EV Tractor Agribot: A Review of Autonomous Electric Tractor Solutions in Precision Agriculture

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Abstract—The integration of autonomous electric vehicles in agriculture presents a promising avenue to address sustainability and labor challenges in modern farming. This review paper explores the development of an EV Tractor "Agribot" designed to operate autonomously for harvesting and weeding in specified land dimensions. It discusses the evolution of autonomous agricultural sys- tems, highlighting recent advancements in electric tractor technology, AI-powered weed detection using convolutional neural networks (CNN), and user interface designs for seamless operation. The proposed model combines electric propulsion with intelligent navigation and real-time weed detection, aiming to reduce environmental impact and operational costs while enhancing productivity. By synthe- sizing existing research and proposing an integrated system tailored for small to medium-sized farms, this review underscores the potential of autonomous EV tractors as a transformative solution in precision agriculture.

Index Terms—Autonomous Tractor, Electric Vehicle, Agribot, Precision Agriculture, CNN, Smart Farming

I. Introduction

The agricultural sector is undergoing a paradigm shift with the integration of advanced automation and electric propulsion technologies. Traditional farming practices, which rely heavily on manual labor and fossil fuel-powered machinery, are increasingly recognized as unsustainable due to their environmental impact and labor intensiveness. In response, the development of autonomous electric agricultural vehicles has emerged as a transformative solution to improve efficiency, reduce emissions, and ensure precision in field operations.

The Electric Vehicle (EV) Tractor Agribot represents a significant innovation in this landscape. Combining electric propulsion with autonomous navigation and AI-based weed detection, the EV Tractor Agribot is designed to automate tasks such as harvesting and weeding, tailored to the specific dimensions and layout of the field. Unlike conventional tractors, the EV-based model minimizes greenhouse gas emissions and operational costs while leveraging cutting-edge sensors and machine learning algorithms for enhanced field performance.

This review paper explores the landscape of autonomous agricultural robotics, analyzing existing technologies and identifying gaps that the proposed EV Tractor Agribot seeks to address. It also presents a detailed model integrating electric power, CNN-based weed detection, and user-friendly interfaces, offering a comprehensive view of how this system could revolutionize precision agriculture for small and medium-sized farms.

II. Literature Survey

The field of autonomous agricultural robotics has seen significant progress in recent years, driven by advances in electric vehicle (EV) technology, computer vision, and artificial intelligence (AI). Several studies have explored the design and implementation of autonomous tractors to optimize farming operations and reduce labor dependency.

A. Electric Tractors in Agriculture

Chen and Kumar (2022) investigated the environmental and economic benefits of electric tractors, concluding that EVs can significantly reduce operational costs and greenhouse gas emissions compared to traditional diesel-powered tractors.

B. Autonomous Navigation and Path Planning

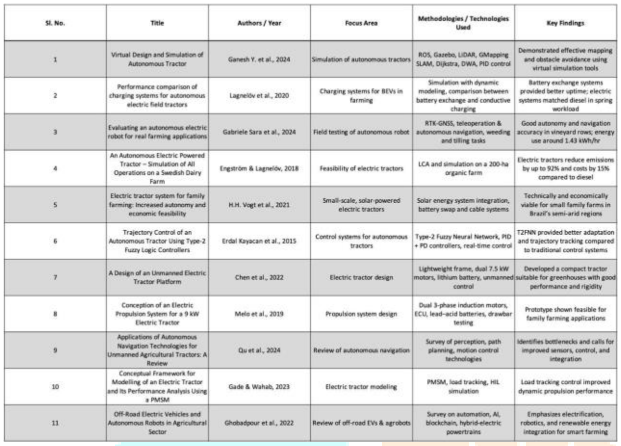
Smith et al. (2023) focused on GPS-based navigation in autonomous tractors, proposing algorithms that enable precise path planning and obstacle avoidance in field environments.

C. Weed Detection Using AI

Lee et al. (2023) explored real-time weed detection using convolutional neural networks (CNNs), achieving high accuracy in classifying crops and weeds. Similarly, Garcia and Singh (2022) proposed an AI-based system for precision herbicide application.

D. Human-Machine Interfaces

Miller and Chen (2023) examined design considerations for user interfaces in agricultural robotics, highlighting the importance of intuitive layouts and real-time feedback.



