UNIVERSITI TEKNOLOGI MARA

E-PROCEEDINGS

INTERNATIONAL TINKER INNOVATION & ENTREPRENEURSHIP CHALLENGE (i-TIEC 2025)

"Fostering a Culture of Innovation and Entrepreneurial Excellence"

23 January 2025
PTDI, UiTM Cawangan Johor
Kampus Pasir Gudang

ORGANIZED BY:

Electrical Engineering Studies, College of Engineering
Universiti Teknologi MARA (UiTM) Cawangan Johor
Kampus Pasir Gudang
https://tiec-uitmpg.wixsite.com/tiec

e ISBN 978-967-0033-34-1

9 789670 033341

E-PROCEEDINGS
of International Tinker Innovation & Entrepreneurship Challenge (i-TIEC 2025)

"Fostering a Culture of Innovation and Entrepreneurial Excellence"

23rd JANUARY 2025
PTDI, UiTM Cawangan Johor, Kampus Pasir Gudang

Organized by

Electrical Engineering Studies, College of Engineering,

Universiti Teknologi MARA (UiTM) Cawangan Johor, Kampus Pasir Gudang.

https://tiec-uitmpg.wixsite.com/tiec

Editors

Aznilinda Zainuddin

Maisarah Noorezam

e ISBN: 978-967-0033-34-1

Published in Malaysia by
Universiti Teknologi MARA (UiTM) Cawangan Johor
Kampus Pasir Gudang, 81750 Masai

CONTENTS

PREFACE

It is with great pleasure that we present the e-proceedings of International Tinker Innovation & Entrepreneurship Challenge (i-TIEC 2025), which compiles the extended abstracts submitted to the International Tinker Innovation & Entrepreneurship Challenge (i-TIEC 2025), held on 23 January 2025 at **PTDI, Universiti Teknologi MARA (UiTM) Cawangan Johor, Kampus Pasir Gudang.** This publication serves as a valuable resource, showcasing the intellectual contributions on the invention and innovation among students, academics, researchers, and professionals.

The International Tinker Innovation & Entrepreneurship Challenge (i-TIEC 2025), organized under the theme "Fostering a Culture of Innovation and Entrepreneurial Excellence," is designed to inspire participants at various academic levels, from secondary students to higher education students and professionals. The competition emphasizes both innovation and entrepreneurship, encouraging the development of product prototypes that address real-world problems and have clear commercialization potential. By focusing on technological and social innovations, i-TIEC 2025 highlights the importance of turning creative ideas into viable, market-ready solutions that can benefit users and society. The extended abstracts in this e-proceedings book showcase the diverse perspectives and depth of research presented during the event, reflecting the strong entrepreneurial element at its core.

We extend our sincere gratitude to the contributors for their dedication in sharing their innovation and the organizing committee for their hard work in ensuring the success of the event and this publication. We also appreciate the support of our collaborators; Mass Rapid Transit Corporation Sdn. Bhd. (MRT Corp), Universitas Labuhanbatu, Indonesia (ULB), Universitas Riau Kepulauan, Indonesia (UNRIKA) and IEEE Young Professionals Malaysia, whose contributions have been instrumental in making this event and publication possible.

We hope that this e-proceedings book will serve as a valuable reference for researchers, educators, and practitioners, inspiring further studies and collaborations in both innovation and entrepreneurship. May the knowledge shared here continue to spark new ideas and market-ready solutions, advancing our collective expertise and fostering the growth of entrepreneurial ventures.

