

The 11th Asian-Australasian Conference on Precision Agriculture (ACPA 11)
October 14-16, 2025, Chiayi, Taiwan

DEVELOPMENT OF RGB AND LIDAR FUSION BASED PEAR FRUIT QUANTIFICATION AND MAPPING SYSTEM

Jaehwan LEE¹, Meguna OHATA¹, Eiji MORIMOTO^{1*}

¹ Graduate School of Agricultural Science, Kobe University.

*Corresponding Author: morimoto@gold.kobe-u.ac.jp

Abstract

This study presents a system for accurate fruit quantification using LiDAR-RGB sensor fusion. The system projects 2D fruit detections from a YOLO model onto a 3D map generated via SLAM, assigning a unique coordinate to each fruit to prevent double-counting. This approach achieved an aggregate accuracy of 98.5%, with a predicted total of 535 fruits compared to the 527 observed. The resulting data revealed significant fruit density variations (3.2 to 12.6 fruits/m²), establishing the system as an effective tool for data-driven, precision fruit load management.

Keywords: LiDAR, sensor fusion, SLAM, fruit density, YOLO

INTRODUCTION

In Japanese pear cultivation, precise fruit load management through thinning is essential for maximizing yield and quality. Growers often target a specific fruit density, such as 9 fruits/m², but manual monitoring is labor-intensive and fails to provide spatial data. While 2D image-based detection techniques have advanced, they face a fundamental limitation: an inability to prevent double-counting as the sensor moves, which hinders accurate quantification. Therefore, the primary objective of this study is to develop and validate a system that leverages 3D mapping to achieve accurate, duplication-free fruit quantification.

MATERIALS AND METHODS

Experimental setup

Field experiments were conducted on August 5, 2025, in a pear orchard at Kobe University. The data acquisition system consisted of an RGB camera (ZED2i), and a LiDAR sensor (Mid-360) mounted on a mobile robot (Hunter SE). To ensure consistent data quality, the system was operated at night under controlled LED illumination (725 lux) using ROS 2 (Humble). For validation, the platform remained stationary for 30 s at each of the 30 locations in the orchard to acquire data.

Fruit localization

The data processing pipeline consisted of three stages. First, in the 3D point cloud map generation stage, the FAST-LIO2 (Xu et al., 2021) SLAM algorithm was applied to the LiDAR data to create a precise 3D map of the orchard. Second, in the 2D fruit detection stage, a YOLOv11n model, trained on 9,000 images ('pear': 451,051 labels), was used to detect fruits in the RGB images. This model achieved a high performance with a mAP@0.5:0.95 of 0.85. Finally, in the sensor fusion and 3D coordinate estimation stage, a precise extrinsic calibration was used to project the center point of each detected fruit from the 2D image onto the 3D point cloud map (Koide et al., 2023). This allowed for the estimation of each fruit's 3D coordinates and prevent double-counting.

RESULTS & DISCUSSION

The quantitative performance of the fruit counting system was validated by correlating system-derived data with ground-truth observations from 30 distinct orchard locations. The system demonstrated a high degree of accuracy, achieving an aggregate fruit count accuracy of 98.5% (535 predicted vs. 527 observed). Furthermore, a strong positive correlation was established between predicted and observed fruit densities on a per-location basis (Fig. 1b), confirming the reliability of the system for localized assessments. The 3D map generated by the system (Fig. 1a) served as the basis for a subsequent spatial analysis of fruit distribution. This analysis quantified the fruit density for discrete zones within the orchard, revealing values that ranged from 3.2 to 12.6 fruits/m². Discrepancies between predicted and observed counts were attributed to two primary error sources related to occlusion. Underestimation occurred in cases where fruits were completely obscured by foliage, preventing their detection in the 2D image. Conversely, overestimation was caused by erroneous 3D coordinate assignments for partially occluded fruits, where the system projected the fruit's position onto a foreground object such as a leaf or branch.

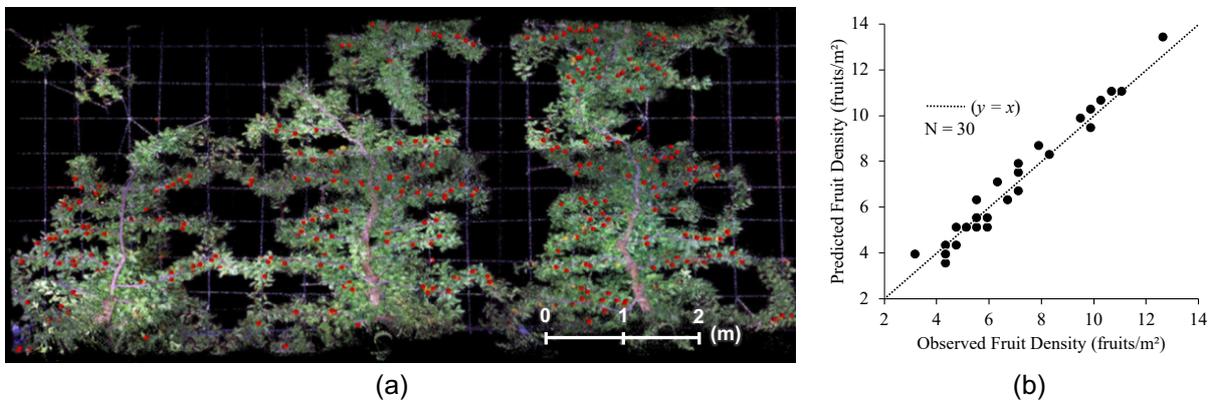


Fig.1 Quantitative and qualitative results of the fruit enumeration system. (a) 3D point cloud map with detected fruits (red dots). (b) Scatter plot of predicted versus observed fruit density.

CONCLUSIONS

This study presented a LiDAR-RGB fusion-based sensing system for accurate pear fruit quantification. By projecting 2D fruit detections from a YOLOv11n model onto a 3D SLAM map, the system assigns a unique coordinate to each fruit, effectively overcoming the critical issue of double counting inherent in 2D based methods. The system achieved an aggregate accuracy of 98.5%, with a total predicted count of 535 fruits compared to the observed 527. Its robust performance across a wide range of densities (3.2 to 12.6 fruits/m²) confirms its utility as a tool for precision fruit load management. Furthermore, the system provides valuable diagnostic insights by identifying low-density zones that lack sufficient fruit-bearing branches, suggesting that corrective actions such as branch training could be implemented to improve future yields.

ACKNOWLEDGEMENTS

This work was supported by JSPS Grant-in-Aid for Early-Career Scientists Grant Number 25K18327.

REFERENCES

- Koide, K., S. Oishi, M. Yokozuka, and A. Banno. 2023. General, Single-shot, Target-less, and Automatic LiDAR-Camera Extrinsic Calibration Toolbox. arXiv preprint arXiv:2302.05094.
- Xu, W., Y. Cai, D. He, J. Lin, and F. Zhang. 2021. FAST-LIO2: Fast Direct LiDAR-inertial Odometry. arXiv preprint arXiv:2107.06829.