The Potential of Robotics for Efficient and Sustainable Harvesting

Ahmad 'Athif Mohd Faudzi* and Mohd Azwan Mohd Bakri*
* CAIRO, Universiti Teknologi Malaysia, Jalan Sultan Yahya Petra, 54100, Kuala Lumpur.
*Malaysian Palm Oil Board, 6 Persiaran Institusi, Bandar Baru Bangi, 43000 Kajang, Selangor, Malaysia.
E-mail: athif@utm.my

INTRODUCTION

Malaysia is the second-largest producer of palm oil in the world, after Indonesia, accounting for 25.8% of global production and 34.33% of palm oil exports in 2020 (MPOC, 2023). Palm oil is used in many industries, such as food, cosmetics, biofuels, and energy applications. Moreover, waste generated from the palm oil industry such as palm biomass and palm oil mill effluent are applicable as alternative for renewable energy generation and the use of palm oil for upstream and downstream products is expected to be increasing in demand.

The labor shortage issue in the oil palm industry has persisted for a long time, with a 10% loss of unharvested palm oil fresh fruit bunches (FFBs) each year, equivalent to RM2.5 billion. The COVID-19 pandemic worsened the condition as many foreign laborers returned to their home countries. The shortage of labour leads to an increase in production costs (Zunaira, 2019).

HARVERSTING METHOD

The current harvesting method is typically carried out in pairs, where one labourer (harvester) cuts the FFBs with an extended sickle, while the other helps to arrange leaves, collects the FFBs and loose fruits using a wheelbarrow to transport them to the platform. Later, the FFBs are sent to the oil palm mill for oil extraction.

Harvesting of FFB depends on a highly skilled labour who needs to handle the tool and is strong enough to carry out the cutting operation. Harvesting accounts for about 60% of the workforce and about 50% of the production cost (Mohd Rizal *et al.,* 2023). The harvester must lift the pole upright and cut fronds and fruit bunches as high as 3 m or more. The difficult and energy-intensive work is less popular among the locals, thus requiring experienced foreign labour to conduct the work. *Figure 1* shows the procedures of the manual harvesting process.

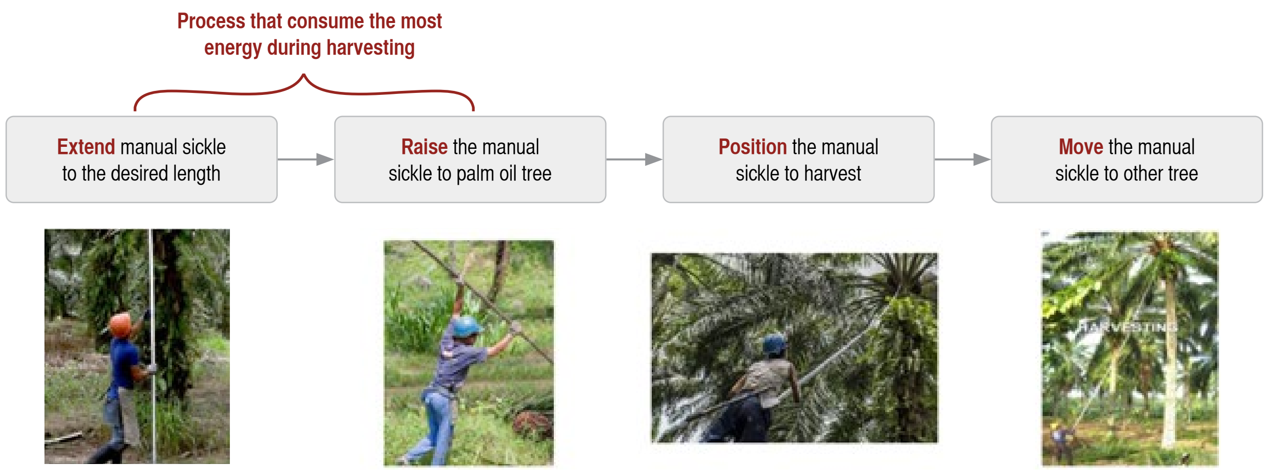

Figure 1. Manual harvesting process.