Sl. No.	Title	Authors / Year	Focus Area	Methodologies / Technologies Used	Key Findings
1	Virtual Design and Simulation of Autonomous Tractor	Ganesh Y. et al., 2024	Simulation of autonomous tractors	ROS, Gazebo, LiDAR, GMapping SLAM, Dijkstra, DWA, PID control	Demonstrated effective mapping and obstacle avoidance using virtual simulation tools
2	Performance comparison of charging systems for autonomous electric field tractors	Lagnelöv et al., 2020	Charging systems for BEVs in farming	Simulation with dynamic modeling, comparison between battery exchange and conductive charging	Battery exchange systems provided better uptime; electric systems matched diesel in spring workload
3	Evaluating an autonomous electric robot for real farming applications	Gabriele Sara et al., 2024	Field testing of autonomous robot	RTK-GNSS, teleoperation & autonomous navigation, weeding and tilling tasks	Good autonomy and navigation accuracy in vineyard rows; energy use around 1.43 kWh/hr
4	An Autonomous Electric Powered Tractor – Simulation of All Operations on a Swedish Dairy Farm	Engström & Lagnelöv, 2018	Feasibility of electric tractors	LCA and simulation on a 200-ha organic farm	Electric tractors reduce emissions by up to 92% and costs by 15% compared to diesel
5	Electric tractor system for family farming: Increased autonomy and economic feasibility	H.H. Vogt et al., 2021	Small-scale, solar-powered electric tractors	Solar energy system integration, battery swap and cable systems	Technically and economically viable for small family farms in Brazil's semi-arid regions
6	Trajectory Control of an Autonomous Tractor Using Type-2 Fuzzy Logic Controllers	Erdal Kayacan et al., 2015	Control systems for autonomous tractors	Type-2 Fuzzy Neural Network, PID + PD controllers, real-time control	T2FNN provided better adaptation and trajectory tracking compared to traditional control systems
7	A Design of an Unmanned Electric Tractor Platform	Chen et al., 2022	Electric tractor design	Lightweight frame, dual 7.5 kW motors, lithium battery, unmanned control	Developed a compact tractor suitable for greenhouses with good performance and rigidity
8	Conception of an Electric Propulsion System for a 9 kW Electric Tractor	Melo et al., 2019	Propulsion system design	Dual 3-phase induction motors, ECU, lead–acid batteries, drawbar testing	Prototype shown feasible for family farming applications
9	Applications of Autonomous Navigation Technologies for Unmanned Agricultural Tractors: A Review	Qu et al., 2024	Review of autonomous navigation	Survey of perception, path planning, motion control technologies	Identifies bottlenecks and calls for improved sensors, control, and integration
10	Conceptual Framework for Modelling of an Electric Tractor and Its Performance Analysis Using a PMSM	Gade & Wahab, 2023	Electric tractor modeling	PMSM, load tracking, HIL simulation	Load tracking control improved dynamic propulsion performance
11	Off-Road Electric Vehicles and Autonomous Robots in Agricultural Sector	Ghobadpour et al., 2022	Review of off-road EVs & agrobots	Survey on automation, AI, blockchain, hybrid-electric powertrains	Emphasizes electrification, robotics, and renewable energy integration for smart farming

Fig. 1. Summary of reviewed literature highlighting autonomous electric tractor developments.

These studies collectively establish a strong foundation for integrating electric propulsion, autonomous navigation, and AI-powered weed detection in agricultural robots. However, few works address comprehensive integration of these technologies for small to medium-sized farms.

III. Proposed Model

A. Overall Description

The EV Tractor Agribot is an integrated system comprising hardware and software components for autonomous electric tractor operation. It focuses on precise weeding and harvesting in small to medium-sized farms.

B. Product Functions

- Electric Propulsion: Eco-friendly, zero-emission operation.
- Autonomous Navigation: GPS and sensors for obstacle detection and safe navigation.
- Weed/Crop Classification: CNN-based image processing for precision weeding.
- User Interface: Real-time monitoring and control via a web application.
- Task Scheduling: Input-based operation to cover field areas efficiently.

