IAES International Journal of Robotics and Automation (IJRA)
Vol. 15, No. 3, September 2026, pp. 553~560
ISSN: 2722-2586, DOI: 10.11591/ijra.v15i3.pp553-560

Remote controlled agricultural robot for spraying liquid type pesticides

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Article Info

Article history:

Received Apr 15, 2025
Revised Jun 6, 2026
Accepted Jul 20, 2026

Keywords:

Agricultural robot
Arduino microcontroller
Radio frequency receiver
Radio frequency transmitter
Remote control

ABSTRACT

In modern agriculture, the use of automation and robotics is becoming increasingly essential to enhance efficiency, reduce labor, and ensure the safe handling of hazardous materials. This paper presents the design and development of a remote-controlled agricultural robot specifically intended for spraying liquid-type pesticides using radio frequency communication. The system comprises a mobile robot platform equipped with a pesticide tank, a spraying mechanism powered by a direct current (DC) pump, and a set of drive motors for navigation. The robot is remotely controlled through a radio frequency (RF) transmitter and receiver pair, allowing the operator to manually guide the robot across agricultural fields without direct contact with pesticides. The RF module transmits commands such as movement directions and spray activation, which are interpreted by an Arduino microcontroller onboard the robot. The system aims to reduce human exposure to harmful chemicals, minimize labor efforts, and increase precision in pesticide application. This solution is cost-effective, user-friendly, and adaptable for small to medium-sized farms, offering a practical step toward smart farming.

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1. INTRODUCTION

The authors present a real-time, data-driven remote-control framework for agricultural robots using human hand gestures. It employs a 3D convolutional neural network with deep separable convolution and inverted residual structures for dynamic gesture recognition. The system is demonstrated on a Unite agricultural robot, showcasing efficient and responsive teleportation in complex environments [1]–[3]. A wireless local-area network (WLAN) based remote monitoring and automatic navigation control system was developed for agricultural vehicles. It includes a vehicle navigation system, a communication server, and a monitoring center. The system allows real-time tracking of multiple tractors on a geographic information system (GIS) map. Using real-time kinematic global positioning system (RTK-GPS), a digital compass, and an angle sensor, it determines the vehicle's position and orientation. Communication is achieved via a wireless local network, and fuzzy control is applied for steering. A line-tracking algorithm enables the vehicle to follow a predefined path automatically [4]–[7]. The authors present a data transmission and interaction platform for intelligent agricultural robots within the Internet of Things framework. It focuses on designing a message queuing telemetry transport (MQTT) based communication protocol with enhanced security, data compression using an optimized Lempel–Ziv–Welch (LZW) algorithm, and efficient storage using Redis and MySQL databases. The system addresses challenges in real-time data processing and large-scale data flow from remote monitoring. Experimental results show the platform ensures stable, secure, and efficient communication for multiple agricultural robots, supporting real-time status updates and remote control [8]–[10]

This article addressed the challenges in agricultural distribution networks, such as wide coverage, high failure rates, and difficult maintenance. It introduces an all-terrain, variable-width tracked robot designed for live operations in narrow spaces. The robot features specialized tools and a visual feedback-based human-machine interaction control strategy. It supports remote and automated operation across various terrains, including soil, rocks, and grasslands [11]–[14].

2. BLOCK DIAGRAM

The radio-frequency identification (RFID) transmitter system using a 433 MHz radio frequency (RF) module and the AT89C2051 microcontroller shown Figure 1. The operates by transmitting identification data wirelessly through radio frequency. At the core of the system is the AT89C2051, an 8051-based microcontroller, which stores or generates the RFID code to be transmitted. This microcontroller sends the identification data through its serial port (UART) to an encoder, such as the HT12E, which converts the parallel or serial data into a properly formatted serial data stream with address and control bits for reliable communication. This encoded signal is then fed into the 433 MHz RF transmitter module. The transmitter modulates the digital data using amplitude shift keying (ASK) and sends it out through its antenna as a radio frequency signal. The RF signal carrying the RFID data can then be received by a compatible 433 MHz RF receiver. This setup allows the system to act as a wireless RFID tag emulator, where the transmitted ID can be used for identification, access control, or other automation tasks. The entire process is low-power and suitable for short to medium-range wireless communication [15]–[20].