Since palm oil harvesting is frequent, with two or more cycles for the same tree in the same month, the process must be done on time to prevent over-ripe FFBs and maintain the quality and yield rate (Castillo *et al.,* 2017). The process of harvesting palm oil must be completed on schedule as there could be two or more cycles for a single tree in a given month. This will avoid overripe FFBs and ensure that the quality and yield are maintained (Castillo *et al.,* 2017).

Assistive tools such as motorised cutter 'CANTAS' developed by Malaysian Palm Oil Board (MPOB), are suitable for harvesting FFBs from palms up to 7 m in height with a harvesting productivity of about 6-12 t day^{-1}. However, it is currently not possible to harvest without proper tools and skilled harvesting labour for oil palm trees that are 25 years old or more and have a height of more than 9 m. Harvesting yield is often affected by labour motivation, experience, and physical strength. One of the best approaches is to reduce labor dependence and increase productivity to mechanise the harvesting activity in order. This could be achieved through introduction of efficient and economical harvesting robotic technology (Shuib *et al.,* 2020).

ROBOTICS TECHNOLOGY

Several countries have started to apply robotics for palm oil harvesting, but most of the research and development in this area is still in experimental stage. In Malaysia, many government-led initiatives, such as the Mechanisation and Automation Research Consortium of Oil Palm (MARCOP), International Competition on Oil Palm Mechanisation (ICOPM), and other competitions under Ministry of Science, Technology and Innovation (MOSTI), such as MyHackathon, have been launched to spur new innovation in robotics technology for the palm oil industries. Several universities and research institutions in Indonesia and Columbia are conducting research on the use of robotics for palm oil harvesting (Munar *et al.,* 2021).

There are four main technologies being developed to assist the operation in palm oil plantations and to address mechanisation in palm oil harvesting: exoskeletons to assist harvesters, drones for FFB observation and pesticide spray, mechanical harvesters with robotic arms and UGVs for FFBs loading.

i) Exoskeletons for Assisting Harvesters

Exoskeletons are wearable devices that provide support and assistance to workers during physical tasks, reducing the strain on their muscles and joints. Exoskeletons have the potential to improve the safety and productivity of workers in the palm oil industry. The physically demanding nature of manual labour in palm oil harvesting can lead to musculoskeletal disorders and injuries among workers, which can have long-term health effects and impact their ability to work. In the palm oil industry, exoskeletons can help workers lift and carry heavy loads of fruit bunches, which can weigh up to 25 kg each. Exoskeletons can also assist with tasks such as pruning, weeding, and fertilising, thereby reducing the risk of repetitive strain injuries. An exoskeleton prototype called Terer™ has been developed by CAIRO UTM, and shown to be able to reduce muscle strain by 22% and increase endurance by 47% (Mei Mei, 2022).

In addition to improving safety of workers, exoskeletons can also increase productivity in the palm oil industry. By reducing physical strain, workers can work more efficiently and for longer periods without the need for frequent breaks or rest periods. Overall, the use of exoskeletons in the palm oil industry has the potential to improve workers safety and productivity, reduce physical strain on workers, and improve their abilities to perform manual tasks. However, there are still challenges that need to be addressed, such as the high cost of exoskeleton technology and the need for specialised training for workers to optimise the suit.

ii) Drones for FFB Observation And Pesticide Spray

Drones are being explored as a potential tool for oil palm harvesting. These unmanned aerial vehicles (UAVs) can fly over the plantation and use sensors and cameras to collect data on the health and maturity level of the oil palm trees and identify ripe fruit bunches. This data can then be used to optimise harvesting schedules and identify areas that need attention.

