

Design of Agriculture Harvesting Robot Model Support for Elderly Farmers

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Abstract

As Thailand's aging population increases, even with Thai farmers entering the senior age group. They require agricultural tools and equipment to facilitate their farming to prevent aging from impacting their careers, modern agricultural technology is also required. This research presents the design of an agricultural harvesting robot to assist elderly farmers and is suitable for Thailand's agricultural areas. It utilizes artificial intelligence concepts and the Internet of Things (IoT) with two objectives: 1) to alleviate the labor shortage for young farmers, providing a tool to assist older farmers; and 2) to serve as a guideline for sustainable agriculture in the future. This agricultural harvesting robot combines advanced technologies, such as machine learning to learn and control robot operations, applications to assist with movement and vision, artificial neural networks, and robotic control for harvesting, resulting in increased precision and increased efficiency. The robot's base is designed to adjust for movement on rough, uneven ground surfaces such as rice paddies, rice fields, ditches, and low, plateau areas to ensure consistent movement. Furthermore, the robot's arm is equipped with sensors to enable it to navigate and detect crops accurately and precisely. These functions make the robot more convenient for elderly farmers, allowing them to control and use the robot correctly and for its intended purpose. They do not need to be experts to use it. Experimental results indicate that agricultural harvesting robots can efficiently harvest longan, Langsat, and Lamberton, all types of agricultural fruits, by reducing steps and increasing yields.

Keywords: Harvesting robot; Elderly farmers; Internet of Things (IoT); Agricultural robot; Robot model

Introduction

In Thailand, most people are farmers, even if in Uttaradit province in our case study. The area of Uttaradit province is between the northern and central regions of Thailand, in the lower northern region. The majority of the population is farmers [1]. Therefore, the problem is that the farmer is aging

older and older. Many farmers are confronted with physical challenges, which affect their farming productivity and their daily livelihoods. Based on this information, this research project presents the design of an agricultural harvesting robot to assist farmers and facilitate the farming of these elderly people. This research aims to relieve the labor shortage of the young smart farmers and provide tools to the elderly farmers. The new technology is used to help older farmers with the heavy workload, increase agricultural efficiency, promote agriculture, and build confidence in the farming practices in the future [2]. This research aims to reduce the physical stress of elderly farmers by automating the harvesting process to increase efficiency. Improved harvesting speed and accuracy reduce worker costs and time. It also promotes sustainable agricultural practices through precision agriculture that can adapt by designing robots that can adapt to different agricultural harvesting crops and terrain found in Thailand. Many researchers try to use research and machine learning tools to support elderly farmers and agricultural production.

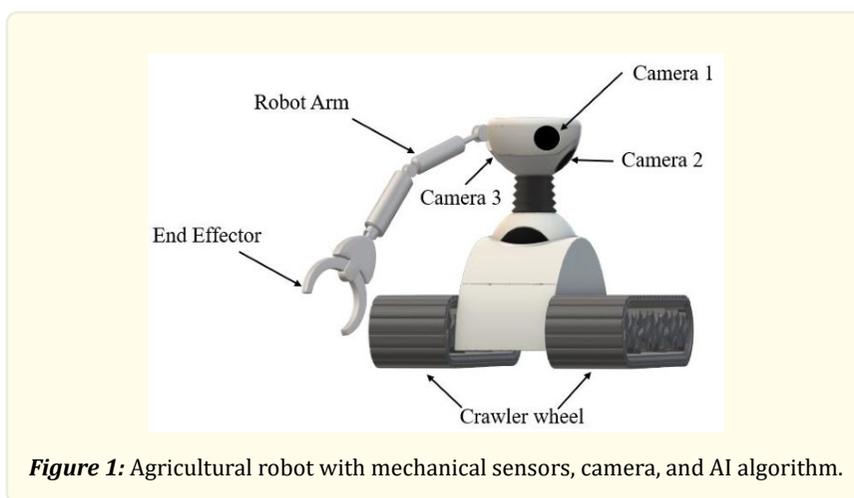
Jun Zhang et al. [3] presented research on the fruit industry, which has become an important part of agricultural development; therefore, fruit harvesting is an important step in production. Therefore, in the harvesting season, fruit harvesting has always been the last and most important step, because fruit picking takes a long time, is expensive, and the harvesting process is not as efficient as it should be. The researchers have conducted many studies on automatic fruit picking equipment. Current fruit picking technology requires research for development in various areas to increase efficiency, reduce damage, and lower production costs. Therefore, they have developed automated fruit picking technology aiming for sustainable development.