The RFID receiver system using a 433 MHz RF module and the AT89C2051 microcontroller are shown in Figure 2. This operates by receiving and processing wireless identification data. The system begins with the 433 MHz RF receiver module, which captures radio frequency signals transmitted by an RFID transmitter. These signals, modulated typically using amplitude shift keying (ASK), are demodulated by the receiver into digital serial data. The output of the RF receiver is then fed into a decoder, such as the HT12D, which converts the serial data into parallel form and verifies the address and control bits to ensure the signal is valid and intended for this device. The decoded data, usually representing an RFID tag or identification number, is sent to the AT89C2051 microcontroller via its I/O ports. The microcontroller then processes the received data—this may involve displaying it on an LCD, comparing it with stored IDs for authentication, or sending it to a PC or control system for further action. This setup provides a simple and efficient means of wirelessly receiving RFID data over short distances for applications like access control, object identification, and wireless monitoring.

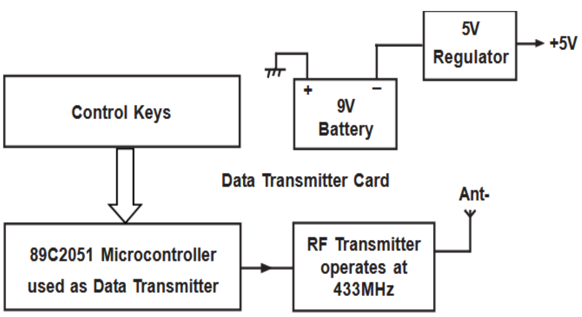

Figure 1. Autonomous firefighting robot

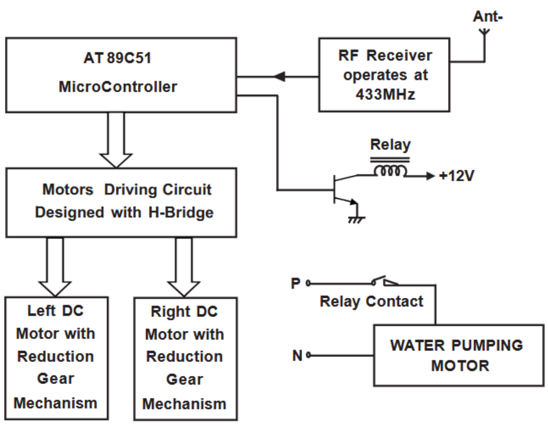

Figure 2. RFID receiver system using a 433 MHz RF module

3. ARDUINO IN TINKERCAD DESIGN

The remote-controlled agricultural robot using Tinkercad design shown in Figure 3. The AT89C2051 microcontroller can be effectively used with an RF transmitter and receiver module to enable wireless remote-control operations. In this setup, the transmitter side typically uses an encoder IC like the HT12E, which converts parallel inputs from push buttons into serial data. This serial data is then sent wirelessly through a 433 MHz RF transmitter module. On the receiver side, the RF receiver module receives the transmitted signal and passes it to a decoder IC such as the HT12D, which converts the serial data back into parallel form. The AT89C2051 reads these decoded inputs through its I/O pins and executes corresponding actions such as controlling motors for movement or activating a spray pump. This wireless control system allows for remote operation of agricultural robots, making the spraying of pesticides safer and more efficient by minimizing human contact with harmful chemicals. Figure 4 shows the schematic diagram firefighting robot [21]–[25].