Moreover, drones can also be used to spray fertilisers and pesticides, reducing the need for manual labour and minimising the environmental impact of these chemicals. Similarly, the use of drones in palm oil harvesting can potentially increase efficiency, reduce labour costs, and minimise the environmental impact of the industry. However, challenges such as limited fly time, the high cost of drone technology, and the need for specialised training for operators need to be addressed. Nevertheless, the development of drone technology for oil palm harvesting is an exciting area of research and has the potential to revolutionise the industry.

iii) Mechanical Harvester With Robotic Arm

MPOB has highlighted the latest research in the integrated oil palm harvesting machine with one of the developments being the 4-in-1 machine that allows pruning, harvesting, catching, and transporting FFB (Parveez *et al.,* 2021). The range variant of the entire harvesting machine is between 10 m and 15 m. The key highlight of the development is its scissor-type design, which can travel at about 80° along the guide rail.

Sime Darby Berhad is also leveraging on robotic advancements to build a machine that can be used to harvest oil palm's FFB (Nurul, 2021). These robotic arms were designed to mimic the motion and dexterity of human arms, allowing them to pluck individual fruit bunches from the trees. They can also be equipped with sensors to detect the fruits ripeness and avoid damaging the trees. Multiple cameras and an onboard monitor can be used for better target detection and depth estimation before the FFB is being cut. Robotic arms can potentially increase the efficiency of palm oil harvesting and reduce the need for manual labor. A2LAB-CAIRO UTM in collaboration with MPOB and other industry partners has developed a series of prototypes for a mechanical harvester with robotic arm. The latest prototype is expected to be able to harvest FFB at up to 4.5 m (Mohammad Afandi *et al.,* 2022).

iv) Unmanned Ground Vehicle (UGV) For Loading FFB

In addition to drones and mechanical harvesters with robotic arms, other robotics solutions are being developed for palm oil mechanisation, such as the UGV for carrying FFB and loose fruits around the tree. Conventionally, wheelbarrows were used to manually move the harvested FFBs and loose fruit to the platform. Currently, mechanised systems such as Badang and Orec Land Surf are widely used in Malaysian plantations. Researchers are now planning to automate this process using unmanned ground vehicles to autonomously collect the FFBs and loose fruits and transport them to the designated station before moving them to the processing plant. These vehicles can be programmed to follow specific routes and avoid obstacles, reducing the need for manual labour and minimising the environmental impact of heavy machinery. The uneven terrain and palm tree canopy, which limit stable GPS signals, are among the main challenges faced.

CHALLENGES

The development of robotics solutions for palm oil harvesting holds great promise in improving efficiency and reducing environmental impact. However, there are still several challenges that need to be addressed before these technologies can be widely adopted.

The cost of robotics technology is still relatively high, making it difficult for many farmers and plantation owners to invest in these solutions. The return of investment (ROI) for using this technology is currently longer compared

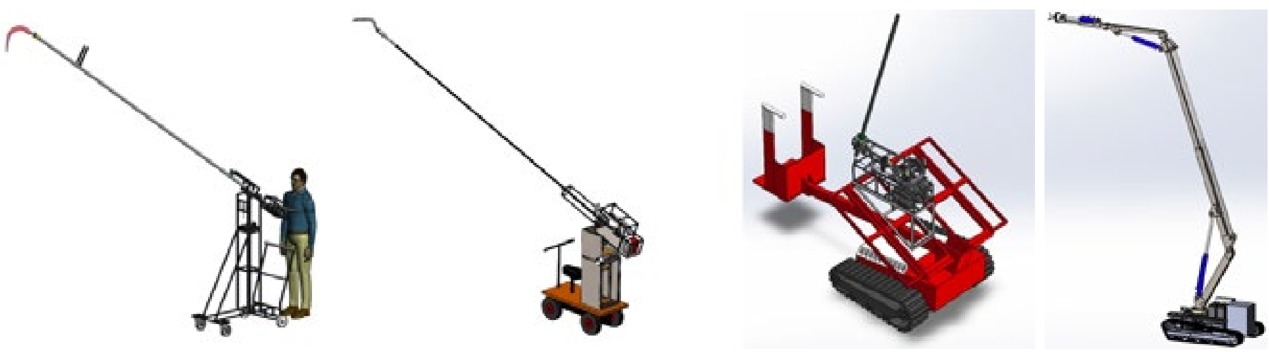

Figure 2. R&D for Mechanical harvester with robotics arm conducted in A2LAB-CAIRO UTM

to foreign labour. Additionally, technical complexity and specialised knowledge needed to operate and maintain robotics technology can be a deterrent to adoption for some farmers and plantation owners. Adapting robotics to the forest ecosystem might be challenging as palm oil plantations can vary greatly in terms of geography, tree density, and others.