Problem destination

Definition of Harvest Robots

Agricultural harvesting robots for seniors and elderly farmers are highly automated machines designed to help harvest more crops from fields or fruit orchards. These robots use mechanical components, sensors, and cameras, as shown in Figure 1. The researchers have also proposed intelligent algorithms to identify, harvest, and manage various fruit produce, such as longans, langsat, and rambutans. Harvesting robots play a crucial role in modern agriculture. the data collections.

Their robots are advanced automated machines designed to assist in the agricultural process of collecting ripe crops from fields. Because the Thai population is steadily increasing, there is a growing demand for food production [4]. Moreover, traditional farming methods often struggle to keep up due to farmer shortages and inefficiencies. The harvesting robots can improve production efficiency, ensuring consistent and high-quality yields. However, the historical background of the agricultural automation concept dates back to the early 20th century, with the advent of mechanical harvesters. These machines were rudimentary compared to present standards. The integration of digital technology, robotics, and artificial intelligence in recent decades has revolutionized the development of sophisticated agricultural harvesting robots, as shown in Figure 1.



Technological Components

The visual sensors and new model color cameras of harvesting robots have various sensors and cameras to detect and analyze the environment of a field, depth sensors, and multispectral cameras, which are available to identify crops and assess their condition in more detail. This research chooses artificial intelligence and machine learning. AI and machine learning algorithms are strong for processing sensor data and making real-time decisions. These technologies enable robots to learn from past experiences, improve accuracy, and adapt to different harvesting situations. Secondly, robotics and mechanical systems with the mechanical aspect of harvesting robots must design robotic arms, grippers, and mobility systems smoothly. All components must be unique and engineered to handle exquisite crops without damage while being durable enough to resist various growing conditions. The next benefit mentioned is communication technologies such as the Internet of Things (IoT). This technology will enable harvesting robots to connect to other machines. For example, connecting these devices will facilitate real-time monitoring, farm management systems and cloud computing platforms, data sharing, and remote control [11-12]. Another benefit is that researchers have designed grippers and movement systems to be used in robotic arm systems. The engineering design of these components must be precise and able to facilitate smooth operation, suitable for applications that harvest delicate crops without causing damage, and at the same time, must be durable enough to work in all uneven terrain. The algorithms of these harvesting robots and the software design consists of the navigation system, the navigation algorithm, the control system and the survey crops program. All of these algorithm is helping the robots to navigate in the farm. It can locate the crops and efficiency of the harvesting them [5].

Design and Development

The researcher starts by analyzing the needs and understanding the specific requirements of agricultural equipment. Therefore, the researcher designed a prototype using engineering principles to visualize the structure and operation of the agricultural harvesting robot through the construction of the prototype and preliminary testing. This prototype is creating a functional model of the robot. The researcher starts by analyzing the needs and understanding the specific requirements of agricultural equipment. Therefore, the researcher designed a prototype using engineering principles to visualize the structure and operation of the agricultural harvesting robot through the construction of the prototype and preliminary testing. This prototype is creating a functional model of the robot. The research team is putting this prototype through extensive testing in many ways, such as test both in controlled lab settings and out in actual field conditions to consider how well the prototype really performs. The main focus during testing will be on how accurate and reliable it is [6]. Building a robot that can actually harvest crops comes with a lot of hurdles to clear. The researchers need to make sure it can correctly identify different crops, avoid damaging or bruising them during picking, and keep working properly even when growing conditions vary from field to field. In addition, the research team focuses on practical concerns such as how much power it uses, how weight it is, and the whether that can hold up to regular use in hardly environments. Getting a harvesting robot right isn't something one group of specialists can do alone. The researchers team bringing together people from mechanical engineering, computer engineering, agricultural science, and data analysis. The integration of these branches means that the knowledge from the different fields and solve solutions, the researcher team have considered before [7-9].

Materials and Methods

Design requirement

The design of an automated agriculture harvesting system with the ability to identify, pick up, and collect various crops. First, the overview of the computer system in the harvesting system for agriculture is divided into several sub-systems and the computerized harvesting system for agriculture are divided into several sub-systems. Designing an automated agriculture harvesting system involves several key components. This research vouches that the system can efficiently and accurately identify, harvest, and handle crops. Firstly, system architecture includes both hardware and software components. Hardware components consist of robotic arms or harvesting units, and the system consists of these, which are equipped with end-effectors (tools) suitable for picking different types of crops. Second, cameras and sensors, including high-resolution, multispectral, and hyperspectral, and various sensors (e.g., LIDAR, ultrasonic, and infrared), are used to identify and assess the crops.