B-ST118: ROBOHARVEST: AI-DRIVEN ROBOTIC SYSTEM FOR AUTOMATED LOOSE PALM OIL FRUITLET DETECTION AND COLLECTION IN PLANTATIONS

Muhammad Hafidz Hasnor Faiz[1], Norashikin M. Thamrin[2], Noor Ezan Abdullah[1], and Muhammad Hasif Azami[2]
[1]School of Electrical Engineering, College of Engineering, Universiti Teknologi MARA, Shah Alam, Malaysia
[2]Microwave Research Institute, Universiti Teknologi MARA, Shah Alam, Malaysia

Corresponding author: Norashikin M. Thamrin, dr.norashikinmt@uitm.edu.my

ABSTRACT

Malaysia and Indonesia remain leading global palm oil producers, with Malaysia's output projected at 19.7 million tonnes for 2023–2024. Despite a century of cultivation, the palm oil industry heavily relies on manual labor to harvest fresh fruit bunches (FFB) and collect loose fruits (LF). LF, the outer layer with the highest oil content, holds significant economic value. However, manual collection exposes workers to musculoskeletal disorders due to prolonged poor postures. This study explores automating LF collection using a cost-effective robotic system with an integrated vision system. A proof of concept employs a 6-degree-of-freedom (DOF) robotic arm controlled by a Raspberry Pi microprocessor within a simulated environment. The system utilises YOLOv10-based object detection and image segmentation, coupled with Particle Component Analysis (PCA), in a Robot Operating System (ROS) framework for precise LF localization. Predictive inverse kinematics using Recurrent Neural Networks (RNN) ensures dynamic adaptability during collection. Preliminary results show the robot collects approximately 2 LF per minute due to hardware limitation, demonstrating its potential to enhance productivity and reduce physical strain on workers. However, advanced processors can significantly improve its performance.

Keywords: Robotic Arm, Inverse Kinematics, Palm Oil Loose Fruitlet, Image Segmentation, Deep Learning

1. Product Description

The AI-Driven Robotic System automates the detection and collection of loose palm oil fruitlets (LF), reducing the industry's dependency on manual labour and related ergonomic issues. This novel technology combines robotics, machine vision, and intelligent processing to achieve rapid and exact LF collecting. The solution includes AI-powered image segmentation and a YOLOv10-based high-precision LF detection and localisation framework. It continuously scans planting regions, gathering exact data for robotic arm activities. The pick-and-place system combines inverse kinematic and deep learning to provide fast joint angle prediction (0.88 milliseconds) while reducing localisation mistakes. Dynamic low-frequency detection allows for flawless functioning in a variety of situations. Key advantages include collecting about 2 LFs every minute due to hardware limitation, which equals 120 LFs per hour, with potential revenue improvements of RM 4,803.50 per tonne. The system decreases dependency on physical labour, which helps to prevent musculoskeletal problems. Its low-cost robotic arm and CPU (such as Raspberry Pi) make it affordable and scalable, especially for small-scale plantations or individual farmers. Using predictive kinematics and real-time AI, the system adjusts dynamically to changing plantation circumstances, providing a cost-effective and ergonomic solution for increasing production and income.

2. Diagrams

A. System design using ROS-based architecture.

The overall framework of the RoboHarvester system consists of several interconnected nodes designed for seamless detection and collection of loose fruitlets as shown in **Figure 1**. The process starts with the scanning mode, identifying the environment using an AI-driven vision system. Detected fruitlets are localized through the Loose Palm Oil Fruitlet Detection Node, while the Inverse Kinematics Solver Node computes the robotic arm's movements. The Pick and Place Node coordinates the collection and placement, ensuring efficiency and precision.