The use of robotics technology in agriculture is subjected to regulatory oversight, which can be complex and vary from country to country. Researchers need to get advice for regulatory matters and get assistance for related regulators and government agencies. When needed certification and regulatory matters will be assisted under MOSTI initiatives for national technology sandbox (NTIS). Finally, the technology needs to be reliable to be adopted as a major part of palm oil harvesting. Reliability is critical for the success of the technology and for farmers and plantation owners to feel confident in adopting it.

CONCLUSION

In summary, the potential benefits of robotics solutions for palm oil harvesting are significant, including improved efficiency, reduced labour cost, and minimised environmental impact. While there are still challenges to be addressed, continued research and development in this area are likely to lead to the adoption of these technologies in the future. By leveraging the potential of robotics, the palm oil industry can achieve greater efficiency, profitability, and sustainability while minimising its impact on the environment and human workers.

REFERENCES

Castillo, E G; Rodríguez, C L F and Páez, A F (2017). Evaluation of two harvesting procedures for oil palm (*Elaeis guineensis* Jacq.) fruits. A case study. *Agronomía Colombiana 35(1)*: 92.

Malaysian Palm Oil Council (MPOC) (2023). Malaysian Palm Oil Industry. https://mpoc.org.my/malaysian-palm-oil-industry/.

Mei Mei, C (2022). Malaysia's palm planters eye robots, drones to combat labour crunch.https://www.reuters.com/article/malaysia-palmoil-labour-exoskeleton-idAFL4N30R299.

Mohd Rizal, A; Mohd Khairul Fadzly, M R; Ahmad Syazwan, R; Mohd Azwan, M B; Mohd Ikmal Hafizi, A; Aminulrashid, I; Ahmad Athif, M F; Ariff Azly, M and Habiel, Z (2023). Evaluation and Comparison of the Ergonomics, Performance, and Economics of Battery-Powered and Engine-Powered Palm Oil Harvesting Tools: Cantas Elektro. *Jurnal Kejuruteraan, 35 (5)*.

Mohammad Afandi, M Z; Tan, J J; Wessam, H; Ahmad Athif, M F and Mohd Rizal, A (2022). Mobile-Based Motorized Cutter Mechanism for Palm Oil Fresh Fruit Bunch Harvesting. *Lecture Notes in Networks and Systems* Book Series (LNNS,volume 429).

Munar, F D A; Chaparro, T D C, Ramírez, C N E and García-Núñez, J A (2021). Greenhouse gas emissions for different harvesting, rising and transportation methods of oil palm fresh fruit bunches. *Palmas, 42(2):* 49-61.

Nurul, S (2021). Sime Darby Plantation to develop FFB robotic machine to lessen foreign work dependency. Retrieved from: https://www.businesstoday.com.my/2021/04/19/sime-darby-plantation-to-develop-ffb-robotic-machine-to-lessen-foreign-work-dependency/.

Parveez, G K A; Azmil, H A T; Shamala, S; Soh, K H; Meilina O B; Kosheela, D P P; Kamalrudin, M S; Sheilyza, M I and Zainab I (2021). Oil palm economic performance in Malaysia and R&D progress in 2020. *J. Oil Palm Res. 33(2)*: 181-214.

Shuib, A R; Radzi, M K F M; Bakri, M A M and Khalid, M R M (2020). Development of a harvesting and transportation machine for oil palm plantations. *J. Saudi Soc. Agr. Sci. 19(5)*: 365-373.

Zunaira, S (2019). Getting to grips with the labour shortage problem. The Star Online, https://www.thestar.com.my/business/business-news/2019/02/02/getting-to-grips-with-the-labour-shortage-problem/.