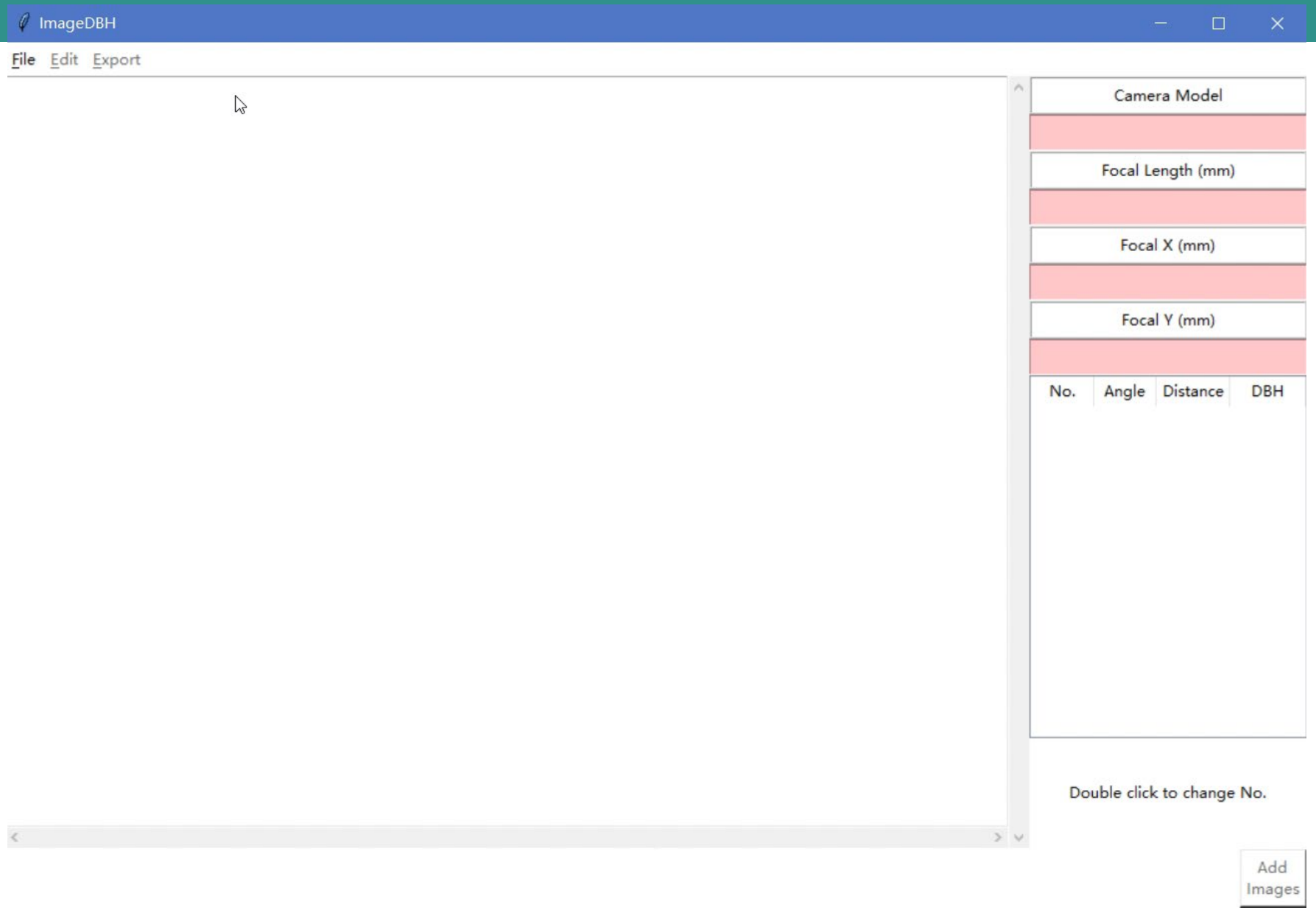
$$\begin{cases} A1 = x_A - x_B \\ B1 = z_A - z_B \\ C1 = \dfrac{x_A^2 - x_B^2 + z_A^2 - z_B^2}{2} \\ A2 = x_C - x_B \\ Bx = z_C - z_B \\ C2 = \dfrac{x_C^2 - x_B^2 + z_C^2 - z_B^2}{2} \\ denom = A1 \times B2 - A2 \times B1 \end{cases} \quad \text{»} \quad \begin{cases} (denom = 0) \begin{cases} x_P = x_A \\ z_P = z_A \end{cases} \\ (denom \neq 0) \begin{cases} x_P = \dfrac{C1 \times B2 - C2 \times B1}{denom} \\ z_P = \dfrac{A1 \times C2 - A2 \times C1}{denom} \end{cases} \end{cases}$$

$$\mathrm{DBH} = 2r = 2 \times \sqrt{\left(x_P - x_{A|B|C}\right)^2 + \left(z_P - z_{A|B|C}\right)^2}$$

$$Distance = \sqrt{(x_P)^2 + (z_P)^2} - r$$

2.3 Algorithm - Software

https://github.com/HowcanoeWang/ImageDBH



03

Results and Discussion

01 Comparison

Compare **DBH** measured results by **Photos** and **Field Survey** in **distance** to camera and breast **diameters**