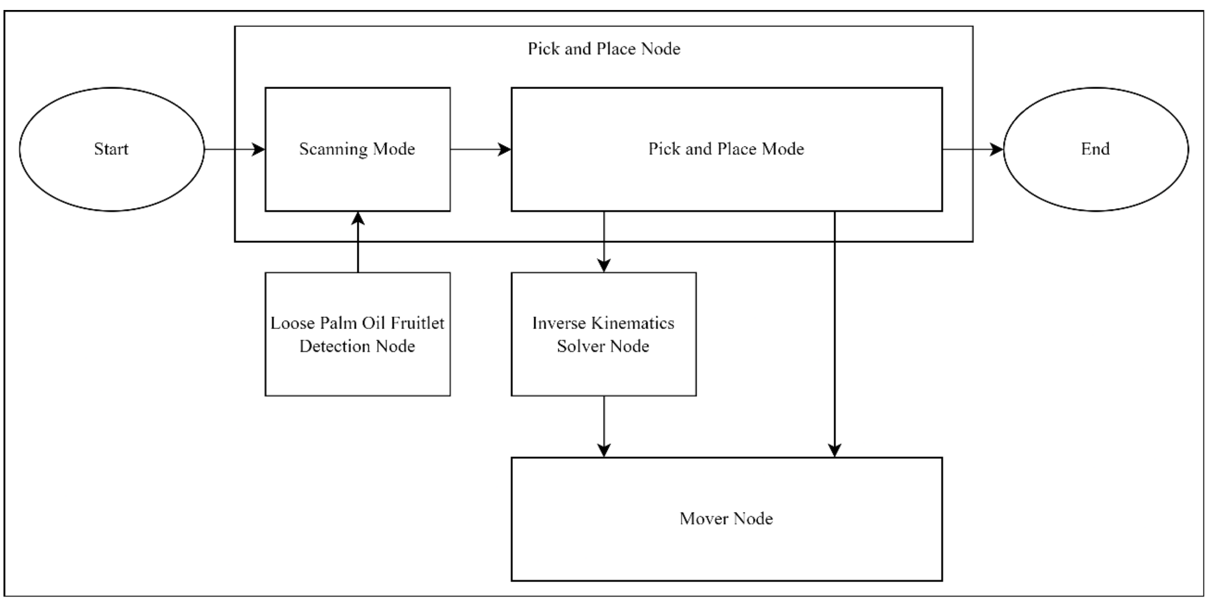

Figure 1. The overall Loose Palm Oil Fruitlet Detection and Picking Framework using AI-driven robotic arm.

The Fruitlet Detection Node operates in several stages. According to **Figure 2**, it begins with image segmentation to identify fruitlets, followed by center estimation for precise location. Orientation and size estimations ensure the system calculates the exact positioning and dimensions for accurate collection. These features work together to enable smooth robotic arm operations.

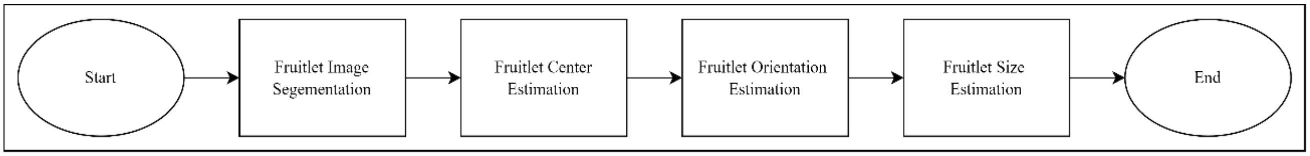

Figure 2. The block diagram of the Palm Oil Loose Fruitlet Detection Node in the ROS-based 6-DOF robotic arm.

The Pick and Place Node in **Figure 3** manages the robotic arm's motion during collection. It navigates to the fruitlet's location, picks it up, and transfers it to a designated area. This node ensures optimal operation through accurate motion control, minimizing errors during the pick-and-place cycle.

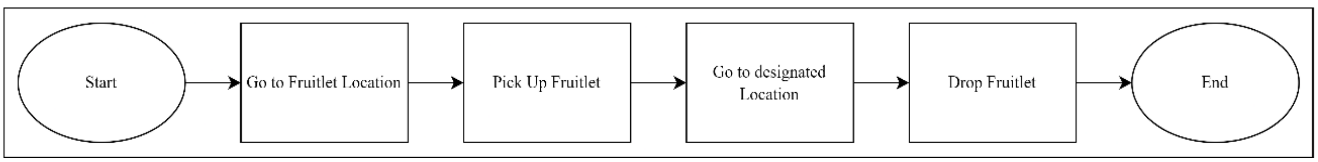

Figure 3. The block diagram of the Pick and Place Node in the ROS-based 6-DOF robotic arm.

The 6-DOF robotic arm shown in **Figure 4** is the manipulator used in the RoboHarvester system. It utilises deep learning in inverse kinematics to perform seamless pick-and-place operations. Its flexibility and precision allow it to adapt to dynamic environments, making it ideal for plantation applications.

