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Drone and Deep Learning-Based Instrumentation for Palm Fruit Detection and Yield Measurement: A Southeast Asian Roadmap

By [Gunawan, TS](#) (Gunawan, Teddy Surya) ^[1]; [Kartiwi, M](#) (Kartiwi, Mira) ^[1]; [Jamali, A](#) (Jamali, Annisa) ^[2]

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Abstract

The palm oil industry, a central component of Southeast Asia's economy, is facing growing pressure to enhance productivity, sustainability, and labor efficiency amid global environmental and market challenges. Recent advances in instrumentation, unmanned aerial vehicles (UAVs), and deep learning have enabled new opportunities for intelligent measurement and monitoring of palm fruit growth, health, and yield. This paper presents a regional perspective on the evolution, current state, and future direction of drone- and AI-based instrumentation for palm fruit detection and yield estimation in Malaysia, Indonesia, and Thailand. The review traces the transition from manual inspection and satellite observation to high-resolution UAV imaging integrated with convolutional neural networks (CNNs), YOLO-based object detection, and hyperspectral data analytics. It also highlights hardware and software developments in multispectral imaging, sensor calibration, and edge-AI deployment for real-time plantation monitoring. Despite rapid progress, major challenges remain, including limited labeled datasets, variable lighting and canopy density, and high operational costs for large-scale automation. This paper identifies these gaps and outlines a roadmap toward affordable, data-driven, and sustainable measurement systems through regional collaboration, open datasets, and hybrid sensing architectures. The discussion aims to guide researchers, policymakers, and industry practitioners toward the next generation of precision instrumentation for smart palm agriculture across Southeast Asia.

Keywords

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Author Information

Corresponding Gunawan, Teddy (corresponding
Address: Surya author)
Int Islamic Univ Malaysia, Kuala Lumpur, Malaysia
E-mail Addresses :
tsgunawan@iium.edu.my
Addresses :

¹ Int Islamic Univ Malaysia, Kuala Lumpur, Malaysia

² Univ Malaysia Sarawak, Kota Samarahan, Malaysia

E-mail Addresses :