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A VISION-GUIDED GANTRY ROBOT FOR EFFICIENT ORCHID BASKET REORGANIZATION IN GREENHOUSES

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ABSTRACT

Proper alignment of orchid baskets in greenhouses is important to maintain visual uniformity, maximize space usage, and ensure consistent light exposure during flowering. Manual arrangement is time-consuming and labor-intensive, underscoring the need for automation. To address this challenge, we propose an integrated robotic system for automated basket organization. The system combines a cartesian gantry robot, a rotation-aware clamping gripper, dual Intel RealSense D435i cameras, and a lightweight YOLOv11-nano model with oriented bounding boxes to detect both position and orientation of baskets. Based on 3D perception, the robot autonomously identifies misaligned baskets, generates motion plans, and reorganizes them into structured rows. The detection model achieves 99% precision and 94.4% mAP50-95 with a compact size of 5.6 MB and a fast inference speed of 4.3 ms per image, ensuring real-time feasibility. In practical deployment, the robotic pipeline operates efficiently and reliably, offering a scalable solution for automating delicate and repetitive tasks in orchid farming.

Keywords: Orchid robot, deep learning, cartesian gantry, gripper design, orchid farming.

INTRODUCTION

Orchid farming, particularly in Taiwan and Vietnam, involves intensive manual labor to manage and maintain thousands of orchid pots. Among these tasks, aligning orchid baskets uniformly on greenhouse benches is crucial for visual consistency, airflow optimization, and efficient space usage. However, arranging these baskets by hand is time-consuming and prone to human error. Recent advances in robotics and artificial intelligence offer promising solutions to automate such delicate operations. Previous studies have demonstrated the effectiveness of deep learning-based robotics in agricultural environments (Chen, Song et al. 2025, Nguyen, Do et al. 2025)

This study develops a robotic orchid space arrangement system that combines deep learning-based detection, 3D perception, and robotic manipulation to autonomously align orchid baskets. The key objective is to enable a practical, and precise robotic system for the real-world greenhouse deployment.

MATERIALS AND METHODS

OVERALL SYSTEM DIAGRAM

The system as shown in Fig. 1 consists of the components: Perception using dual RealSense D435i cameras to capture RGB-D images; computation using a central computer to run

YOLOv11n-OBB for detecting basket position and orientation; and the actuation using a gantry robot and gripper to perform manipulation based on detection results. The detection model was trained on 504 annotated images and validated on 50 images using online augmentation. It outputs oriented bounding boxes (OBBs) capturing both position and rotation. Training settings: 640x640 input, 50 epochs, Adam optimizer.

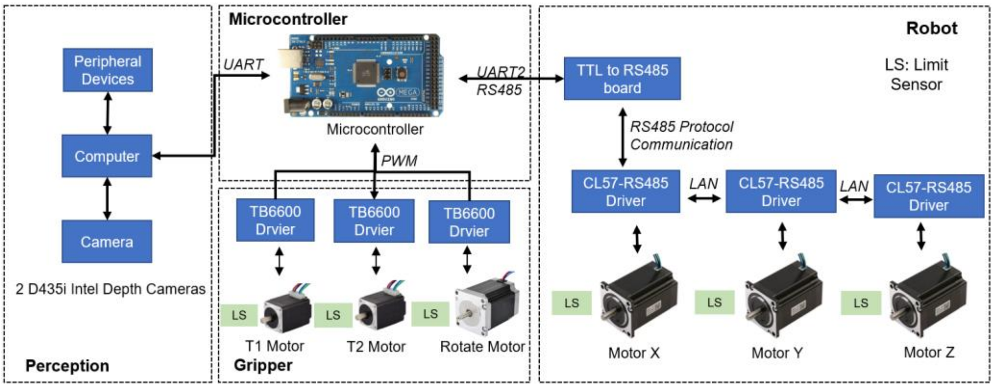

Fig. 1 The overall of the robotic orchid arrangement system.

ROBOT AND GRIPPER

The gantry robot features X-Z-Y motion with 1850 mm x 900 mm x 500 mm range, driven by CL57-RS485 stepper motors. The gripper includes two curved clamps powered by linear actuators and a rotatry motor for orientation correction. It handles baskets ranging from 90 mm to 200 mm in diameter. The gripper structure is shown in Fig. 2.

