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SeedBot: Solar Powered Semi-Autonomous Reforestation

Yash Kamlesh Petkar, Vaishnavi Babasaheb Mapri, Siddharth Gopinath Nale, Nikhil Sanstosh Mali,
Mr. I. K. Sayyad, Mr. C. N. Wani

Student, Diploma in Mechatronics, Sanjivani K.B.P Polytechnics, Kopergaon, India

Student, Diploma in Mechatronics, Sanjivani K.B.P Polytechnics, Kopergaon, India

Student, Diploma in Mechatronics, Sanjivani K.B.P Polytechnics, Kopergaon, India

Student, Diploma in Mechatronics, Sanjivani K.B.P Polytechnics, Kopergaon, India

Lecture, Diploma in Mechatronics, Sanjivani K.B.P Polytechnics, Kopergaon, India

Lecture, Diploma in Mechatronics, Sanjivani K.B.P Polytechnics, Kopergaon, India

ABSTRACT: Reforestation efforts are often hampered by hazardous terrain with steep slopes, hidden roots, and loose soil, despite the fact that deforestation is a serious global crisis. Standard agricultural robots made for flat fields frequently fail because of traction loss, and manual planting in these conditions is hazardous and labor-intensive. The design and development of "Seedbot," a sturdy, tracked robotic platform designed to automate the planting of trees in such challenging environments, is presented in this paper. The system has a unique, specially made telescoping steel linear actuator and a high-torque skid-steer drive system that can support a 20 kg payload. The control architecture uses an ESP32-CAM as the Master node in a hierarchical Master-Slave configuration for exact motor control in real time. In isolated, off-grid forests, this architecture guarantees reliable operation. According to experimental results, the platform can traverse 30-degree inclines without stalling and drill 15-cm planting holes in compacted soil with a 300 RPM auger.

KEYWORDS - Agricultural Robotics, Reforestation, LoRaWAN, Master-Slave Architecture, Skid-Steer Mechanism

I. INTRODUCTION

Global biodiversity and climate stability are seriously threatened by deforestation.

Initiatives for mass planting are becoming more popular, but they frequently encounter a logistical obstacle: the terrain. Rarely is deforested land level; instead, it is usually uneven, full of hidden roots, tree stumps, and different soil densities. The environment is dangerous for human workers and inaccessible to conventional wheeled robots due to these conditions.

The main goal of this research is to close the gap between lightweight hobbyist robots and costly, heavy forestry machinery. Three key engineering innovations are the focus of the suggested solution, "Seedbot":

1. High-Torque Mobility: To get around root obstacles, a skid-steer tracked chassis powered by industrial square-gearbox motors replaces wheels.
2. Environmental Hardening: The lead screw mechanism is sealed against dust and debris by a specially made "telescoping" linear actuator.
3. Robust IoT Architecture: In remote forests where Wi-Fi and cellular networks malfunction, a split-processing design utilizing LoRa (Long Range) technology maintains control links

II. LITERATURE REVIEW

1. Vision-based planting position selection system for an unmanned reforestation machine

Authors: Rossander & Lideskog et al.

Journal: Forestry: An International Journal of Forest Research

Summary: Uses vision (YOLO v7 + stereo camera) to detect stumps/stones and plan plantable locations. Oxford Academic.



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2. Research on structural innovation of intelligent tree planting robot

Authors: Miao Chen, Qiandi Zhou, Peixin Zhong

Journal: Highlights in Science, Engineering and Technology

Summary: Integrates drilling, seedling delivery, mulching, compaction and watering in one robot.

Darcy & Roy Press

3. Design of an Autonomous Seed Sowing Robot Sweety Dutta, "Agribot"

Theory and Applications of Engineering Research, Vol. 9, March 2024

Summary: Integrated robot that digs holes, drops seed, distances holes, sensor- based obstacle detection.