C. Hardware Components

- Electric propulsion system with a BLDC motor and controller.
- Battery pack with Battery Management System (BMS).
- Arduino microcontroller for hardware management.
- Edge AI processor (Raspberry Pi 4 or NVIDIA Jetson Nano) for real-time inference.
- GPS, ultrasonic sensors, IMU, and high-resolution camera.
- Actuated weeding/harvesting tool and robust chassis.

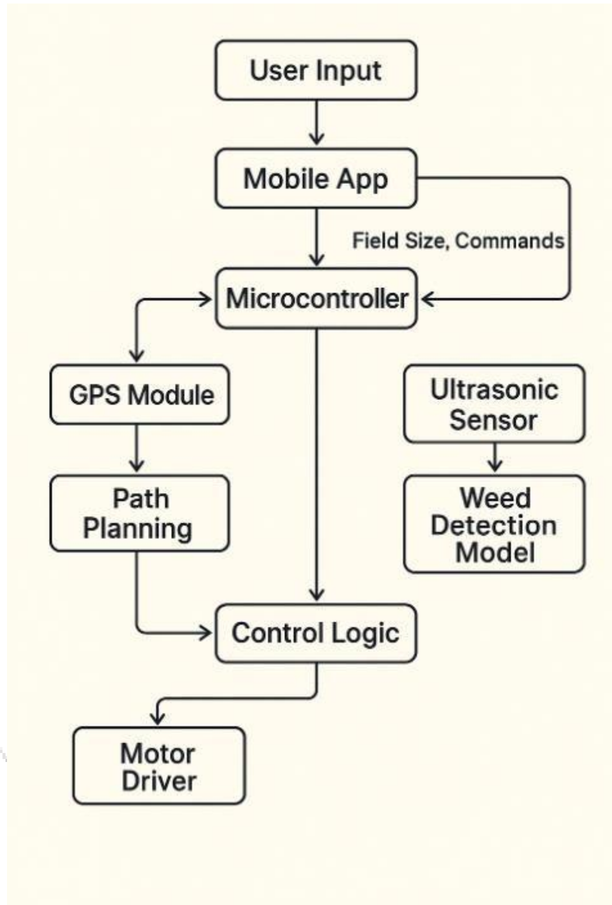


Fig. 2. System design of the EV Tractor Agribot showing hardware and communication components.

D. Software Components

- CNN-based AI module for weed/crop classification.
- Python-based image processing pipeline.
- Flask backend server and ReactJS frontend.
- Arduino firmware for sensor and actuator control.
- REST API for secure communication.

E. Operational Workflow

1) Users input field dimensions and task parameters via the web interface.
2) The system calculates an optimal path based on GPS and sensor data.
3) The camera captures images, and the CNN model classifies them in real time.
4) When a weed is detected, the control unit activates the weeding mechanism.
5) Sensors continuously monitor for obstacles and ensure safety.
6) Real-time status updates are displayed on the web interface.

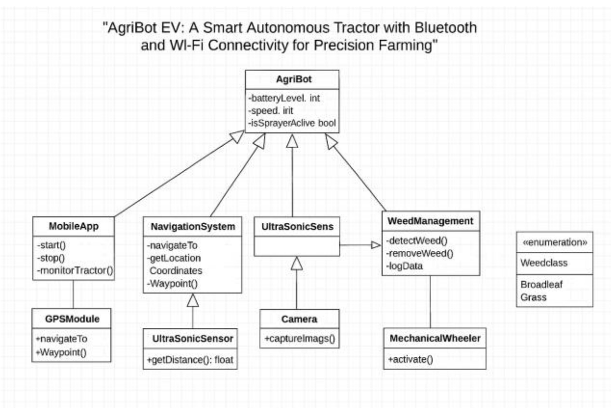


Fig. 3. Class diagram of the EV Tractor Agribot showing hardware and communication components.

IV. Conclusion

The EV Tractor Agribot project demonstrates a promising advancement in precision agriculture by integrating autonomous navigation, electric propulsion, and AI-powered weed detection. This system reduces labor intensity and operational costs while promoting sustainable farming through zero-emission technology. While challenges such as battery limitations and environmental variability remain, the proposed model offers a robust foundation for future enhancements and deployment in real-world conditions.

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