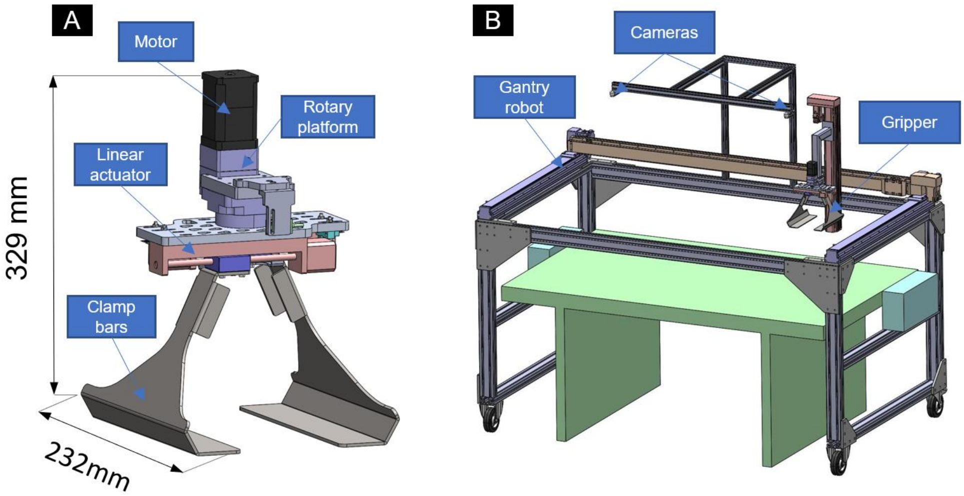

Fig. 2 The gripper (A) and gantry robotics (B) for orchid space arrangement.

RESULTS & DISCUSSION

Table 1 summarizes the performance of the YOLOv11n-OBB model in detecting orchid baskets. The model achieved a precision of 99% and a mAP50–95 score of 94.4%, indicating strong localization and classification capability. Despite its high accuracy, the model remains lightweight with only 2.6 million parameters and a size of 5.6 MB. Furthermore, it delivers fast inference at 4.3 milliseconds per image, making it well-suited for real-time deployment in automated orchid arrangement systems.

Table 1. Detection evaluation of the model.

Model	Size	Params	Precision	mAP50-95	Inference Time
YOLOv11n-OBB	5.6MB	2.6M	99%	94.4%	4.3ms

The working flow of the orchid robot system begins with device initialization. The cameras then capture images of the workspace, which are processed by a YOLOv11n-OBB model to detect baskets and estimate their orientations. Once detected, the system extracts position and commands the gantry robot and rotation-aware gripper to reorganize the baskets. The effectiveness of this process is demonstrated in Fig. 3. Before arrangement, baskets exhibit large angular deviations and irregular spacing. After robotic reorganization, the baskets are aligned into structured rows with near-uniform orientation and spacing. Quantitative evaluation shows that the mean angular deviation after arrangement is reduced to approximately 0.93° ± 0.3°, indicating that most baskets are nearly parallel and consistently aligned.

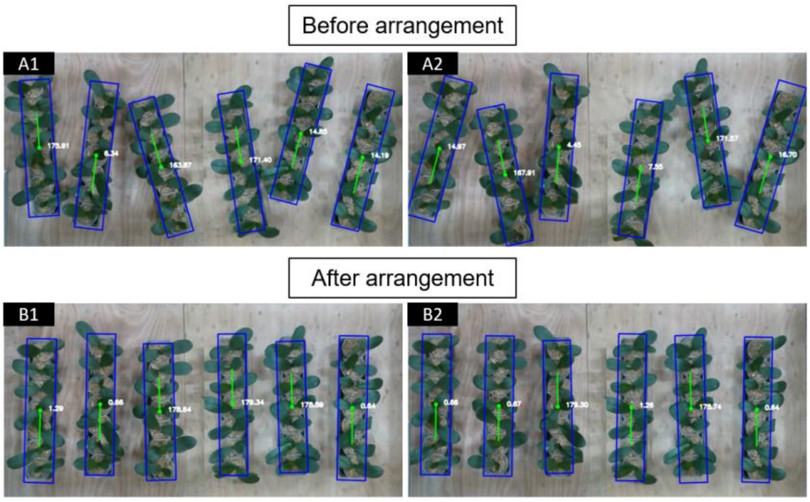

Fig. 3 (A1-B2) Basket orientation and spacing before and after robotic arrangement.

CONCLUSIONS

This work presents a complete robotic system for improving the spatial organization of orchid baskets in greenhouse settings. The integration of 3D vision, orientation-aware detection, and coordinated gantry-based manipulation enables the system to autonomously align baskets with high precision and stability. By combining real-time perception, precise mechanical handling, and lightweight AI inference, the proposed approach ensures both accuracy and responsiveness under practical conditions. The promising performance highlights its potential for deployment in horticultural automation, effectively reducing manual workload while enhancing consistency, productivity, and operational efficiency in orchid farming.

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