Bookpi

4. Design of an autonomous agricultural robot

Springer Applied Intelligence, 1995

Summary: Early prototype for field crop robots with vision sensors and manipulators, for tasks including harvesting; gives fundamentals applicable to seed planting.9

5. Survey Paper on IoT-Enabled Seed Dispensing Robot Authors: Sakshi Chandekar, Prof. Dattatray Jadhav IJRASET, 2024

Summary: Focuses on environmental sensing (soil moisture, temperature), GPS, IoT for remote control, optimizing seed placement.

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6. Design of Automated Seed Sower with extended application using IoT Authors: Priyadharshni K., Dr. J. Mohana International Journal of Psychosocial Rehabilitation, India

Summary: Uses IoT and wireless sensor networks; seeds in predefined distance; also covers soil covering action.

7. Re-forestation using robotic vehicle

Published 2025 (Zenodo)

Summary: A robotic vehicle combining ploughing, sowing, irrigation, using sensors and ML algorithms for reforestation tasks.

III. METHODOLOGY

The architectonic design of the Seedbot system is partitioned into three main parts: mechanical, electronics, and power.

A. Mechanical Design and Fabrication The robot, which is the main

part of the system, is made of a specially designed 20 kg chassis that can withstand the maximum punishment and is thus very durable.

1. Drive System: The chassis has high-friction tracks on it so it can turn around its axis with zero radius. Two MG555 Square Gearbox DC Motors (12V, 150 RPM) give the tracks the power to move. The square gearbox is very robust in dealing with shock loads when compared to planetary gears, thus, providing the torque necessary for skid steering.



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Drive System

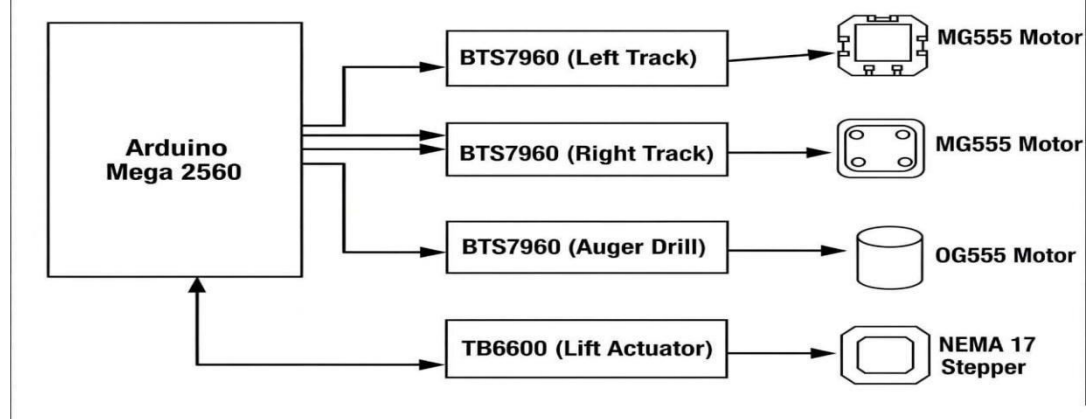


Figure No 1 : Drive System

2. Linear Actuator: One of the key innovative features of the system is the telescoping steel tube linear actuator. In this design, a 20×20 mm inner steel tube slides smoothly inside a rigid outer guide tube. The outer tube encloses the T8 lead screw mechanism and the NEMA 17 stepper motor, forming a compact and protected actuation unit. This enclosure not only improves structural rigidity and alignment but also protects the precision drive components from dust, moisture, and abrasive soil particles generated during the drilling process. As a result, the actuator achieves better durability, smoother linear motion, and reliable performance in harsh outdoor environments.

