

Embedded System to Control Automated Vegetable Transplanter Vehicle

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Abstract: *Embedded System in Multivegetable Transplanter is an automated system designed to reduce human effort and increase the efficiency of the vegetable planting process. The system is capable of handling different types of seedlings and planting them accurately into the soil with minimal manual intervention. It integrates mechanical, electrical, and embedded control systems to perform synchronized operations such as seedling picking, placement, and soil covering. The system uses an Allen Bradley MicroLogix 1400 PLC (1766-L32BXX) as the main controller to manage all major functions of the transplanter, including conveyor movement and actuator operation. An Arduino UNO acts as a secondary controller, controlling servo motors (MG996R) responsible for the gripper mechanism that picks and places seedlings. Power is supplied through a 24 V DC system, with a buck converter used to step down the voltage to 5 V DC for sensors and the Arduino. A fuse and MCB are included for electrical protection, while an HMI provides an operator interface for cycle start/stop, I/O monitoring, and process tracking.*

This automation ensures precise planting, uniform spacing, and reduced labour dependency. The combination of PLC-based control, servo-driven mechanisms, and real-time monitoring makes the system efficient, reliable, and adaptable for multiple vegetable types. The project demonstrates the practical application of embedded systems and industrial automation in modern agricultural equipment.

Keywords: Embedded System, Precision Agriculture, PLC, Arduino Uno, Real Time Monitoring

I. INTRODUCTION

Agriculture has always been the backbone of the global economy, providing essential food and raw materials. However, traditional agricultural methods are often labor-intensive, time-consuming, and less efficient. With the rapid advancement in technology, the integration of automation and embedded systems into agricultural equipment has become a key factor in improving productivity, precision, and sustainability. One such innovation is the Automatic Multivegetable Transplanter Vehicle, which aims to automate the process of transplanting vegetable seedlings in the field.

Transplanting is a critical stage in vegetable farming where young seedlings are shifted from nursery trays to the main field. Conventionally, this process requires a large amount of manual labor, which leads to high labor costs, uneven spacing, and irregular planting depth. Moreover, the efficiency of manual transplanting is highly dependent on the skill and consistency of the workers, which often results in non-uniform crop growth and reduced yield. To overcome these challenges, this project introduces an embedded system-based control mechanism for an automatic vehicle that can perform multi-vegetable transplanting operations with high precision and consistency.

The proposed system uses an embedded controller (such as an Arduino, PLC unit) as the central processing unit. It coordinates and controls various mechanical and electrical components, including motors, sensors, actuators. The vehicle is designed to pick seedlings from the tray, place them into the soil at a defined depth and spacing, and move automatically across the field. The embedded system continuously monitors parameters such as position, speed, and plant count to ensure uniform operation.



In addition, the system can be programmed to handle multiple vegetable types by adjusting parameters like plant spacing and planting frequency. This feature enhances the versatility of the transplanter, allowing farmers to use the same vehicle for different crops without major mechanical adjustments. The control algorithms implemented in the embedded system ensure smooth coordination between all the subsystems movement control, seedling handling mechanism, and soil placement unit.

Automation through embedded systems not only reduces dependency on manual labor but also improves operational accuracy, productivity, and field efficiency. By adopting such technology, farmers can achieve better crop uniformity, reduced transplanting time, and increased profitability. In summary, the System aims to bridge the gap between traditional agricultural methods and modern automation technology. The successful implementation of this project can contribute significantly to precision agriculture, helping farmers achieve higher yields with lower operational costs.

A. Problem Statement

Agriculture in developing countries still largely depends on manual labor for most operations, including transplanting vegetable seedlings. The process of transplanting is one of the most labor-intensive and time-consuming tasks in vegetable cultivation. Farmers face several challenges such as shortage of skilled labor, high labor cost, inconsistent transplanting accuracy, and physical fatigue. Manual transplantation often leads to non-uniform spacing, uneven depth of planting, and damage to seedlings, which collectively result in reduced crop yield and lower productivity.