Figure 4. The 6-DOF robotic arm is used for picking up loose fruitlets by implementing deep learning in the inverse kinematic computation for seamless pick-and-place operation.

B. Performance of the YOLOv10-based image segmentation for

Using YOLOv10-based image segmentation, the system identifies loose fruitlets on the ground with high accuracy. The fruitlets' centroids are computed to guide the robotic arm's pickup operation, ensuring efficiency and precision in the collection process. The image segmentation process can be seen in **Figure 5**.

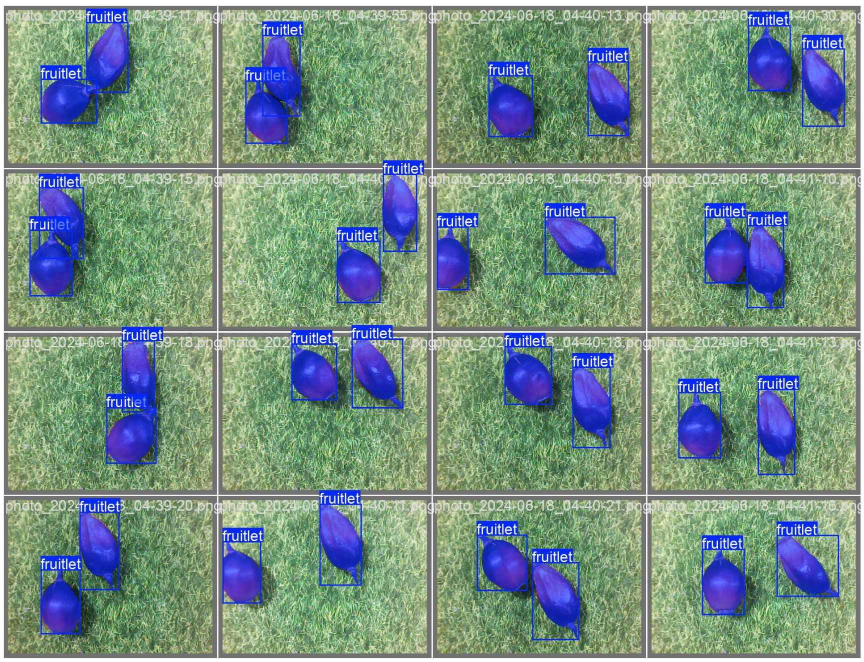

Figure 5. The fruitlet is detected using YOLOv10-based image Segmentation in the image, which later the centroid of the fruitlets are computed for smooth pick up operation by the robotic arm.

Figure 6 shows the detection distribution chart highlights the concentration of loose fruitlets captured by the YOLOv10 model. This visual representation demonstrates the model's effectiveness in identifying multiple fruitlets in diverse plantation environments. Meanwhile, The F1-Confidence curve in **Figure 7** illustrates the relationship between the F1 score and confidence thresholds. A peak F1 score of 1.0 is achieved at a confidence threshold of 0.875, indicating the model's optimal performance in balancing precision and recall. **Figure 8** showcases the precision achieved at various confidence thresholds. The model reaches a precision of 1.0 at a threshold of 0.926, reflecting its ability to minimize false positives effectively. The Recall-Confidence curve in **Figure 9** demonstrates the model's ability to maintain a recall value of 1.0 across most confidence levels. This indicates strong detection coverage, even at lower thresholds, ensuring reliable fruitlet identification.