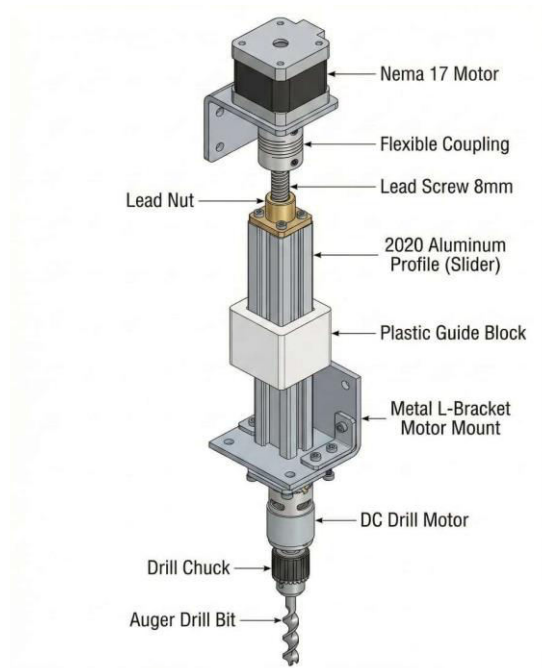


Figure No 2 : Novel Linear Actuator

3. Drilling and Assembly: The drilling head takes out the soil with the help of an OG555 DC Motor (300 RPM) which is connected to a steel earth auger. The RPM in this case was consciously chosen to provide sufficient torque to break the roots that are compacted while keeping the speed of ejection of soil the same.



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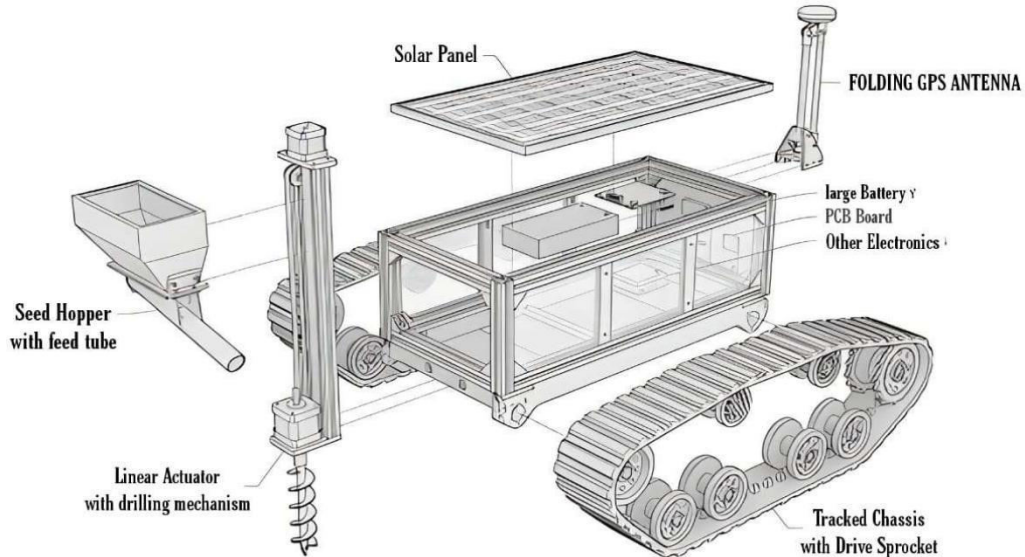


Figure No 3: Drilling Assembly

B. Electronics and Control Architecture

The system first adopts the Master-Slave architecture allowing the real-time tasks with high priority to be executed without being affected by the communication latency.

- **Master Node (ESP32-CAM):** The part of the system which is responsible for making decisions and facilitating communication.

1. **Sensors:** Incorporates a GPS module (NEO-7M) for positioning and a gyroscope (MPU6050) for survey and control of horizontal alignment.

2. **Communication:** Operates Wi-Fi for transmitting video locally and LoRa for remote telemetry and control signals with less power consumption.

3. **Vision:** Provides the ground operator with a view of the planting site through live video streaming.

- **Slave Node (Arduino Mega 2560):** The microcontroller takes care of the execution of low level hardware tasks only.

1. It gets commands from the Master through UART in a high-level form (e.g., "Drill", "Forward").

2. It controls the motor with a precise timing that is required for the stepper and generates PWM signals for the DC motors.

- **Motor Drivers:**

1. **Drive & Drill:** Two MG555 drive motors and one OG555 drill motor are powered up and controlled by three high-current drivers (BTS7960).