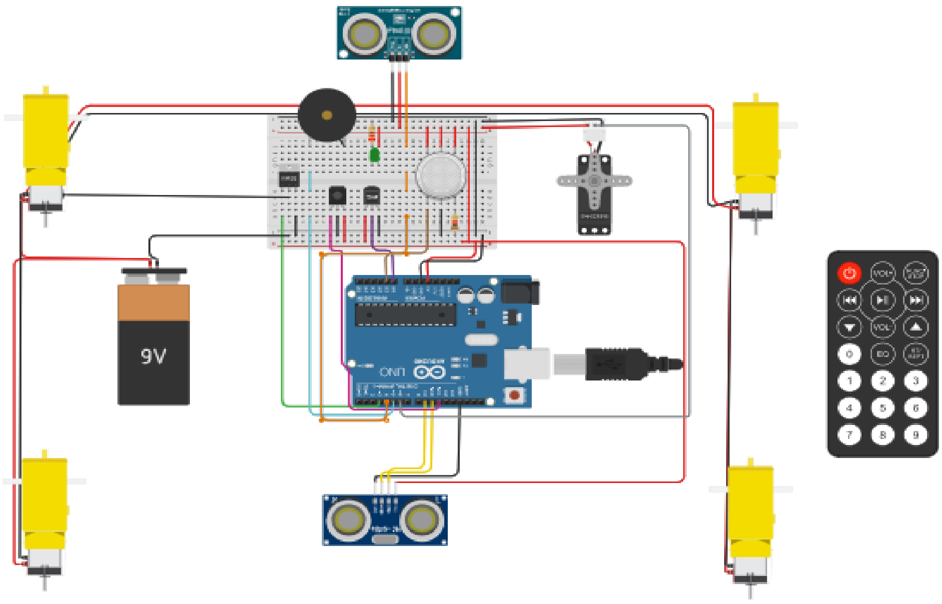

Figure 3. Remote controlled agricultural robot using Tinkercad design

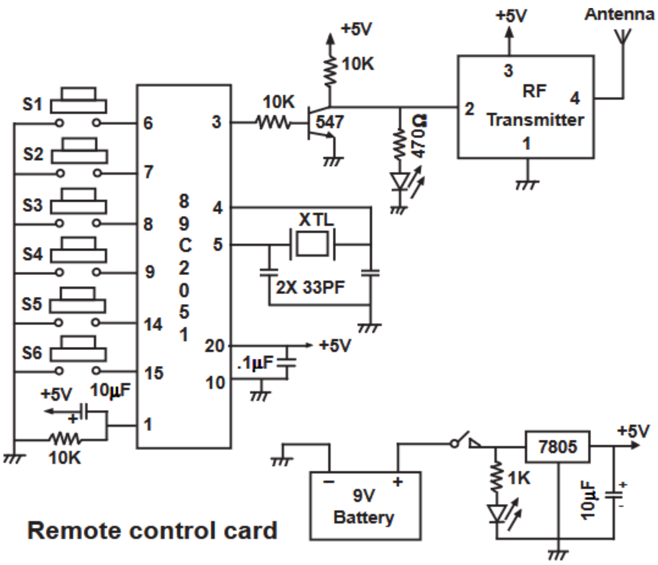

Figure 4. Schematic diagram firefighting robot

The receiver system using the AT89C2051 microcontroller and the L293D motor driver operates as a wireless robot control unit. The system begins with a 433 MHz RF receiver module, which receives control signals wirelessly from a transmitter. These signals are typically encoded and transmitted as digital data using a compatible encoder (*e.g.*, HT12E on the transmitter side), and decoded on the receiver side using a decoder like the HT12D. Figure 5 shows the firefighting robot in Tinkercad. The decoder outputs parallel control signals based on the data it receives, which are then fed into the input pins of the AT89C2051 microcontroller. The microcontroller interprets these signals—such as commands for forward, backward, left, or right movement—and accordingly sends control signals to the L293D motor driver. The L293D, which is a dual H-bridge motor driver IC, receives these logic-level inputs and drives the robot's DC motors in the required direction by adjusting the polarity and enabling appropriate motor channels. This setup allows for simple and efficient wireless control of a robot using basic RF modules, with the microcontroller acting as the decision-making unit and the L293D serves as the power driver for the motors.