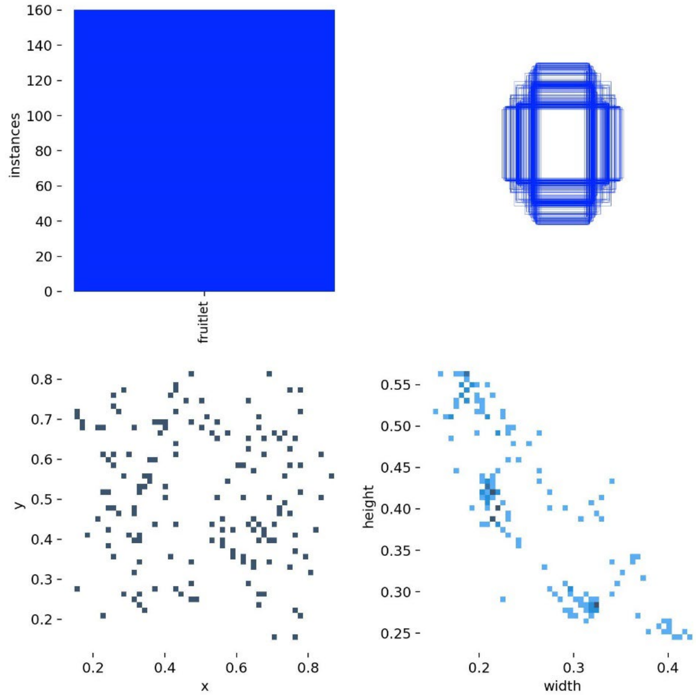

Figure 6. The distribution of detected instances of loose palm oil fruitlets, indicating the concentration of fruitlets captured by the YOLOv10 image segmentation model

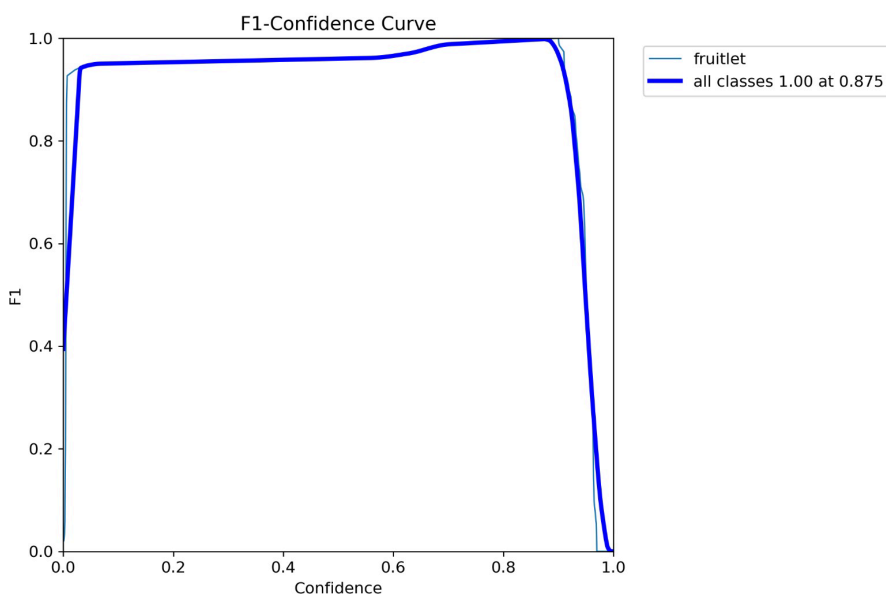

Figure 7. The F1-Confidence curve demonstrates the relationship between the F1 score and confidence thresholds for the detection of loose fruitlets (LF). A peak F1 score of 1.0 is achieved at a confidence threshold of 0.875, indicating optimal model performance at this threshold