Another major issue arises from the fact that each type of vegetable crop requires specific planting conditions such as spacing, depth, and orientation which are difficult to maintain manually over large field areas. In addition, changing climatic conditions and the need for timely transplantation put extra pressure on farmers to complete the process quickly and accurately.

Existing mechanical transplanters are usually designed for single-type crops and lack flexibility. They also require manual supervision and are not easily adaptable to multiple vegetable types without significant mechanical adjustments. This creates a need for a smart, automatic, and adaptable system that can handle the transplantation of multiple vegetable seedlings with minimal human intervention.

Therefore, the problem addressed by this project is the development of an automated multivegetable transplanting vehicle that integrates embedded system technology to ensure precision, efficiency, and adaptability in the transplanting process. The system should be capable of performing multiple task such as soil digging, seedling picking, placing, and vehicle movement while maintaining uniform spacing and depth according to the crop requirements.

B. Need and Necessity of Project

An embedded system is an essential part of an automatic multivegetable transplanter as it provides intelligent control and precise coordination among different subsystems. It replaces traditional manual operation with automated and programmable control, improving accuracy, efficiency, and productivity. The embedded controller manages the timing and movement of all mechanical parts such as the conveyor, pick-and-drop mechanism, mini conveyor, and digger system. It processes input signals from various sensors and ensures that each seedling is picked, transferred, and planted at the correct position, depth, and spacing.

The use of an embedded system allows real-time monitoring and adjustment of system parameters based on field conditions, ensuring consistent planting performance even in uneven terrain. It also makes the system flexible for different types of vegetables by allowing the operator to modify settings like plant spacing, planting depth, and planting frequency through the HMI interface. This not only simplifies the operation but also reduces human effort and error. Furthermore, the embedded system improves energy efficiency by optimizing motor operations and provides reliability through fault detection and correction. Overall, it acts as the brain of the entire machine, ensuring smooth, synchronized, and precise functioning of the multivegetable transplanter



II. LITERATURE SURVEY

For our project we are surveying some reports and references which are helping us to make it easy and simplest and they are as follows

Table 1.Literature Survey

Sr. No	Title	Author	Year	Key Finding	Application in our project
1.	Development of Embedded Automatic Transplanting System	Khadatkar A.	2021	Improved planting precision and speed	Base design reference for PLC sequencing and timing control
2.	Automation in Multi-Crop Transplanter using Embedded Control	Rahul & Singh	2022	Reduced human effort	Example for multi-vegetable compatibility and low-cost embedded implementation
3.	Automating Seedling Counts Using AI & Mobile App	Fuentes-Peñailillo F.	2023	Real-time data visualization of tray counts	Reference for our app development & sapling count management module
4.	IoT-Based Field Monitoring and Transplanting Control	Patel & Mehta	2023	Enabled real-time position tracking and operation logging	Used as concept for GPS and IoT integration in your system

