

## Background and Motivation

- Accurate timber volume estimation is essential for valuation, logistical and inventory management. [1]
- Conventional stack-based methods rely on geometric approximations and scale factors, introducing systematic errors due to occlusion, irregular formations and void spaces. [2][3][4]
- Recent advances in computer vision enable automated extraction of geometric features from images, supporting low cost and scalable measurement systems. [5]

### Project Aim and Objectives

Develop a computer vision system for log detection, diameter estimation and volume calculation from RGB images.  
Integrate image segmentation and geometric modelling to estimate log volumes.

## Materials

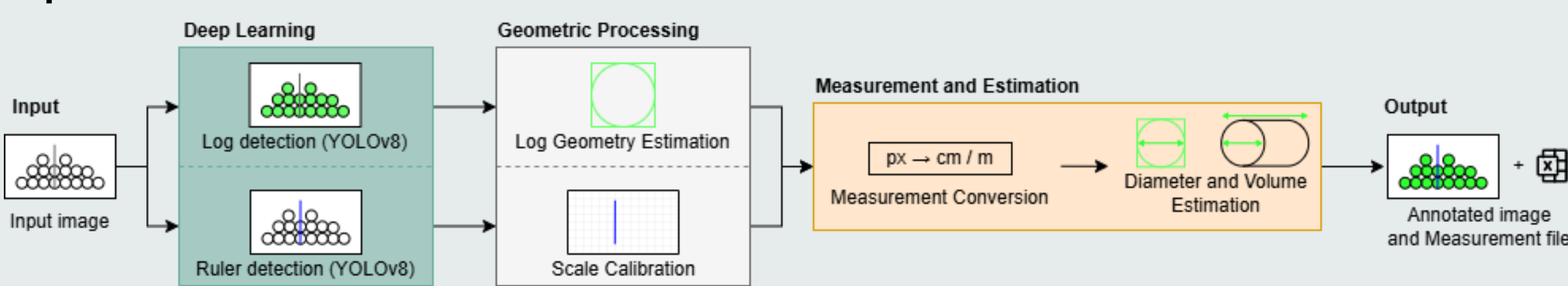
- Real world log stack images provided by Interpine Group Ltd, captured during post-harvest forestry operations.
- Dataset comprises 43 RGB images (~3,900 logs) with visible cross-sections and an in-frame reference ruler for scale calibration.
- Images exhibit scene variability, including non-uniform lighting, occlusion and background noise.



Figure 1: Sample of dataset images

## Methodology

### Pipeline overview



- Evaluated circular and square annotation strategies for log detection (Figure 2), training separate models to identify optimal representation.
- Training incorporated data augmentation (rotation, scaling, illumination variation) to improve robustness under uncontrolled field conditions.
- Separate models were trained to detect log faces and rulers to enable bespoke optimisation for each object class.
- Pixel to meter calibration was performed using the detected ruler mask and user-defined ruler length.
- Instance segmentation masks were used to extract log cross-sections, enabling diameter estimation and subsequent volume calculations.
- Evaluation:** Detection performance was assessed against ground truth labels whilst diameter and volume estimations were assessed against 3D measurements.