Design of the agricultural harvesting robot

The goal is to design a small, efficient, user-friendly agriculture harvesting robot tailored to elderly farmers. The robot will assist in harvesting various crops, reducing physical strain and increasing productivity.

Design of the specification

The specification of the model is as follows:

Dimensions	The arm high	Weight	Materials
50 x 50 x 50 cm (W x L x H)	150 cm.	15 kg.	Lightweight aluminum frame, durable plastic casing

Table 1: Dimensions and weight.

Crawler wheel	Motors	Speed	Navigation
all-terrain wheels with	Independent suspension for uneven surfaces	Eight brushless motors for the crawler	The structure of the crawler wheel of the robot is shown in Figure 3

Table 2: Mobility.

Micro controller	Vision	Proximity	Environmental	Communication
Arduino Mega	Dual cameras (RGB and NIR) for crop detection and ripeness assessment	Ultrasonic sensors for obstacle Detection	Temperature and humidity sensors	Wi-Fi and Bluetooth for remote control

Table 3: Control system.

Actuators	Cutting	Grabbing	Tool Swapping	Adjustability
Linear actuators for the precise movement of harvesting tools	Rotating blades for crops like lettuce	Robotic gripper with soft, silicone fingers for delicate fruits	Automatic tool changer for different crops	Adjustable height and angle for various plant sizes and types

Table 4: Harvesting mechanism.

Control Panel	Remote Control	Mobile App
Simple control panel with an LCD screen and tactile buttons	Handheld remote with joystick and buttons for manual operation	User-friendly app for smartphone/tablet with real-time monitoring and control

Table 5: User interface.

Figure 2(a) shows the structure of the elderly farmers' robots, which are part of this research's agricultural harvesting design. The robots have two cameras, two robot arms, and an end effector.

Figure 2(b) shows the complete design of the agriculture harvesting robot. It consists of a crawler wheel. The goal is to design a small, efficient, user-friendly robot tailored to elderly farmers. The robot will assist in harvesting various crops, reducing physical strain and increasing productivity [10].

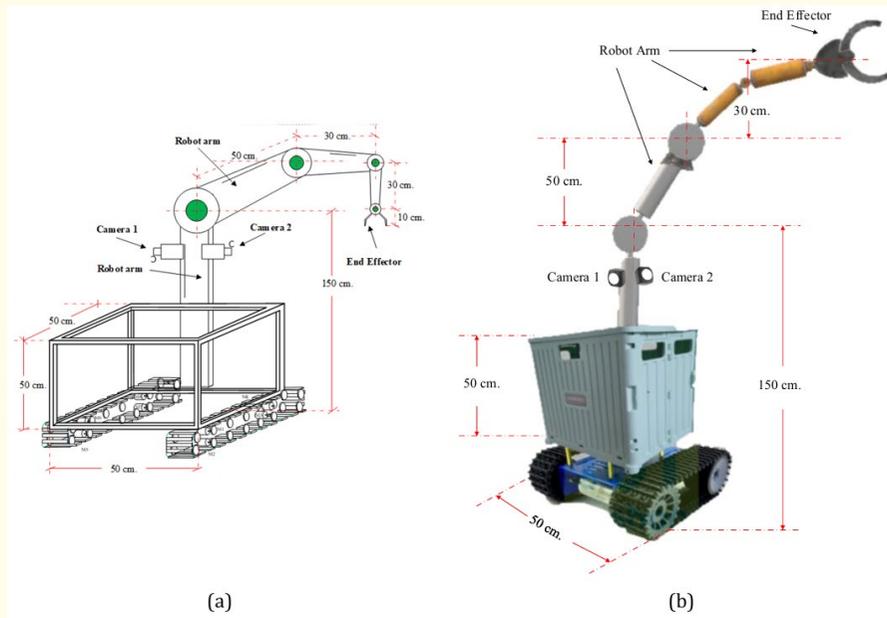


Figure 2: (a) The structure design of an agriculture harvesting robot for elderly farmers, and (b) an agricultural robot with mechanical sensors, a camera, and an AI algorithm.

The researchers have proposed a range of farmer-friendly and actionable interventions that can be implemented at both policy and community levels to help reduce the fears and anxieties experienced by older farmers as they approach retirement from agriculture. These interventions emphasize promoting social and emotional well-being through participation in social groups that embody the values and aspirations associated with farming later in life [14].

