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Apple phenotyping using deep learning and 3D depth analysis: An experimental study on fruitlet sizing during early development

Read the full study here

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INTRODUCTION

Experimental activities in apple-growing focus on collecting extensive **biometric data** to better understand physiological processes, improve orchard productivity, and guiding coherent horticultural decisions.

Removing excess fruitlets, a horticultural practice known as **fruit thinning**, is essential to enhance fruit size and quality, as well as to prevent alternate bearing.

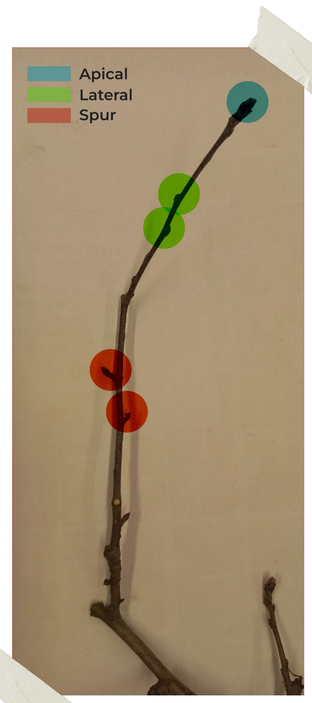
Building **predicting models** requires extensive data collected over time, but traditional acquisition methods are time-consuming and prone to error.

Machine vision could support data acquisition, making the monitoring of fruitlet development scalable and more efficient.

Development of a rapid in-field RGB-D system for monitoring fruitlet size and count in apple flower corymbs during early development

EXPERIMENTAL STUDY

- ☒ **35 flower corymbs** from a commercial Fuji apple block (Aztec clone)
- ☒ 7 field surveys between April and May
  - ↪ **Manual caliper measurements** of labeled diameters
  - ↪ **RGB-D video acquisition** through a standardized and reproducible approach replicating agronomist's real-world procedure
- ☒ Comparative study among 3 flower bud types:
  - ↪ Apical
  - ↪ Lateral
  - ↪ Spur



RGB-D VISION SYSTEM DEVELOPMENT

Fruitlet detection, clustering & sizing → **Frame filtering** → **Fruitlet linear assignment**

Combination of YOLO models with depth information to estimate size and cluster fruitlets into flower corymbs

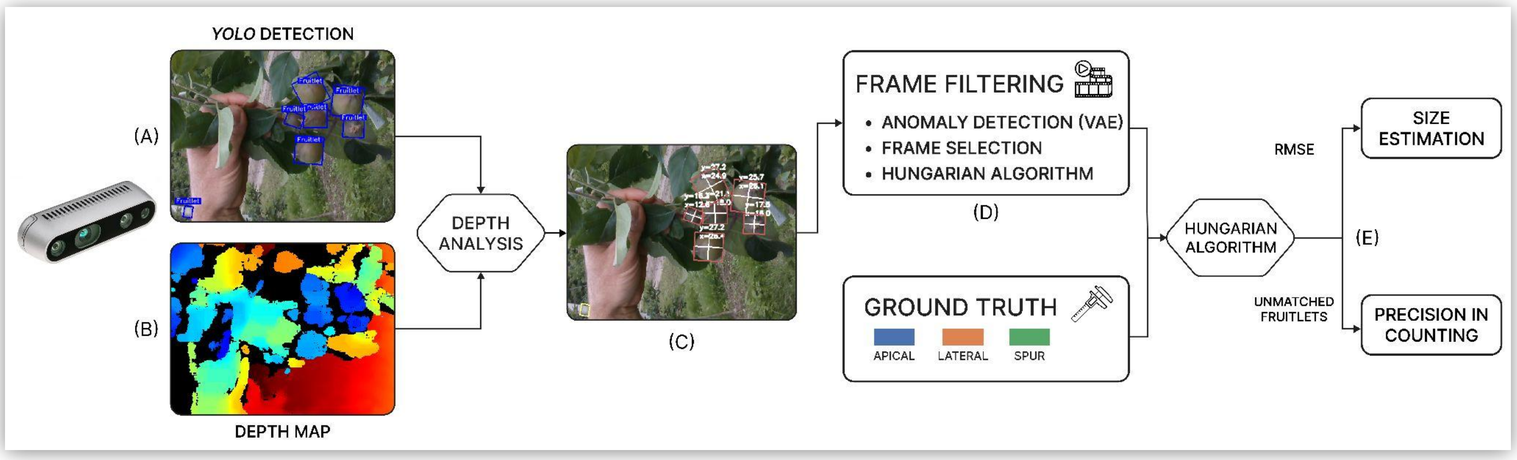
Automatic extraction of the most informative frames across the video sequence based on consistency in fruitlet count