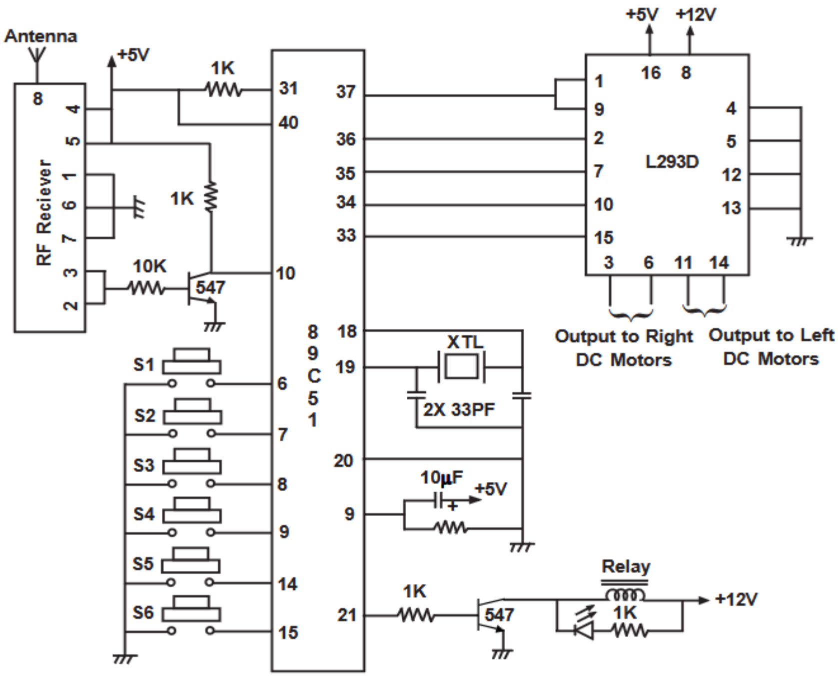

Figure 5. Firefighting robot in Tinkercad

4. MECHANICAL DESIGN

The remote-controlled agricultural robot for spraying liquid type pesticides shown in Figure 6. This operates using an RF transmitter and receiver system to enable wireless communication between the user and the robot. The transmitter unit, held by the operator, includes push buttons connected to an encoder IC (such as HT12E), which converts manual commands into serial data. This data is transmitted wirelessly via a 433 MHz RF transmitter. On the robot side, a corresponding RF receiver captures the signal and passes it to a decoder IC (like HT12D), which converts it back into parallel signals. These decoded signals are then read by a microcontroller, such as the AT89C2051, which controls the robot's movement (forward, backward, left, right) and the pesticide spraying system using a pump and nozzle setup. This system allows farmers to remotely navigate the robot through crop fields and spray pesticides safely and efficiently, reducing manual labor and minimizing direct exposure to harmful chemicals. Figure 7 shows the agricultural robot receiver.

Agricultural robot vertical view shown in Figure 8. The robot controller receiver system based on the AT89C2051 microcontroller and L293D motor driver is designed to wirelessly control the movement of a robot using received commands, typically via a 433 MHz RF link. In operation, the RF receiver module captures encoded control signals sent from a remote transmitter. A decoder like the HT12D converts the received serial data into parallel signals, which are read by the AT89C2051 microcontroller. The microcontroller interprets the commands—such as moving forward, backward, turn left, or right—and then sends appropriate logic signals to the L293D motor driver. The L293D drives the DC motors according to these inputs, controlling both direction and movement of the robot. This system enables responsive, real-time wireless control of robotic platforms. Figure 9 agricultural robot working model in terms of applications, this setup is widely used in wireless robotic cars, obstacle-avoiding robots, line-following robots with manual override, military or surveillance robots, remote-controlled material handling bots, and educational robotics projects. Its low cost, simplicity, and ease of implementation make it popular in both learning environments and basic industrial use cases where wireless mobility and remote operation are required. Table 1 shows the firefighting robot components.