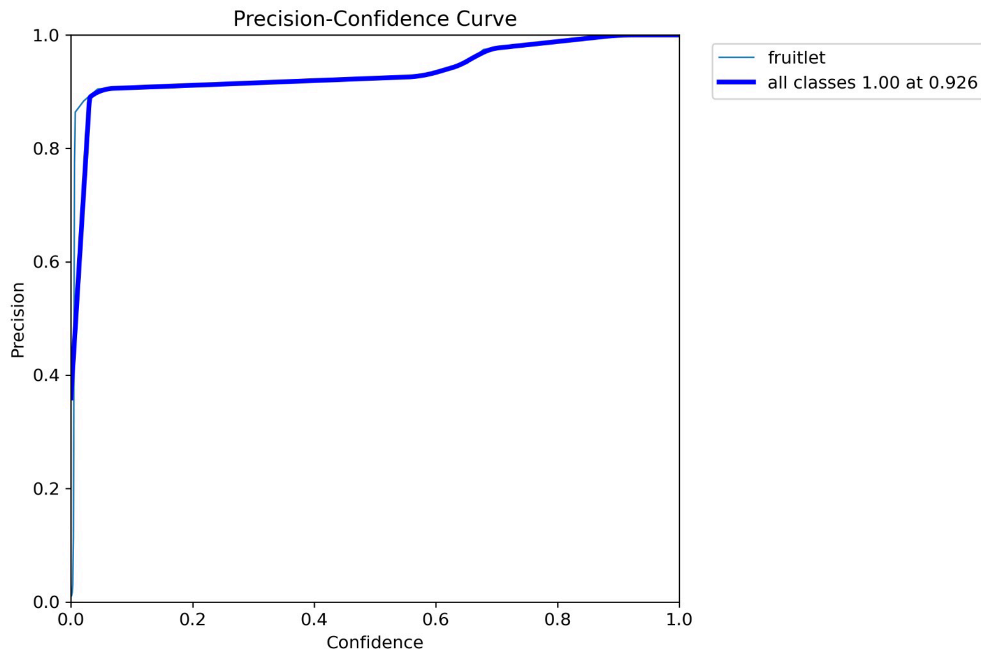

Figure 8. This curve illustrates the precision values achieved at varying confidence thresholds. The precision reaches 1.0 at a threshold of 0.926, reflecting the high accuracy of the detection model in minimizing false positives.

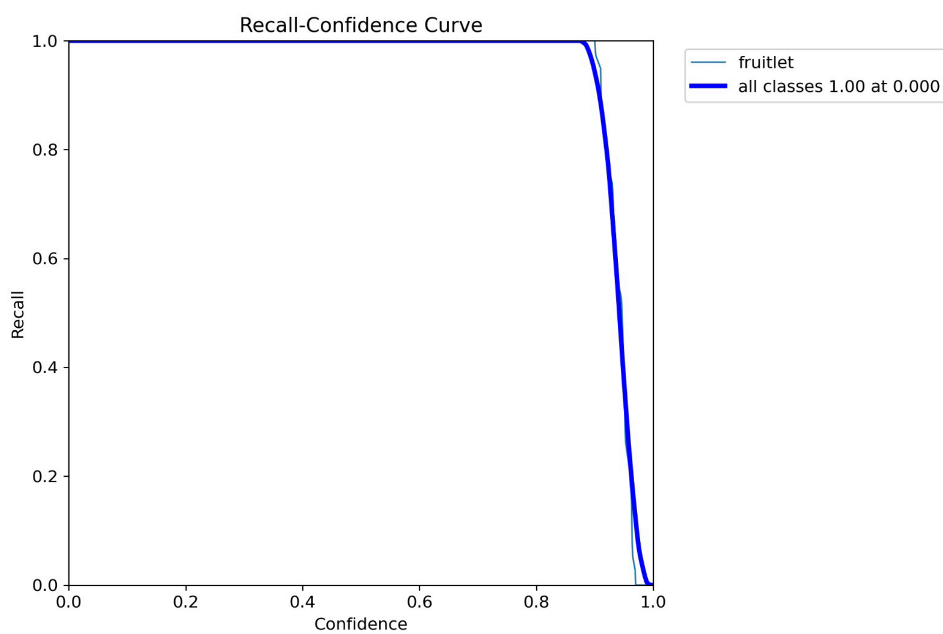

Figure 9. The recall-confidence curve shows how the recall metric changes with confidence levels. A recall value of 1.0 is maintained across confidence levels until it begins to drop near the highest thresholds, indicating strong detection coverage at lower thresholds

C. Performance analysis between RNN models for Inverse Kinematic Prediction

Table 1 provides a comprehensive comparison of various Recurrent Neural Network (RNN) models for predicting the joint angles of a 6-DOF robotic arm, based on inverse kinematic equations. These models include Simple RNN, Gated Recurrent Unit (GRU), Long Short-Term Memory (LSTM), and their bidirectional variants (BiSimple RNN, BiGRU, and BiLSTM). The evaluation criteria include metrics such as Mean Squared Error (MSE), Root Mean Squared Error (RMSE), Mean Absolute Percentage (MAP), R-squared (R^2), training time, and prediction time. These parameters were analyzed to identify the most efficient model for achieving accurate and real-time motion predictions for the RoboHarvester system.