Fruitlets matched across frames via the Hungarian Algorithm using size similarity; median values to determine the individual measures of the target corymb

$$AP = \int_0^1 p(r)dr$$

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = z \cdot \begin{bmatrix} \frac{x-p_x}{f_x} \\ \frac{y-p_y}{f_y} \\ 1 \end{bmatrix}$$

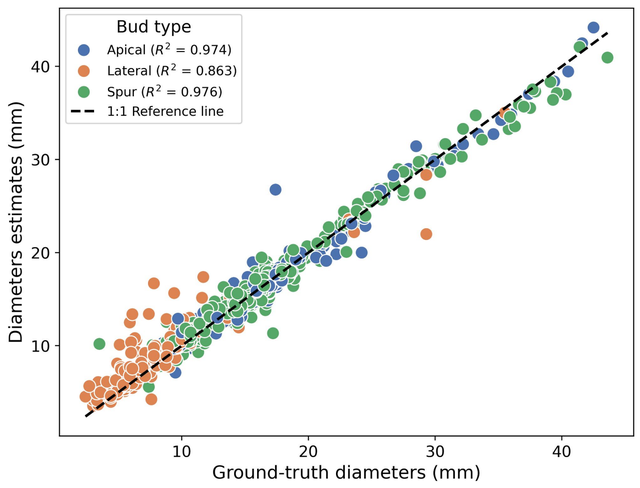
$$\Delta N_f(t) = N_f(t+1) - N_f(t)$$

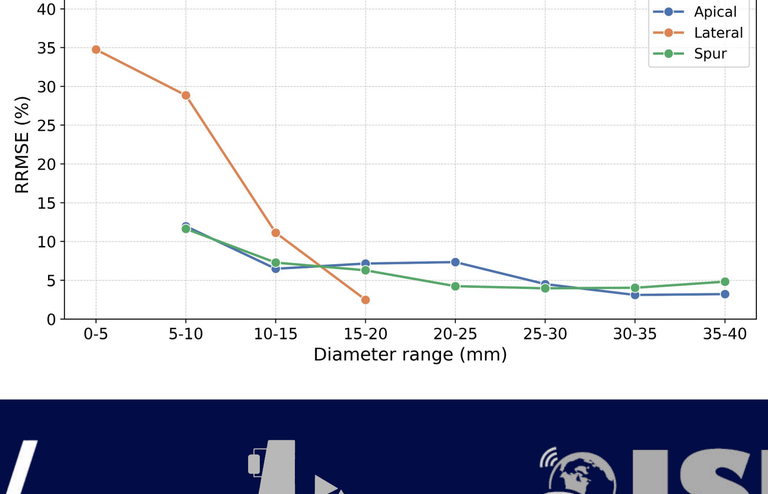


RESULTS & CONCLUSIONS

DETECTION → **FRAME PROCESSING** → **SIZE ESTIMATION**

- ↪ **0.894 AP@0.5** and **0.77 AP@[0.5:0.95]** on the test set
- ↪ **Complete fruitlet count match** in **56.4%** of videos, increasing to **~75%** when excluding cases where the correct count was not detected in any frame
- ↪ 918 true positives
  136 false negatives
  12 false positives
  } **Mean counting error** 0.63 fruitlets per video
- ↪ **TP estimates vs ground truth:** R^2 = 0.974, 0.863, and 0.976 for the 3 bud types
- ↪ **Mean RMSE: 1.05 mm**
- ↪ **RRMSE** decreased with size: **< 10% for *d* > 10 mm**





- ☒ Released the first RGB-D image and video dataset of annotated apple fruitlets and manual caliper measurements during early development.
- ☒ The use of depth cameras combined with the proposed video frame analysis could offer a promising approach for object tracking and sizing in complex orchard environments.
- ☒ Future efforts should focus on enhancing the generalization of the detection model across multiple phenological stages, as well as improving the correct count measurement.
- ☒ Frequent leaf occlusions suggest the need of alternative orchard designs to improve visibility and access for automated systems.

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ISPA International Society of Precision Agriculture