2. **Actuator:** A TB6600 Stepper Driver gives micro-stepping control to the NEMA 17 lift mechanism.

- **Power System:** The whole robotic system is powered by a 12V 20Ah Lithium Battery with a built-in BMS (Battery Management System). A high-efficiency Buck Converter is used to regulate the voltage down to 5V for the micro-controllers and sensors and thus ensure stable logic levels even during spikes in the current drawn by the motors.



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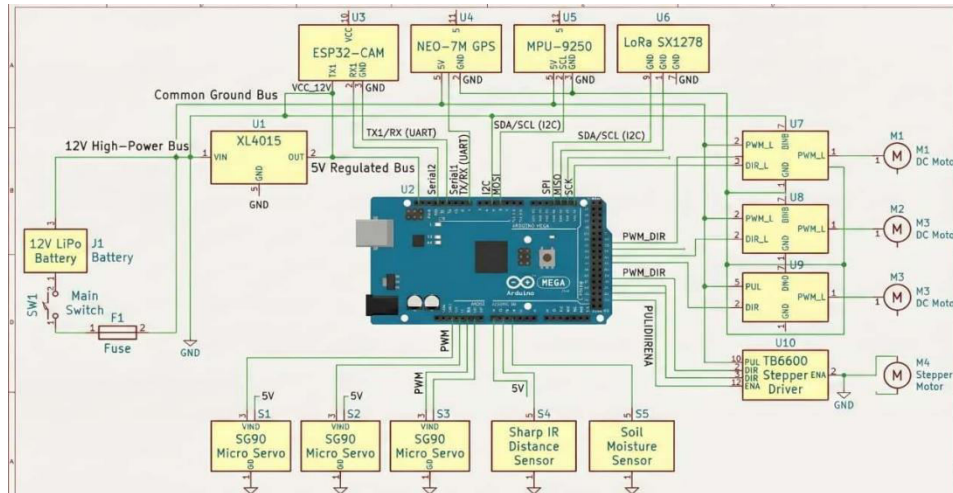


Figure No 4 : Electronics and Control Architecture

IV. RESULTS AND DISCUSSION

The Seed-bot prototype was subjected to rigorous field testing to assess its mechanical and control performance.

A. Mobility and Traction The replacement of the 150 RPM MG555 motors turned out to be a major decision. The corresponding stall torque that was measured went above 30 kg-cm, thus, the 20 kg robot was able to ascend inclines up to 30 degrees.

B. Drilling Performance The Arduino Mega takes care of the drilling cycle (Lower -> Drill -> Retract) and it is done automatically. The TB6600 driver provides noiseless vertical movement, and the OG555 motor operates at a rate of 300 RPM successfully drilled 15cm holes in clayheavy soil without stalling.

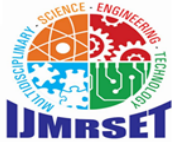
Table 1: Performance Metrics

Parameter	Value	Unit
Max Payload	20	kg
Drilling Depth	150	mm
Comms Range (LoRa)	>1.5	km
Auger Speed	300	RPM
Max incline	30	Degree
Operating Time	2.5	Hours

Figure No 5: Performance Metrics

V. CONCLUSION AND FUTURE WORK

The Seedbot is a perfect example of a low-cost, highly durable robotic platform which can be deployed in the difficult-to-reach areas for reforestation without any problem. It uses a MasterSlave architecture that helps to get the real-time stability control for the motors together with the high-speed processing of video/comms.



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The future plans will be targeted at three main points:

- 1. Automated Planting Mechanism:** Making a 3D-printed "carousel" dispenser that will automatically drop saplings into the drilled holes.
- 2. Energy Independence:** Connecting a solar charging panel that will just keep on charging the battery bank slowly, during the idle times.
- 3. Autonomous Navigation:** A combination of NEO-8M GPS and MPU9050 9 axis with magnetometer data that would enable the robot to go through the pre-set waypoints without any human interference. And there is an YoLo V7 with steror Camera which work like Human Eye for Precise object detection and Avoidance

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