Using 3d and 2d Photogrammetry to Maximize the Efficiency of Identifying Pileated Woodpecker Cavities and their Dimensions

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Introduction

- Pileated woodpeckers (*Dryocopus pileatus,* AKA PIWO) = **largest**[1,2] **woodpecker** in North America = **keystone species.**
- PIWO cavities are used by other species once vacated.[1,2]
- Their cavities are **protected** under the Migratory Bird Convention Act (MBCA), and must be left alone for 3 years after the latest activity by a migratory bird.[1,2]
- A need for effective, efficient methods to measure and identify active and recent PIWO cavities.

Pileated Woodpecker (*Dryocopus pileatus*)[3]

Objective:

- Determine variables needed to estimate the **dimensions** of a pileated woodpecker cavity from a single photograph
  - Finding depth using observations, as well as **three dimensional modelling.**
- Develop a statistical equation that can consistently identify the dimensions from single photographs.

Methods

Figure 1: Synthetic cavity

Using **simulated cavities** of **known sizes and heights** to determine how accurately we can predict cavity height from **rangefinders** and distance to tree. (**Trigonometry**)

- Example: angle, distance, direction, etc.
- Using **R software**[4] to help create a prediction of height through **linear regression models.**
- **Predicted cavity height = camera height + X**
  - **X = rangefinder distance (from camera to cavity)*sin(θ)**
- Same equation for predicting height of top and bottom of cavity.

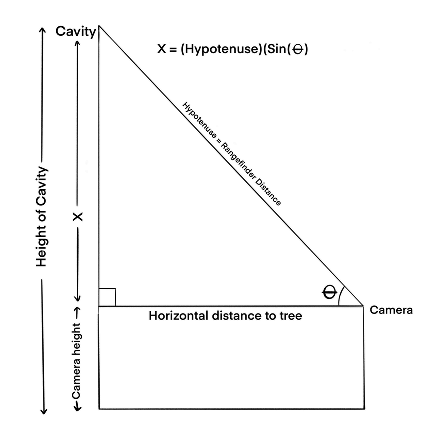

Figure 2: Example of how to apply sine in trigonometry (sohcahtoa) to find height

Determining width:

- Using **ArcGIS**,[5] we used the measure tool to determine the percentage of the trunk that the width of the cavity was taking up.
- Using the percent, we compared that percentage to what the actual DBH (diameter at breast height) was.
- Percent accuracy range for identifying a cavity **should be above 82%.**

3D photogrammetry[6] through Meshroom and Blender to create a 3D model of the cavity, and from there, extrapolating depth by slicing the model.

How to:

- Take 50-100(+) different images of the object
- Upload into Meshroom and begin texturing
- Once dense point cloud is created, transfer the file as an .obj to Blender.
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Figure 3: Synthetic cavity on an adjustable pole to determine controls needed for trigonometry to be used.

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The simulated cavity was 11cm in diameter. **PIWO cavities are minimum 9cm width.**

- **Angles corresponding to percent accuracy of measurement** through ArcGIS using a known cavity size via synthetic cavity:[5]
  - **13 degrees,** 4.5m horizontal distance to tree, 2m height from ground to cavity had a **94% accuracy rate when calculated.**
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Figure 5: an example of measuring the ratio between cavity width and tree diameter using ArcGIS Pro.

Relative positions -> angles to take photos:

- Short cavities = little influence from angles.
- Tall cavities = angle less than ~60 for higher accuracy.
  - Higher photo quality = larger angle .
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Influencing factors:

- Image quality
- Lighting and lighting consistency
- Quantity of images

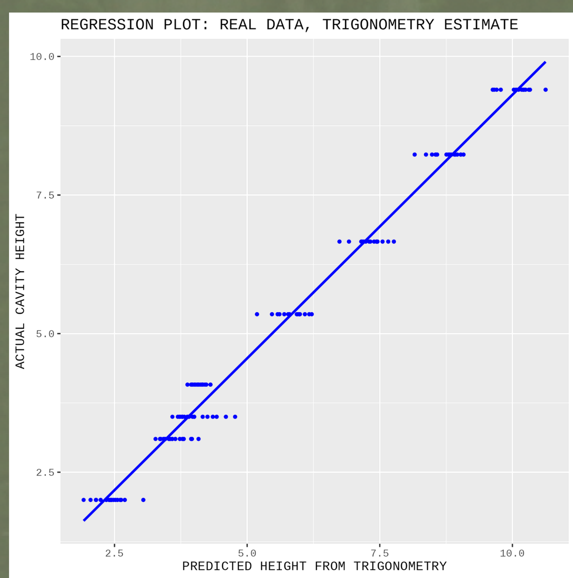

Figure 4: Linear regression model utilizing trigonometry to estimate the height of the cavities.

Statistics: $R^2 = 0.99$ **Actual cavity height ~ -0.20 + 0.95*Predicted cavity height (from trigonometry)**

Using consistently measured variables, we were able to **determine an estimated height for the cavity,** specifically using sine.

- **Viewing angle**
- **Hypotenuse**

We compared it to the actual heights for the simulated cavity.

Solid line = estimated values

Dots = actual values

3D Modelling with Blender and Meshroom[6]

3D photogrammetry can be achieved through Blender and Meshroom.

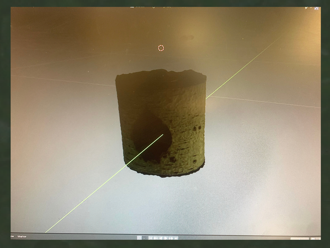

Figure 6: 3D model of synthetic cavity

Usage:

- Non-invasive analysis of tree cavities with fewer needed resources.
- Development in 3D photogrammetry for use in ecology.

Issues to consider:

- The software **couldn't register the inside of a deep cavity** — instead, it generated a hollow object.
  - Finding methods of filling the object without overriding the dense point cloud's observations.

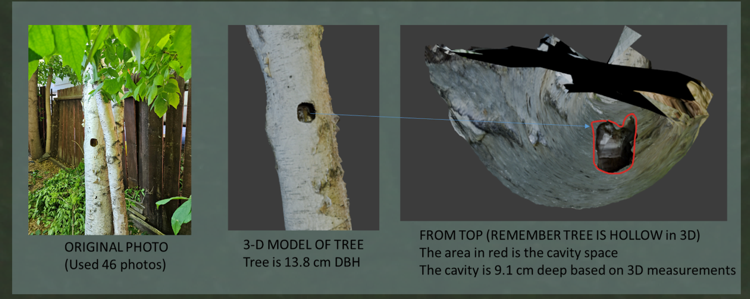

Figure 7: an example of a successful estimation of depth through 3D modelling.

- In **figure 7**, because the hole was shallow and lighting was consistent, the depth was found through modelling.
- Major contender: **lighting.**
  - constant lighting and imagery via UAV (unmanned aeriel vehicle).[6]
- Experimenting with different softwares for 3D modelling.
- Technological developments in camera imaging quality, softwares, further research on photogrammetry.

Discussion

Lab-provided materials	VS	more accessible materials
Laser hypsometer (one decimal)		Rangefinder (no decimals)
Rangefinder (no decimals)*		Cell phone
Canon 101 camera**		

For identification within the field, it would be recommendable to use a laser hypsometer and a high quality camera for the best results.

Figure 8*: Laser hypsometer. **Figure 9**:** Canon 101 camera.

You must have:

- forestry or measuring tape
  - for ground distance
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Issues encountered:

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Real Life Application of Results on Roost Cavities

- **Tapered** trunk = variation in width of the surrounding tree in relation to the cavity.

Figure 10: Roost cavity of a pileated woodpecker at an unknown height, 10m away and 10.7m hypotenuse. Angles vary based on top or bottom of cavity.