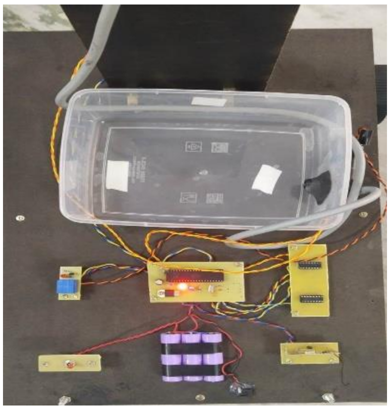

Figure 6. Agricultural robot for spraying liquid

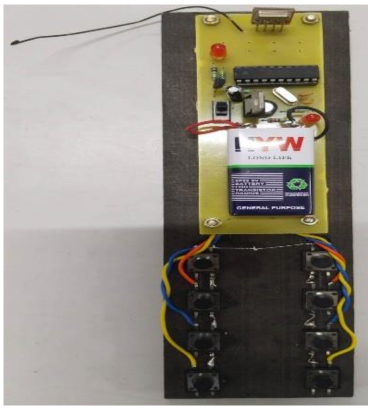

Figure 7. Agricultural robot transmitter

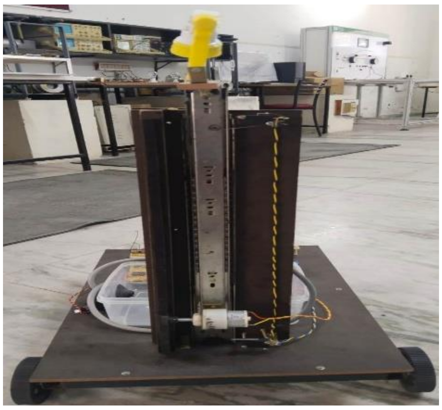

Figure 8 Agricultural robot vertical view

Figure 9. Agricultural robot working model

Table 1. Firefighting robot components

Component Name	quantity
Arduino Board	1
L298 Motor Driver Module	1
Flame Sensor Module	1
Servo Motor	1
On-Off switch	1

5. CONCLUSION

The remotely controlled agricultural robot for spraying liquid pesticides was successfully designed and constructed, according to the research. A prototype module is built for demonstration purposes, and the outcomes are deemed satisfactory. We sought advice from a few mechatronics experts during the design and development of this prototype module. These individuals, who work for several Hyderabad-based firms, assisted us in creating the spraying robot. Since it is a prototype module, not much money was spent, and the entire machine is built using locally accessible parts. In particular, the mechanical parts utilized in this project are purchased from mechanical fabricators and are subpar.

FUNDING INFORMATION

Authors state no funding involved.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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Kalagotla Chenchireddy	✓		✓		✓			✓	✓		✓			
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Malaji Sushama		✓		✓	✓	✓	✓		✓		✓	✓		
Varghese Jegathesan	✓			✓	✓			✓	✓				✓	
Shabbier Ahmed Sydu	✓			✓		✓	✓			✓			✓	✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

Data availability is not applicable to this paper as no new data were created or analyzed in this study.

REFERENCES

[1] J. Li, H. Liu, X. Luo, C. L. Philip Chen, and C. Yang, "Gesture-based human-robot interaction framework for teleoperation control of agricultural robot," in *Proceedings of 2023 IEEE International Conference on Unmanned Systems, ICUS 2023*, 2023, pp. 1171–1176, doi: 10.1109/ICUS58632.2023.10318494.

[2] Z. Jianjun, C. Min'gang, Z. Man, and L. Su, "Remote monitoring and automatic navigation system for agricultural vehicles based on WLAN," in *2008 International Conference on Wireless Communications, Networking and Mobile Computing, WiCOM 2008*, 2008, pp. 1–4, doi: 10.1109/WiCom.2008.721.