III. METHODOLOGY

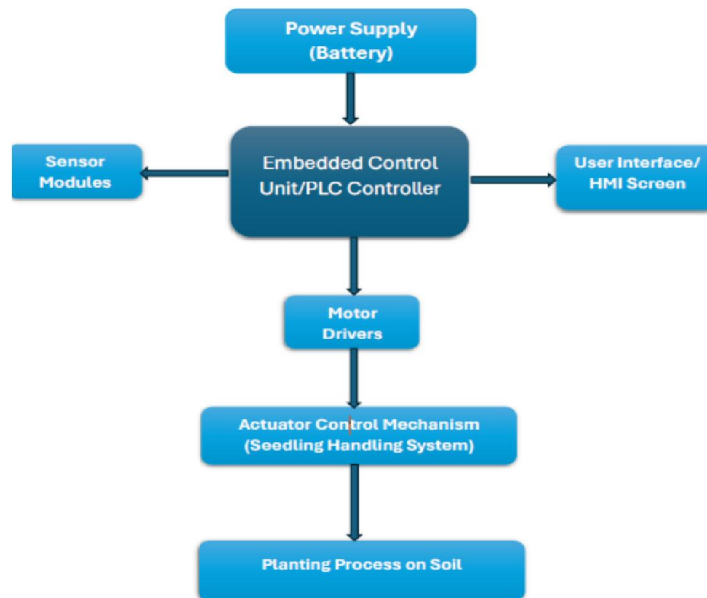


Fig. 1. Block Diagram

The methodology of the Multiple Vegetable Transplanter project involves a systematic approach that integrates mechanical design, automation, and control using a PLC system. The process is divided into the following stages:

1. Problem Identification and Objective Setting

The traditional vegetable transplanting process requires significant human Labour and time, resulting in irregular spacing and planting depth. The objective of this project is to design and develop an automated system capable of transplanting multiple vegetable seedlings efficiently, accurately, and with minimal human intervention.



2. System Design

The transplanter is designed with mechanical and electronic subsystems working in coordination.

Mechanical Design:

The mechanical structure includes the seedling tray holder, pickup mechanism, planting arm, and wheel assembly. The design ensures smooth movement, precise planting depth, and accurate spacing between plants. CAD software (like SolidWorks or AutoCAD) can be used for designing and simulating the model.

Electrical and Control Design:

An Allen Bradley PLC acts as the main controller.

The system includes:

Servo Motor: Controls the rotational and linear motion of the planting arm for precise placement.

Proximity Sensor: Detects the presence of seedlings or tray position.

Limit Switches: Define end positions and prevent mechanical overrun.

24V DC Power Supply: Provides reliable power to the PLC and actuators.

3. Programming and Automation

The PLC is programmed using RSLogix 500 software. The program defines sequences for seedling pickup, movement, and placement. Input signals from sensors and limit switches are processed by the PLC to control the servo motor output. Timers and counters are used to maintain uniform spacing and synchronize all actions in each transplanting cycle.

4. Integration and Assembly

All components — mechanical, electrical, and control — are integrated into a single working model. Proper wiring and interfacing are done between PLC I/O ports and sensors, motors, and switches. Testing is carried out to verify correct operation of each subsystem.

5. Testing and Calibration

The prototype is tested under different conditions to check:

Accuracy of seedling placement

Uniformity in spacing and depth

A. PLC CONTROLLER (Allen-Bradley MicroLogix 1400 PLC)

A Programmable Logic Controller (PLC) is an industrial digital computer designed to perform control operations such as monitoring inputs, processing logic, and controlling outputs. It is widely used in automation systems because of its high reliability, flexibility, and ease of programming.

For this project, the Allen-Bradley MicroLogix 1400 PLC is selected as the main controller. It is a compact and powerful industrial-grade programmable logic controller designed by Rockwell Automation. This PLC is chosen because it offers high reliability, easy programmability, and excellent communication capabilities suitable for automation applications like the Multivegetable Transplanter.

PLC Features Requirement for the Application:

In the Multivegetable Transplanter, the controller must handle multiple sensors and actuators with reliable performance and easy programmability.

The following PLC features are required for this application:

1. Power Supply Compatibility:

The system operates on a 24 V DC power supply; hence, the PLC must support 24 V DC input operation.

2. Input/ Output Capacity:

The application requires around 20 digital inputs for sensors (such as soil detection, position sensors, and limit switches) and 10–12 digital outputs for actuators (such as servo motors, solenoids, and conveyors).