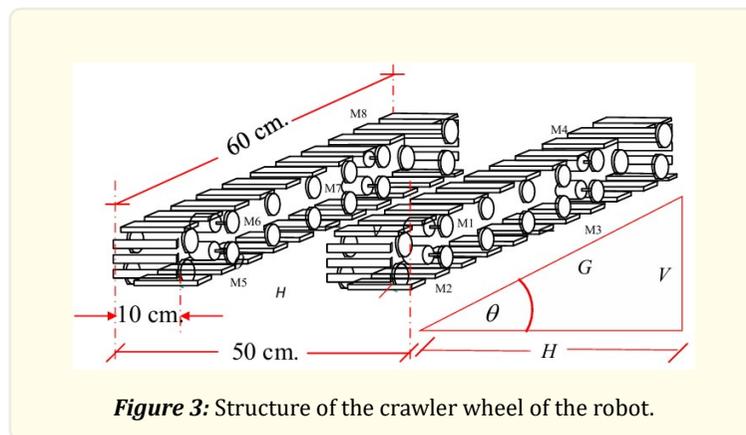


Figure 3: Structure of the crawler wheel of the robot.

$$\frac{V}{l} = \sin\theta \approx \tan\theta = \frac{V}{H} = \left(\frac{G}{100}\right) \quad (1)$$

$$F_{GR} = W \tan\theta = w \left(\frac{G}{100}\right) \quad (2)$$

Where V denotes the vertical height of the surface, H is the horizontal height, and the road surface's angle is horizontal.

Software design

The software algorithm of the mini harvesting robot is as follows:

Initialization	The robot is initialized with the size of the field and the type of plant it needs to harvest. Initial position, battery level, basket capacity, and current load are set
Path Planning	The robot creates a path plan in a zigzag pattern to cover the entire field efficiently.
Crop Detection	A simple simulation of detecting ripe crops based on the plant type
Harvesting	The robot checks each position in the path plan for ripe crops and harvests them if found. If the basket reaches its capacity, it is emptied.
Movement and Battery Management	The robot moves to each position in the path plan, checks the battery level, and returns.
Initialization	to the charging station if the battery is low. After harvesting, the robot returns to the charging station for recharging.

Table 6: The general characteristics of farming fields.

Flowchart diagram

The software algorithm of the mini harvesting robot is as follows, with Figure 4 showing a flowchart diagram that outlines the primary software flow for the agriculture harvesting robot's operation, from initialization to harvesting and shutdown. The optional maintenance mode includes regular system checks and alerts for maintenance needs. The algorithm of the flowchart diagram representation needs to start in the initialized system. The initialization stage consists of initialized sensors, which are calibrated and tested sensors.

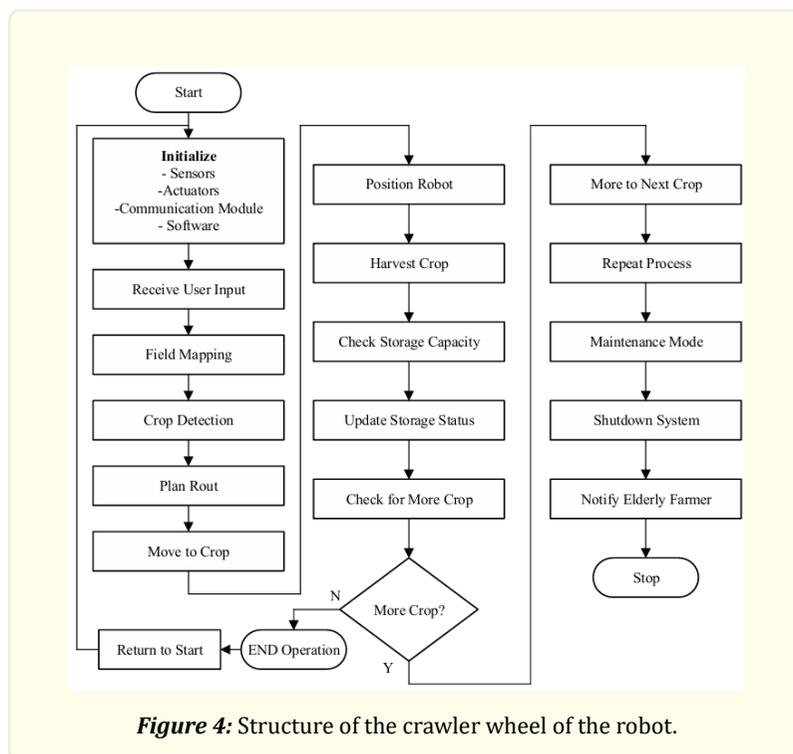


Figure 4: Structure of the crawler wheel of the robot.