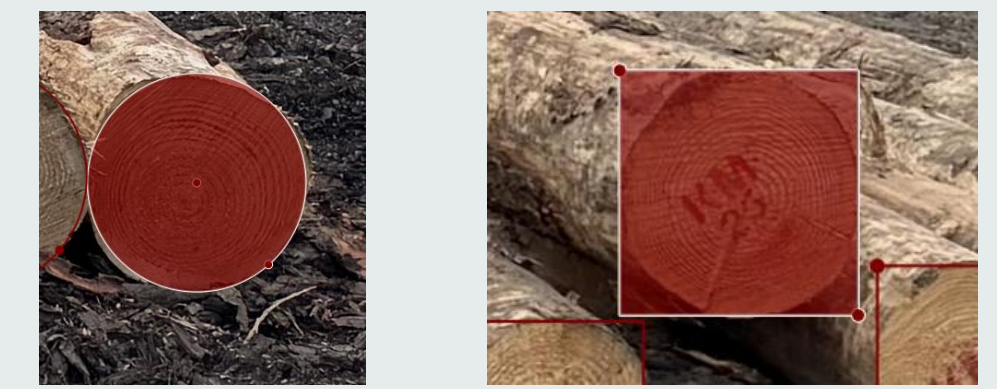


Figure 2: Circular and bounding box annotations in labelling suite



Figure 3: Full bounding box annotations including ruler

### Model

YOLOv8-small segmentation [6]

- Single-stage, real-time object detection and segmentation framework.
- Produces pixel-level masks for precise boundaries.
- Optimised for low computation cost, enabling efficient deployment for in the field.

## Results

### Detection Evaluation

- Square annotations (Figure 4) yielded more consistent detections with an Intersection over Union (IoU) of 0.905 compared to 0.800 for circular labels.

Metric	Square	Circle
Precision	0.994	0.997
Recall	0.990	0.973
mAP50	0.994	0.985
mAP50-95	0.872	0.838
Number of logs	326	326



Figure 4: Log detection [Bounding boxes]



Figure 5: Detection pipeline [Log + Ruler]

### Diameter and Volume Estimation Evaluation

- Circular fitting produced accurate diameter estimates, with low error against ground truth despite occlusion and irregular log shapes, Table 1.
- Aggregated volume estimates were accurate although demonstrated negative bias, Table 2.

Metric	Value
MAE	2.65 cm
MAPE (%)	7.86%
Bias	2.15 cm

Table 1: Error metrics for diameter estimations

Metric	Value
MAE	0.239 m <sup>3</sup>
MAPE (%)	17.22%
Bias	-0.187 m <sup>3</sup>

Table 2: Error metrics for volume estimations



Figure 6: Sample of test set post detection



Figure 7: Volume estimation on test set

## Conclusion and Discussion

- The proposed pipeline successfully detected logs and estimated diameters and volume, demonstrating a practical and automated alternative to manual measurement.
- Object detection combined with geometric fitting provided accurate diameter estimates, with results remaining robust under varying real-world conditions.
- Assumptions with consistent log diameter and single log face measurements resulted in underestimation of volume.
- Future work will focus on refining geometric calibration alongside development of a user interface for manual correction and real-world deployment.

## References

- C. Li, D. Sidders, H. J. Barclay, and H. Hans, Estimation of log volumes: a comparative study. Natural Resources Canada, Canadian Forest Service, Canadian Wood Fibre . . . , 2015, no. FI-X-11.
- F. Cabbage, B. Kaniieski, R. Rubilar, A. Bussoni, V. M. Olmos, G. Balmelli, P. Mac Donagh, R. Lord, C. Hernandez, P. Zhang et al., "Global timber investments, 2005 to 2017," Forest Policy and Economics, vol. 112, p. 102082, 2020.
- R. E. Thomas and N. D. Bennett, "An analysis of the differences among log scaling methods and actual log volume," Forest Products Journal, vol. 67, no. 3-4, pp. 250-257, 2017.
- F. de Miguel-Diez, T. Purfurst, M. Acuna, E. Tolosana-Esteban, and T. Cremer, "Estimation of conversion factors for wood stacks in landings and their influencing parameters: a comprehensive literature review for America and Europe," Silva Fennica, vol. 57, no. 1, pp. 1-47, 2023.
- V. Grondin, J.-M. Fortin, F. Pomerleau, and P. Giguere, "Tree detection and diameter estimation based on deep learning," Forestry, vol. 96, no. 2, pp. 264-276, 2023.
- Ultralytics, "YOLOv8 Documentation," 2023. [Online]. Available: <https://docs.ultralytics.com/models/yolov8/>