WIDTH

- DBH is **58cm.**
- Cavity is taking up 23.7% of the trunk's width.
- Estimated width = **13.8cm.**

HEIGHT

- Top of cavity vs bottom cavity angles = different trigonometric measurements.
  - **Difference = vertical size of cavity.**
- Height to **top of cavity** ~ 6.2m (rounded).
- Height to **bottom of cavity** ~ 6.3m (rounded).
  - Difference = 0.1160065442m, or **11.6cm.**

Figure 11: cavity at 25 degrees and 10m horizontally.

Average angle = 27.5 degrees.
Horizontal distance = 10m.

- Comparable to figure 11 (25 degrees, 10m)

if compared to **fig. 11**, there is a 3.72% potential for error.

Therefore, the range for **height** is 11.2cm - 12.0cm.

Assumptions made:

- the angle from the base of the tree is 90 degrees.

References

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6. Iglhaut, J., Cabo, C., Puliti, S., Piermattei, L., O’Connor, J., & Rosette, J. (2019, July 16). Structure from motion photogrammetry in Forestry: A Review - current forestry reports. SpringerLink. https://link.springer.com/article/10.1007/s40725-019-00094-3

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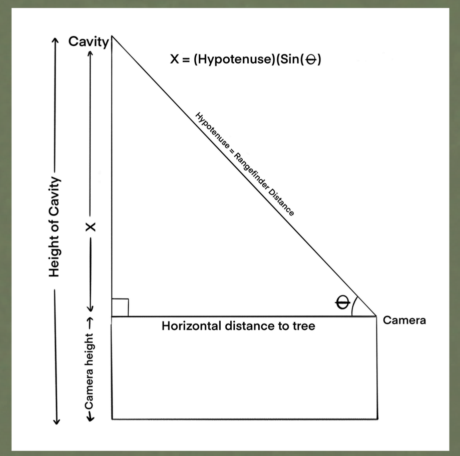

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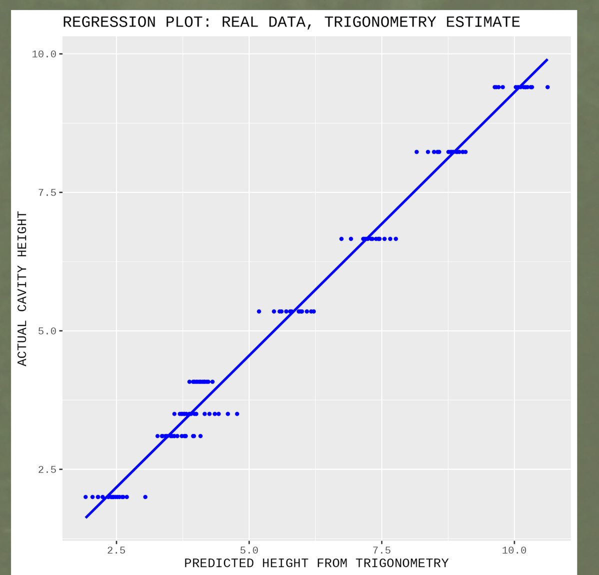

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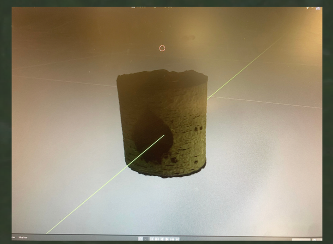

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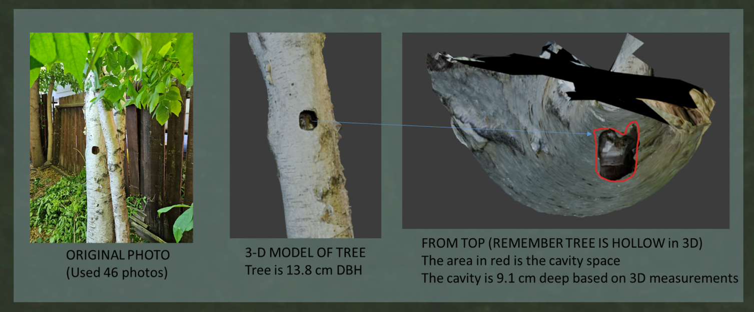

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