The algorithm of the flowchart diagram is as follows: Initialize Actuators, test and calibrate robotic arms, wheels, and other movement mechanisms. Initialize Communication Modules and establish communication with remote controls or mobile apps. Then, the software modules are loaded, and the necessary software libraries and algorithms are loaded. User Input, Receive User Input, and get input from the user (e.g., field boundaries, crop type, harvesting preferences).

Field Mapping: Use GPS and sensors to map the field and identify rows and columns of crops. *Crop Detection:* Capture images using the camera. Process images using machine learning to detect ripe crops and mark detected crops in the field map. *Navigation Plan Route:* Calculate the optimal route for harvesting based on crop locations. *Move to Crop:* Navigate to the nearest detected crop. Avoid obstacles using distance sensors. *Harvesting:* Position the robot to align with the crop. *Harvest Crop:* Activate the robotic arm to pick the crop. Store the harvested crop in the storage compartment.

Storage Management: Check Storage Capacity and Verify if the storage compartment is full. If it is, alert the user or navigate to the drop-off point. *Update Storage Status:* Update the number of harvested crops in the system. *Repeat Process:* Check for More Crops: Verify if there are more crops to harvest. If yes, repeat steps 6-8. If no, proceed to the next step.

Detection and identification of different crop types

Detect and identify different crop types in the field using images captured by a high-resolution camera mounted on a drone [13]. Location at the experimental farm, Faculty of Industrial Technology, Uttaradit Rajabhat University. To detect and identify different crop types in the field using images captured by a high-resolution camera mounted on a drone. The equipment consists of a DJI Phantom 4 Pro drone, a Sony Alpha a7R IV camera (61MP), Pix4Dmapper software for image processing, and a custom-trained convolutional neural network (CNN) model for crop detection.

Experimental Results and Discussion

The experiment procedure is as follows: Firstly, a drone was flown over the field at 50 meters. High-resolution images were captured every 5 seconds. The photos were stitched together using Pix4Dmapper to create a mosaic map of the field. The method was processed using the custom-trained CNN model to detect and classify crops.

This research presents a case study of the robot for agricultural harvesting control to support the elderly farmers, an experiment in Uttaradit Province, Thailand. The research teams are considering the hardness, compatibility, and efficiency for the elderly. The main components include the vehicle frame and maneuverability. The robust and lightweight vehicle frame, made of high-strength materials, offers flexibility and agility. The robot was installed with all-terrain wheels to navigate a wide range of farm conditions. While the compact robot has a harvesting mechanism, it also features a versatile harvesting arm with adjustable grips that can handle a wide range of crops. High-resolution servo motors and sensors ensure the accuracy of the harvesting arm. Advanced sensors include LiDAR, ultrasonic, and infrared. They permit the robot to detect hurdle and an autonomous navigation system. The GPS and RTK modules guarantee detect the positioning in the farm. A solar-powered and power system addendas the rechargeable lithium-ion battery, assuring extended operation with optimal downtime.

The software application support, It is applied for the elderly robot and setting the priority for the user and dependable efficiency. The key modes consist of a user interface (UI), who is an intuitive touchscreen interface with functions for manual control, job planning, and the status monitoring. The research team designs the UI function for users with constrained technical knowledge. The software for the elderly robot uses advanced techniques for path scheduling and obstacle escapade, This function could permit it to operate harvesting tasks autonomously. The machine learning algorithms are employed to improve efficiency in during time with remote monitoring control. Elderly farmers can remotely monitor and control the robot directly with a mobile app, with short-time updates and alerts. This functionality supports elderly farmers to manage their own jobs without constant human contact. The robot summarizes data on plant health, soil environment, and harvested produce, which is beneficial information to the elderly farmers. This data is processed and displayed in an easily understandable format on the mobile application.