Table 1. Overall Performance Analysis Comparison between deep learning algorithm to predict the joint angles of the 6-DOF robotic arm based on inverse kinematic equations.

RNN Model	MSE	RMSE	MAP	R-Squared	Training Time (ms)	Prediction Time (ms)
Simple RNN	0.118	0.434	0.312	0.993	7130	0.81
Gated Recurrent Unit (GRU)	0.0869	0.2948	0.1957	0.9966	10430	0.45
Long Short-Term Memory (LSTM)	0.1346	0.3669	0.2466	0.9952	14320	1.61
BiSimple RNN	0.1117	0.3341	0.2206	0.9955	9720	0.49
BiGRU	0.0619	0.2489	0.1638	0.9975	14420	0.73
BiLSTM	0.0729	0.2699	0.1891	0.9977	19150	1.19

Among the models, BiGRU exhibits the best overall performance. It achieves the lowest MSE (0.0619) and RMSE (0.2489), indicating minimal prediction errors. These values demonstrate the model's high accuracy in predicting joint angles, which is critical for precise and efficient robotic arm movements. Furthermore, BiGRU achieves a strong R^2 value of 0.9975, reflecting its excellent predictive capability in fitting the actual data. While BiLSTM slightly outperforms BiGRU in R^2 with a value of 0.9977, its higher computational complexity and longer prediction time (1.19 ms) make it less practical for real-time applications.

Regarding MAP, which measures percentage error, BiGRU again leads with the lowest value of 0.1638. This result highlights its robustness in minimizing deviation in predictions, further solidifying its suitability for precision-critical tasks such as fruitlet collection. Training time is another critical factor, as it influences the model's scalability and deployment. GRU demonstrates an advantage in training time (10,430 ms), compared to BiGRU's 14,420 ms. However, BiGRU's superior accuracy metrics justify the additional training time for real-time implementations. Prediction time is particularly crucial for real-time robotic operations. BiGRU achieves a reasonable prediction time of 0.73 ms, making it a highly efficient choice for controlling the robotic arm dynamically in response to changing environments. GRU, with a faster prediction time of 0.45 ms, offers an alternative for scenarios prioritizing speed over minimal accuracy loss. Nevertheless, BiGRU's overall balance of high accuracy and moderate computational efficiency makes it the most suitable model for this application. In conclusion, BiGRU emerges as the optimal model for the RoboHarvest system due to its combination of low prediction error, strong data fit, and reasonable computational efficiency. Its ability to provide accurate inverse kinematic predictions ensures seamless and precise robotic arm movements, enabling effective loose fruitlet collection. While other models like GRU and BiLSTM demonstrate certain strengths, BiGRU strikes the best balance between accuracy and practicality, making it ideal for scaling the RoboHarvester system to larger plantations and more complex operational conditions. This selection underscores the importance of considering both accuracy and computational efficiency in developing AI-driven robotic solutions.

3. Novelty and uniqueness

The AI-Driven Robotic System for Automated Detection and Collection of Loose Palm Oil Fruitlets is characterised by its incorporation of sophisticated machine vision, robotics, and real-time decision-making capabilities. This system utilises a YOLOv10-based object recognition framework with Particle Component Analysis (PCA) for accurate localisation and segmentation of fruitlets, surpassing traditional vacuum or raking processes in precision and efficiency. Moreover, applying predictive inverse kinematics facilitates dynamic adaptability in plantation environments, tackling irregular topography and dispersed fruitlets. The system's dependence on an economical CPU (e.g., Raspberry Pi) renders it a scalable and cost-efficient alternative to high-end industrial robots.