[3] Z. Miao, H. Mao, F. Wu, and C. He, "Research on data transmission and processing technology of intelligent agricultural robot based on internet of things," in *IEEE Information Technology, Networking, Electronic and Automation Control Conference, ITNEC 2021*, 2021, pp. 519–523, doi: 10.1109/ITNEC52019.2021.9587027.

[4] Y. Zhao, H. Qi, W. Xu, J. Li, and J. Zhao, "Research on master-slave controlling remote operation of live working robots in agricultural distribution network," in *Proceedings of 2018 IEEE 3rd Advanced Information Technology, Electronic and Automation Control Conference, IAEAC 2018*, 2018, pp. 1401–1405, doi: 10.1109/IAEAC.2018.8577683.

[5] J. Mao *et al.*, "An agricultural spraying and fertilization robot based on visual navigation," in *Proceedings of the 15th IEEE Conference on Industrial Electronics and Applications, ICIEA 2020*, 2020, pp. 586–591, doi: 10.1109/ICIEA48937.2020.9248224.

[6] J. Sun *et al.*, "Research on the design of transfer equipment cask for Tokamak equator port plug," in *2015 IEEE International Conference on Information and Automation, ICIA 2015 - In conjunction with 2015 IEEE International Conference on Automation and Logistics*, 2015, pp. 487–492, doi: 10.1109/ICInfA.2015.7279337.

[7] R. Dong *et al.*, "Study on remote control system of rural water treatment equipment based on LabVIEW," in *Proceedings - 2018 International Conference on Robots and Intelligent System, ICRIS 2018*, 2018, pp. 44–47, doi: 10.1109/ICRIS.2018.00019.

[8] R. Dong *et al.*, "Software development of remote control system for water treatment equipment based on Internet of Things technology," in *Proceedings - 2018 International Conference on Robots and Intelligent System, ICRIS 2018*, 2018, pp. 33–39, doi: 10.1109/ICRIS.2018.00017.

[9] K. Priandana, I. Abiyoga, Wulandari, S. Wahjuni, M. Hardhienata, and A. Buono, "Development of computational intelligence-based control system using backpropagation neural network for wheeled robot," in *Proceedings of 2018 International Conference on Electrical Engineering and Computer Science, ICECOS 2018*, 2019, pp. 101–106, doi: 10.1109/ICECOS.2018.8605183.

[10] X. K. Xu, X. M. Li, and R. H. Zhang, "Remote configurable image acquisition lifting robot for smart agriculture," in *Proceedings of 2019 IEEE 4th Advanced Information Technology, Electronic and Automation Control Conference, IAEAC 2019*, 2019, pp. 1545–1548, doi: 10.1109/IAEAC47372.2019.8997721.

[11] B. Zhang, S. Yu, H. Xu, and S. Yang, "A mobile robot system based on electromagnetic navigation," in *ICEMS 2005: Proceedings of the Eighth International Conference on Electrical Machines and Systems*, 2005, vol. 2, pp. 1559–1562, doi: 10.1109/icems.2005.202810.