Fig. 2. PLC Controller

Model	Power Supply	Inputs	Outputs
1766-L32BWA	120/240V AC	Twelve Fast 24V DC, Eight Normal 24V DC	Twelve Relay
1766-L32AWA	120/240V AC	Twenty I20V AC	Twelve Relay
1766-L32BXB	24V DC	Twelve Fast 24V DC, Eight Normal 24V DC	Six relay, Three Fast DC, Three Normal DC
1766-L32BWAA	120/240V AC	Twelve Fast 24V DC, Eight Normal 24V DC, Four Analogue Voltage Inputs	Twelve relay, Two Analogue Voltage Inputs
1766-L32AWAA	120/240V AC	Twenty I20V AC Four Analogue Voltage Inputs	Twelve Relay, Two Analogue Inputs
1766-L32BXBA	24V DC	Twelve Fast 24V DC, Eight Normal 24V DC, Four Analogue Voltage Inputs	Six relay, Three Fast DC, Three Normal DC, Two Analogue Voltage Outputs

Table 2.PLC Selection Table

3. Easy Programming:

The PLC should support Ladder Logic programming using user-friendly software like RSLogix 500 or CCW, making it simple to develop and modify control logic.

4. Ethernet Communication:

Required for data exchange and remote monitoring, allowing easy connectivity with HMIs or SCADA systems.

B. MCB:

The Miniature Circuit Breaker (MCB) is an essential protection device used in the electrical circuit of the Multivegetable Transplanter. It automatically disconnects the power supply when an overload or short-circuit occurs, protecting components like the PLC, sensors, motors, and power supply from damage.

Requirement for the Application

The system operates on a 24 V DC power supply and includes electrical components such as motors and control circuits. Therefore, an MCB is required that can: Handle the total current load of the system, Operate reliably under DC voltage, and Provide overload and short-circuit protection.



Fig. 3. MCB



C. Arduino Uno:

The Arduino UNO is selected as the secondary controller in the Multivegetable Transplanter system. It is used to control the servo motor-based seedling picking mechanism, which requires precise position and timing control. The Arduino UNO works in coordination with the main PLC (Allen Bradley MicroLogix 1400) to ensure accurate and synchronized operation.

The Arduino UNO receives command signals from the PLC or sensors and controls the servo motors that perform the seedling picking and placing operation. It generates PWM (Pulse Width Modulation) signals to set the servo motor angle precisely according to the seedling's position.



Fig. 4. Arduino Uno

D. Servo Motor:

The MG996R Servo Motor is used in the Multivegetable Transplanter for operating the gripper mechanism in the pick-and-drop system. It controls the opening and closing of the gripper, which is used to hold and release seedlings from the tray during the transplanting process.

Technical Details:

Operating Voltage: 4.8 – 7.2 V DC

Stall Torque: 9.4 kg·cm (at 4.8 V), 11 kg·cm (at 6 V) Rotation Range: 0°–180° (approx.)

Control Signal: PWM (Pulse Width Modulation)



Fig. 5. Servo Motor

IV. RESULT

The project successfully developed a functional model of an automated vegetable transplanter. Field trials were conducted over 25 m bed lengths at three different plant-to-plant spacings (300 mm, 450 mm, and 600 mm) across two independent test runs. The key results are presented below.



Hybrid Control Success: The integration of an Allen Bradley MicroLogix 1400 PLC as the primary controller and an Arduino UNO as a secondary controller was successful. This allowed for robust industrial-grade logic combined with precise PWM control needed for servo-driven grippers.

Operational Precision: The system achieved accurate seedling placement and uniform spacing. The use of stepper motor drivers (DM542E and DMA860E) ensured smooth, vibration-free movement of the planting arms and conveyors.