4. Benefit to mankind

This unique technology mitigates the ergonomic difficulties plantation workers encounter, decreasing the incidence of musculoskeletal illnesses resulting from physical labour. The technology improves worker safety and well-being while augmenting operational productivity by automating the labour-intensive task of loose fruitlet gathering. The efficient design minimises fruitlet waste, enhancing oil yields and optimising resource utilisation in the palm oil sector. Furthermore, the system conforms to sustainable development objectives by diminishing reliance on labour-intensive practices and fostering technology advancement in agriculture.

5. Innovation and Entrepreneurial Impact

The system implements an innovative application of robotics and artificial intelligence in the palm oil sector, converting a historically labour-intensive process into an automated, high-precision operation. The modular and scalable architecture facilitates local manufacturing, promoting innovation in developing economies. The project facilitates entrepreneurial opportunities aimed at improving plantation management, incorporating AI-driven systems, and creating supplementary technologies. Developing a cost-efficient robotic solution illustrates how technology may be customised to address industry-specific difficulties, fostering technological adoption and innovation.

6. Potential commercialization

The technology possesses considerable commercial potential within the worldwide palm oil sector, valued at billions of dollars annually. Its economical yet highly efficient design appeals to plantation owners aiming to minimise labour expenses and enhance productivity. The system's scalability and adaptability provide customised solutions for plantations of diverse sizes and complexities. Through enhanced refinement and incorporation into current supply chains, the product has the potential to secure significant market share as plantations progressively embrace automation to sustain competitiveness. Supplementary revenue sources may arise from license agreements, collaborations for hardware production, and software enhancements for improved functionality.

7. Acknowledgment

We would like to express our sincere gratitude to the Microwave Research Institute (MRI) and the School of Electrical Engineering, College of Engineering, Universiti Teknologi MARA for providing the facilities, resources, and support essential for conducting this research. Their contribution has been invaluable in enabling the successful completion of this work.

8. Authors' Biography

Mohammad Hafidz Hasnor Faiz is a postgraduate student at the School of Electrical Engineering, College of Engineering, Universiti Teknologi MARA (UiTM) and Data Engineer. He began coding during his Bachelor's degree, focusing on robotics. He later pursued a Master's degree in artificial intelligence and machine learning. During this time, he also practised data engineering. He frequently programs in Python for applications such as robotics, among others. He is proficient in data engineering languages such as SQL and tools like dbt,snowflake, databricks, apache spark, and more. He can be contacted at email: hafidzhasnor1@gmail.com

Norashikin M. Thamrin is an Associate Professor at the School of Electrical Engineering, College of Engineering, Universiti Teknologi MARA (UiTM), Malaysia where she has become a faculty member since 2008. She graduated from Universiti Teknologi Malaysia with her bachelor's degree (honours) in electrical-electronic engineering and Master's in Engineering in 2005 and 2007, respectively. She then received her Ph.D. in automation and robotics from Universiti Teknologi MARA (UiTM) in 2017. Her research interest is primarily in automated system development, water security, agriculture, and robotics. She has become the author/co-author of more than 50 publications. She can be contacted at email: norashikin@uitm.edu.my.

Noor Ezan Abdullah is a dedicated researcher and academic affiliated with Universiti Teknologi MARA (UiTM) Shah Alam. She holds a PhD in Electrical Engineering and has extensive expertise in various engineering and technology fields. Her primary research interests include signal processing, instrumentation systems, optical sensing, artificial neural networks (ANN), statistical analysis, and agriculture applications. Noor Ezan Abdullah is committed to advancing knowledge in these areas and contributing to innovative solutions for real-world challenges. She can be contacted at noor_ezan@uitm.edu.my

Muhammad Hasif Azami is a Senior Lecturer at the College of Engineering, Universiti Teknologi MARA (UiTM) and an associate member of the Microwave Research Institute. His expertise lies in the development of nanosatellites, with hands-on experience spanning the complete lifecycle of CubeSat projects. During his graduate studies, he contributed to two successful initiatives: BIRDS-2 and KITSUNE, which honed his skills in CubeSat design, testing, and deployment. His research focuses on remote sensing applications, utilising deep learning to enhance CubeSat capabilities. He can be contacted at hasif@uitm.edu.my.