02 Error reasons

Analyze the reasons that cause these error

03 Improvements

Four possible ways to improve photo measurement

03 Results and Discussion

01 Comparison

Compare **DBH** measured results by **Photos** and **Field Survey** in breast **diameters**

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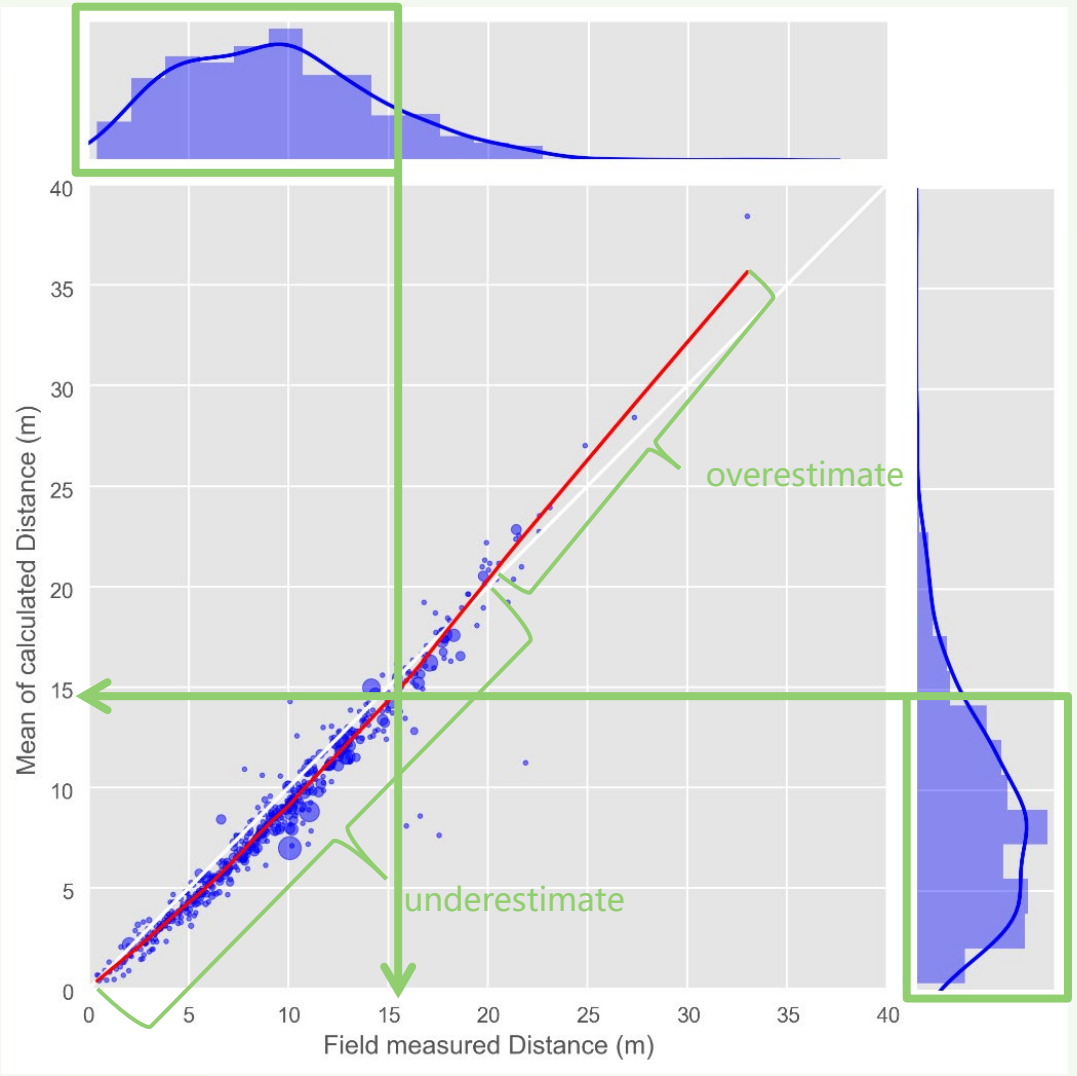
Four possible ways to improve photo measurement