Field Trial Photographs



(a) Field observers evaluating transplanting rows (b) Transplanting mechanism during planting



(c) Live demonstration to agricultural observers (d) Successfully transplanted seedling in field

Fig. 6. Field Trial Photographs of the Automated Vegetable Transplanter

Table 3. Field Test I – Performance Data for 25 m Bed Length

Sr. No	Distance Between Plant-to-Plant	No. of Seedlings Picked	No. of Seedlings Planted
1	300 mm	65	53
2	450 mm	45	39
3	600 mm	32	23



Table 4. Field Test II – Performance Data for 25 m Bed Length

Sr. No	Distance Between Plant-to-Plant	No. of Seedlings Picked	No. of Seedlings Planted
1	300 mm	70	61
2	450 mm	52	42
3	600 mm	40	37

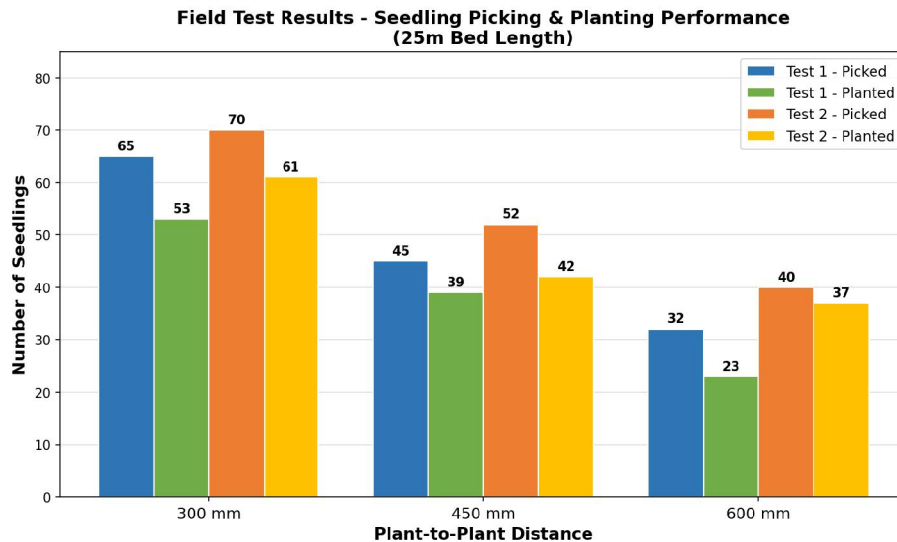


Fig. 7. Seedling Picking and Planting Performance – Field Test I vs. II (25 m Bed Length)

The chart above compares picking and planting counts across both field tests at three spacing configurations. At 300 mm spacing, the highest throughput was recorded (65/53 in Test I and 70/61 in Test II). At 600 mm spacing, the planting accuracy ratio improved significantly, reaching up to 92.5% in Test II, indicating better individual seedling placement precision at wider spacings. The consistent improvement from Test I to Test II across all spacings demonstrates progressive system calibration and reliability.

Manual vs. Automated: Traditional transplanting is labor-intensive and prone to fatigue, leading to irregular spacing. This system significantly reduces labor dependency and human error, directly contributing to higher yield quality.

System Adaptability: A major discussion point is the system’s flexibility. Unlike many existing single-crop mechanical transplanters, this embedded system allows operators to modify parameters (spacing, depth, frequency) via the HMI interface, making it compatible with various vegetable types.

Industrial Reliability: By using industrial-grade components like the MicroLogix PLC and DC MCBs (64A), the system is designed to withstand the rugged conditions of an agricultural environment while maintaining stable operations.

V. CONCLUSION

The Embedded System in Multiple Vegetable Transplanter successfully demonstrates how automation can enhance agricultural efficiency, precision, and productivity. By integrating a PLC-based control system (Allen Bradley), along with key components such as a servo motor, proximity sensor, limit switches, and a reliable 24V power supply, the system achieves accurate seedling placement and synchronized mechanical operation. The methodology implemented ensures consistent spacing, reduced manual Labour, and improved crop uniformity.



This project shows that automated transplanting not only saves time and effort for farmers but also minimizes human error and increases overall yield quality. The prototype developed validates the feasibility of adopting automation technologies in agriculture, especially for small and medium-scale farming. With further refinement, such as improved mechanical design and integration with IoT-based monitoring, the system has strong potential for commercial deployment.

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