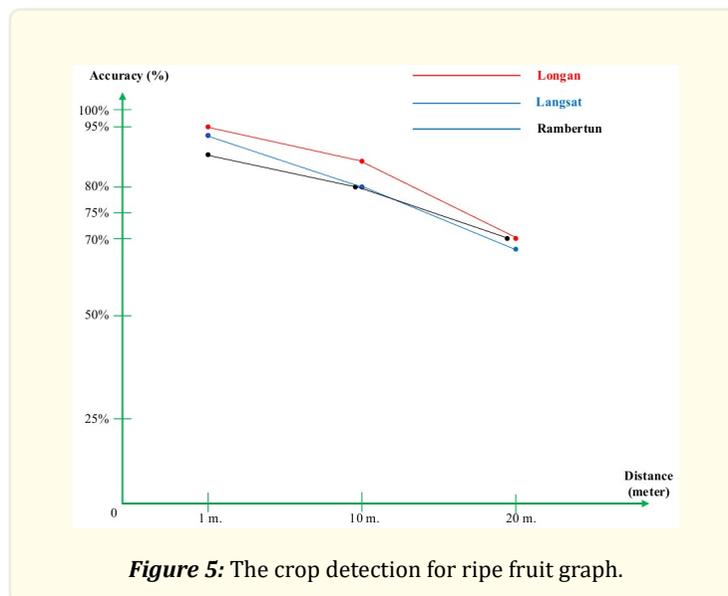
Crop detection for ripe fruit

The CNN model identified three main fruit types: longan, langsat, and rambutan. The three main fruits are famous and economically important in Thailand. Therefore, the research team chose these fruits for the sample in the case study.

Fruits	Accuracy (%)		
	1 m.	10 m.	20 m.
Longan	95%	85%	72%
Langsat	92%	80%	68%
Rambutan	90%	80%	70%

Table 7: Crop detection for ripe fruit comparison depends on distances.

As shown in Table 7, the detection accuracy for the three main fruits was as follows: longan, 95% at 1 m, 85% at 10 m, and 80% at 20 m. Longan was 72%. At the same time, the Langsat was 92% at 1 m, 80% at 10 m, and 68% at 20 m. The rambutan was 90% at 1 m., 80% at 10 m., and 70% at 20 m. respectively.



The experimental graph in Figure 5 shows the use of a camera for image processing and comparison of three main fruits: longan, langsat, and rambutan. The y-axis is the accuracy in percent units, and the x-axis is the distance in meters.

Image Capture and Processing

The research used an agricultural harvesting robot and a drone to capture 50 images of ripe fruit over a 10-square-meter field. The research teams chose one picture example, as shown in Figure 6.

The software successfully stitched the images to form a detailed ortho-mosaic map. The final map's resolution was 5 cm/pixel, allowing for clear visualization of individual plants. Figure 6 shows a drone and an agriculture harvesting robot to test longan fruit picking using a smartphone to monitor the robot's performance, detecting ripe longans ready to be harvested.



Field Testing and Results

The research tested various fields in Uttaradit province, especially the fruit farm (longan, langsat, and rambutan). The research teams are using both the drone and the robot to test the experiment and obtain the results. Then, the experiment results from the testing phase include, first, that the robot's efficiency can reduce the time required for harvesting compared to manual methods. On average, productivity increased by 40 percent. Secondly, the reports on the ease of use among elderly farmers. The experimental results show that most users are satisfied with its ease of use, especially with the user interface (UI) functionality and remote-control features. Third, the harvesting robot performance can work in many obstacles and terrains, such as uneven garden areas, the ground in the garden, and high and low areas. Fourth, the sensors and data accuracy to detect and report correctly, such as the accuracy in percent units, and the distance in meters. The experiment shown in graph in figure 5.

Conclusion

This research presents the robot for an agricultural harvesting robot for the elderly farmers in Uttaradit Province, Thailand. A case study, represents the evolution in the application of new technology to agriculture farmers. They is applying and improving the performance of the robot and supporting the elderly farmers. The researchers presented a design that is adaptable and replicable in other agricultural regions in Thailand facing similar challenges, specifically addressing the needs of elderly farmers. This research not only increases the agricultural productivity but also preserves traditional agricultural knowledge and utilizes a mix of the original and innovative approaches to foster intergenerational unity. The use of these innovations that matching the challenges of cost, training, and ability to resize the foundation for this research, providing a strong platform for future advancements and the wider adoption of agricultural robotics in the region.

The development and idea design of an agricultural harvesting robot for elderly farmers in Uttaradit Province, Thailand, is to be a successful project. The researcher represents the integration of advanced hardware and software innovations; the robot enables an increase in productivity and also provides a practical solution to identify the challenges faced by elderly farmers. Continuous development and improvement hold promise for further improving agricultural practices and the quality of life of elderly farmers.

Conflict of interest

The authors declare that they have no known financial or personal relationships that could have influenced the work reported in this paper.

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