3.1.1 Distance Comparison

1.Most of calculated distance distributed below 15m

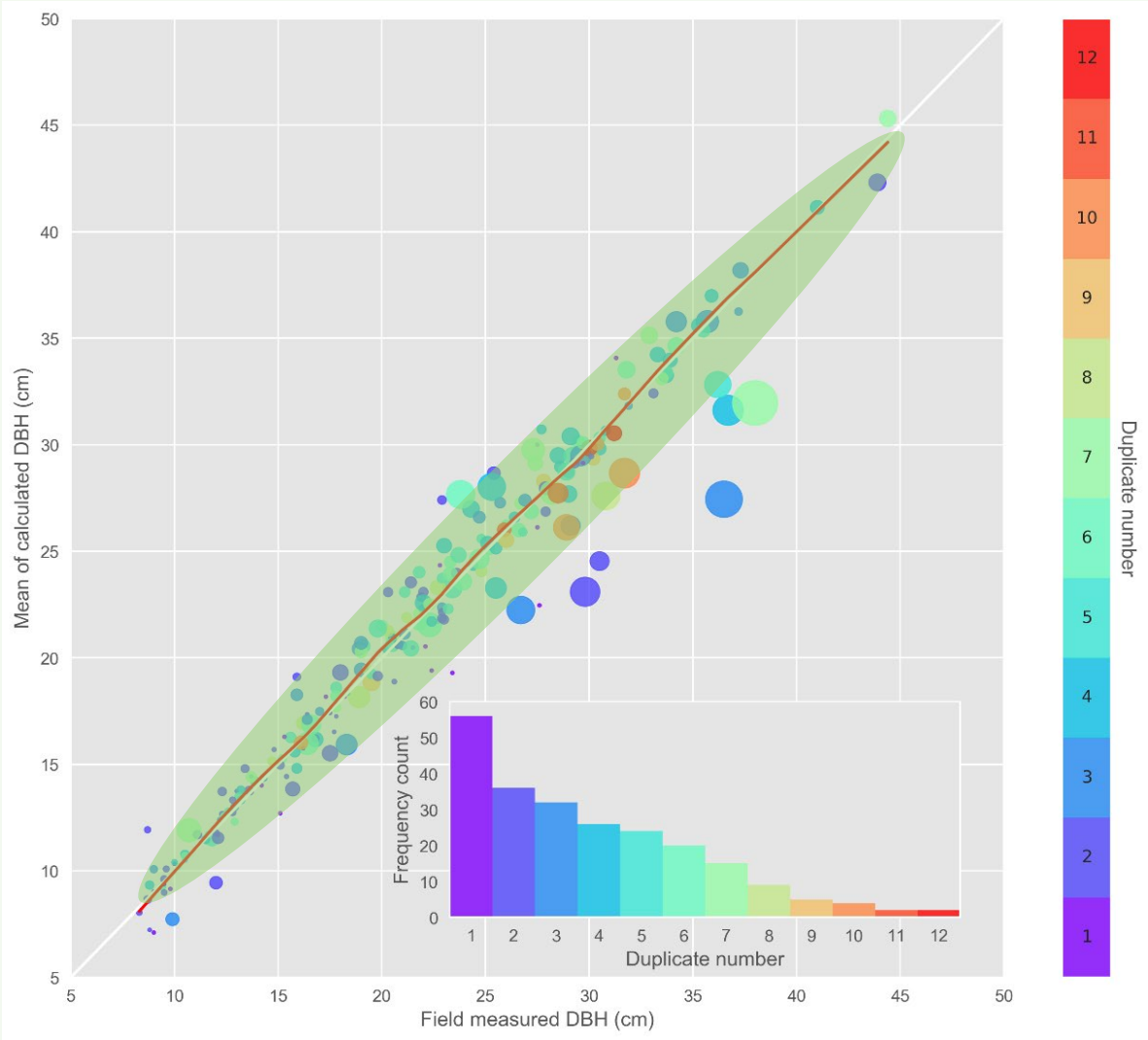
2.Underestimate：hard to guarantee the tape no curving

3.Overestimate：distance too far, the trunks in photo are too small (only a few pixels), causes variance



3.1.2 DBH results comparison

1. Equivalence test: region of similarity = 32% at α = 0.05
2. The DBH results between field measured and photo calculated are similar and this method is applicable.