[12] M. J. Baucas, Z. Xu, P. Spachos, and S. Andrew Gadsden, "Formation control design for remote field monitoring with IoT-enabled mobile robots," in *2024 IEEE 10th World Forum on Internet of Things, WF-IoT 2024*, 2024, pp. 876–881, doi: 10.1109/WF-IoT62078.2024.10811369.
[13] W. Wang, C. Y. Li, L. H. Chu, and C. Y. Qu, "Study on air-ground amphibious agricultural information collection robot," in *2016 13th International Conference on Ubiquitous Robots and Ambient Intelligence, URAI 2016*, 2016, pp. 938–944, doi: 10.1109/URAI.2016.7734115.
[14] N. Du, Z. Zhang, J. Chen, X. Liu, B. Ma, and K. Zhang, "Timing-based sensor fusion mapping method for indoor remote surveying robot," in *2019 IEEE International Conference on Unmanned Systems and Artificial Intelligence, ICUSAI 2019*, 2019, pp. 251–255, doi: 10.1109/ICUSAI47366.2019.9124871.
[15] D. N. Vinod, A. Kamalesh, B. Bhaskar, and B. R. Teja, "Riddance of weed using an agri-robot employed by Arduino and ESP32-CAM," in *2024 15th International Conference on Computing Communication and Networking Technologies, ICCCNT 2024*, 2024, pp. 1–6, doi: 10.1109/ICCCNT61001.2024.10724013.
[16] H. Durmus, E. O. Gunes, M. Kirci, and B. B. Ustundag, "The design of general purpose autonomous agricultural mobile-robot: 'AGROBOT,'" in *2015 4th International Conference on Agro-Geoinformatics, Agro-Geoinformatics 2015*, 2015, pp. 49–53, doi: 10.1109/Agro-Geoinformatics.2015.7248088.
[17] S. Kalaivanan and R. Kalpana, "Coverage in agricultural farmlands: A ubiquitous approach for smart farming," in *2017 International Conference on Energy, Communication, Data Analytics and Soft Computing, ICECDS 2017*, 2018, pp. 746–750, doi: 10.1109/ICECDS.2017.8389536.
[18] J. Katupitiya, R. Eaton, A. Cole, C. Meyer, and G. Rodnay, "Automation of an agricultural tractor for fruit picking," in *Proceedings - IEEE International Conference on Robotics and Automation*, 2005, vol. 2005, pp. 3201–3206, doi: 10.1109/ROBOT.2005.1570603.
[19] A. R. Tiongson *et al.*, "Initial development of remote-controlled coconut harvesting robot prototype," in *2023 IEEE 15th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment, and Management, HNICEM 2023*, 2023, pp. 1–6, doi: 10.1109/HNICEM60674.2023.10589196.
[20] R. Eaton, J. Katupitiya, K. W. Siew, and K. S. Dang, "Precision guidance of agricultural tractors for autonomous farming," in *2008 IEEE International Systems Conference Proceedings, SysCon 2008*, 2008, pp. 314–321, doi: 10.1109/SYSTEMS.2008.4519026.
[21] V. R. Beldar, R. V. Deore, S. M. Bhavsar, V. V. Patel, and M. B. Dembrani, "Solar-powered, multi-use, remote-controlled farm robot," in *2024 Parul International Conference on Engineering and Technology, PICET 2024*, 2024, pp. 1–7, doi: 10.1109/PICET60765.2024.10716121.
[22] A. Kamboj, T. Ji, and K. Driggs-Campbell, "Examining audio communication mechanisms for supervising fleets of agricultural robots," in *RO-MAN 2022 - 31st IEEE International Conference on Robot and Human Interactive Communication: Social, Asocial, and Antisocial Robots*, 2022, pp. 293–300, doi: 10.1109/RO-MAN53752.2022.9900859.
[23] S. Sankarananth and R. S. Arun, "A smart cable-driven parallel robot assistant for individual plant care in farming," in *Proceedings of the International Conference on Electronics and Renewable Systems, ICEARS 2022*, 2022, pp. 295–301, doi: 10.1109/ICEARS53579.2022.9752311.
[24] N. Z. Fanani *et al.*, "Teleoperation system on differential mobile robot for online greenhouse monitoring," in *Proceedings - International Seminar on Intelligent Technology and its Applications, ISITIA*, 2024, no. 2024, pp. 583–588, doi: 10.1109/ISITIA63062.2024.10668172.
[25] T. Fujinaga, "Development of a plant monitoring system using a drone-equipped agricultural robot," in *Conference Proceedings - IEEE International Conference on Systems, Man and Cybernetics*, 2023, pp. 2501–2506, doi: 10.1109/SMC53992.2023.10394231.

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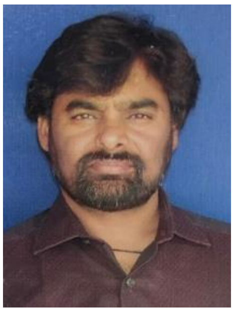

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