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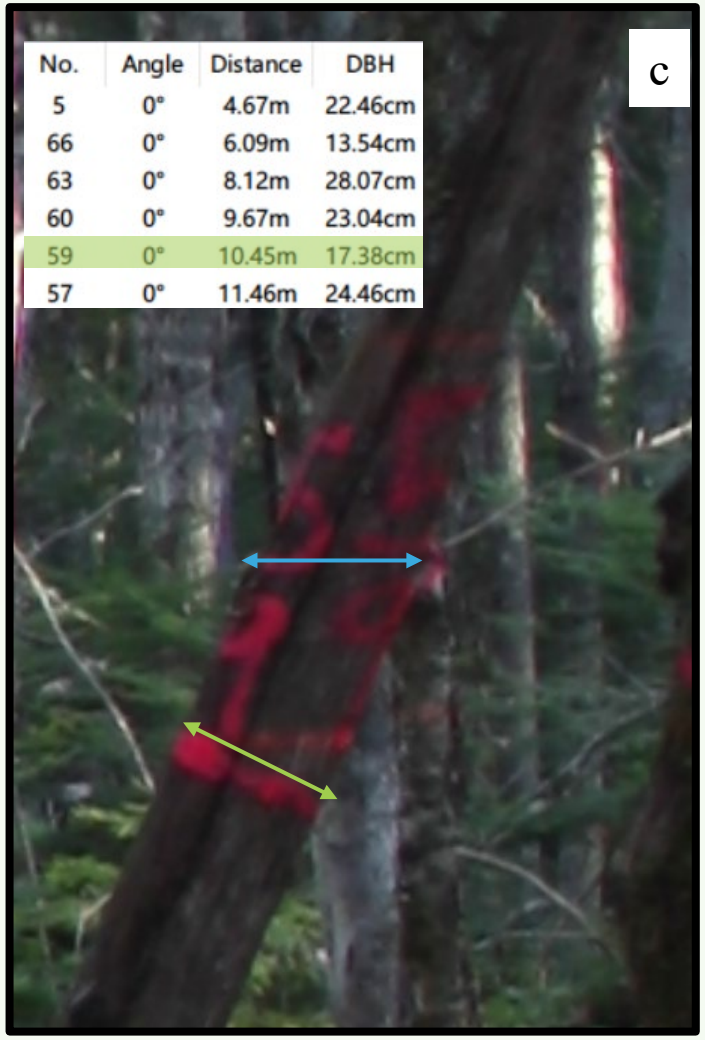
3.2 Error Reasons

1. Different photo angles may capture shorter or longer axes of the stem cross-section

Field measured: No.203 = 17.5cm

3.2 Error Reasons

2. Tree lean is another factor that contributes to large deviations in DBH measurement



Field measured: No.59 = 16.4cm

3.2 Error Reasons

3. The photo measured diameter positions are not exactly same to that of field survey (Field not flat)

4. Key points are marked manually which may cause error

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Compare **DBH** measured results by **Photos** and **Field Survey** in **distance** to camera and breast **diameters**

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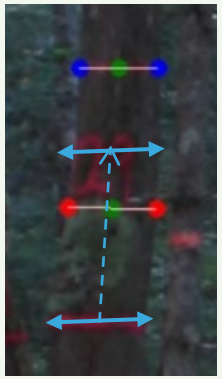
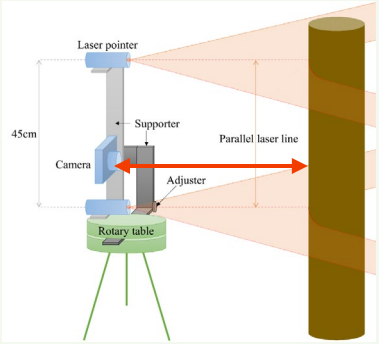
3.3 Improvement

1 2 3 4



Make two methods measured places on trunk closed to each other (take photos for **single trees** rather than multiple trees)

The **best distance** between trees and camera should around 10-20m



Vanishing point horizon algorithm is too complex, simplify algorithm by **direct estimation of scale** (In future)

Automate laser line detection through **AI** to **minimize** human-induced errors associated with **manual selection**

04

Conclusion

04 Conclusion

Algorithm

The **procedure and algorithms** to **extract the DBH** of trees from digital images with laser line have been illustrated.

Application

An **open source software** developed in **Python 3.5** makes great contribution for **simplify** the **calculation procedure** and making it convenience for other researchers' usage

Validation

The calculated results have also been **validated** by the field survey data. It is **applicable** to obtain DBH from photos

04 Conclusion

Future work

This new technology could

1. Simplify algorithm by estimating scale
2. Be validated and applied for estimating the **upper-stem diameter**
3. Optimize **image identification algorithm** and reduce people participation

Thanks for Your Attention

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