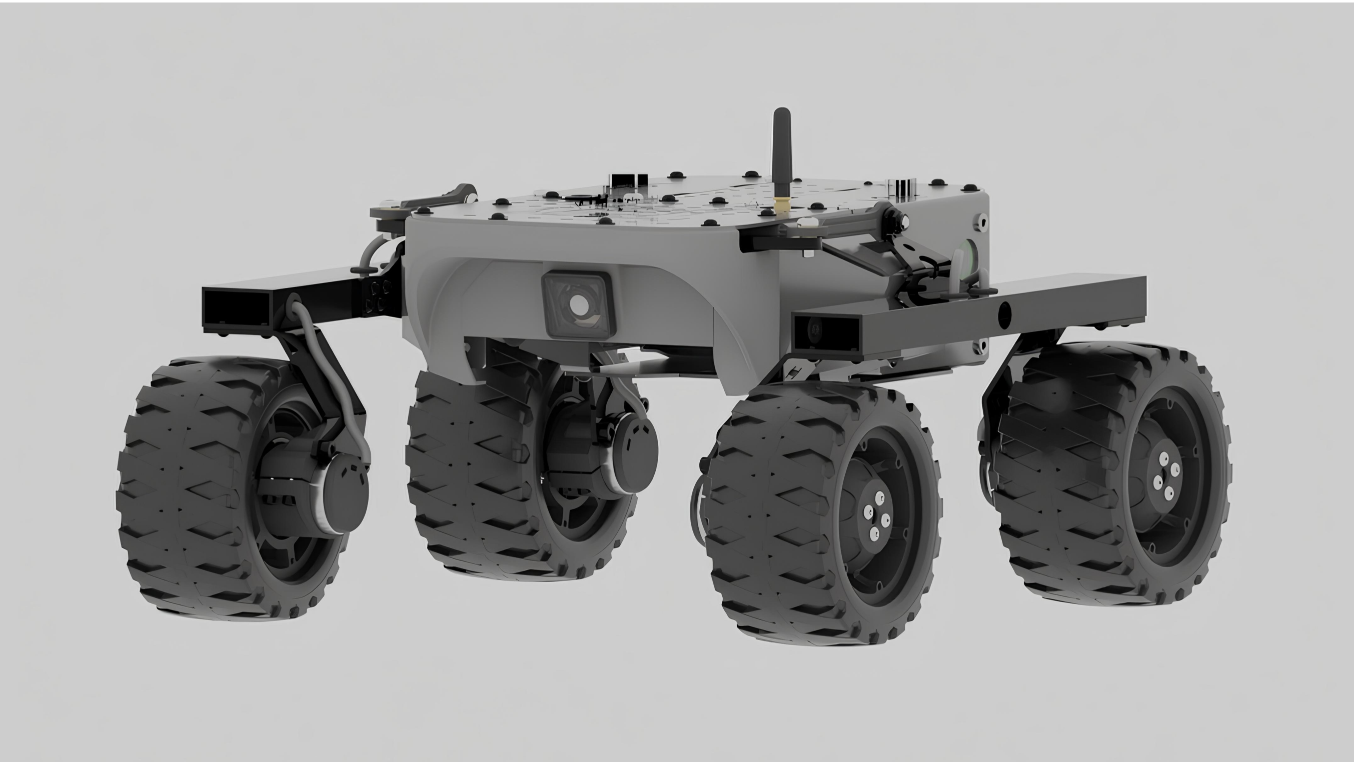
Ceres: A Mobile Farming Robot

Abstract: The concept of Ceres comes from the idea of making a perserverance like rover but not for the exploration of the surface of mars rather perform agricultural tasks here on Earth. Ceres is an autonomous rover designed for precision agriculture, capable of sowing seeds, analyzing soil, and mapping fields in real time. Using AI-driven decision-making, it optimizes seed placement based on soil conditions, ensuring maximum yield efficiency with minimal resource wastage. Equipped with advanced sensors, GPS, and LiDAR, Ceres operates independently, adapting to varying terrain and environmental factors to revolutionize modern farming.

Objective: To develop an agentic autonomous rover robot that optimizes precision farming by analyzing soil, mapping fields, and sowing seeds intelligently, ensuring efficient resource utilization and maximizing crop yield.



Model of Ceres. It may be subject to change.

Key Functions

1. **Autonomous Navigation:** Moves across the field using GPS and LiDAR for accurate path planning.
2. **Soil Analysis:** Collects real-time soil data (moisture, pH, nutrients, etc.) to determine optimal seed placement.
3. **Precision Seeding:** Sows seeds at the best depth and spacing based on soil conditions.
4. **Field Mapping:** Generates a 3D soil fertility and moisture map to assist farmers.

Core Components & Technologies

Navigation & Mapping

– GPS Module: Enables autonomous movement and accurate field coverage.

– LiDAR & Depth Camera: Used for obstacle avoidance and terrain mapping.

– RTK-GPS: For high-precision navigation with cm-level accuracy.

– SLAM (Simultaneous Localization & Mapping): Helps create a 3D field map.

Soil Analysis

– pH Sensor: Measures soil acidity/alkalinity.

– NPK Sensor: Determines Nitrogen (N), Phosphorus (P), and Potassium (K) levels.

– oil Moisture & Temperature Sensor: Helps assess the best seeding conditions.

– Spectrometer (Optional): Analyzes organic matter content in soil.

Precision Seeding Mechanism

– Seed Dispenser: Drops seeds at calculated locations with adjustable depth.

– Stepper Motor & Drill Mechanism: Controls planting depth based on soil type.

AI & Software Stack

– ROS 2: Manages robot control, navigation, and sensor data fusion.

– OpenCV: Used for image-based field analysis.

– TensorFlow/PyTorch: AI-based soil analysis and seed placement optimization.

– IoT Connectivity: Sends real-time field data to a cloud dashboard for farmers.

Workflow

Step 1: Rover Deployment & Field Mapping

– Starts from a designated point using GPS coordinates.

– Scans the field, mapping terrain & obstacles using LiDAR & SLAM.

– Generates a digital **field map** showing elevation & soil zones.

Step 2: Soil Data Collection & Analysis

– Stops at specific points to collect **moisture, pH, NPK** data.

– Sends real-time soil data to an AI system for analysis.

– AI predicts the best locations for seed placement.

Step 3: Precision Seeding

– Moves in a calculated path, drilling holes at optimized locations.

– Drops seeds with precise spacing and depth.

– Adjusts seed rate based on soil conditions to maximize germination.

Step 4: Data Logging & Cloud Upload

– Creates a **heatmap** of soil quality & moisture.

– Syncs field data with a **farmer's dashboard (IoT/cloud-based).**

– Sends alerts if any part of the field has poor soil quality.

Frameworks & Libraries Used

– **OS & Middleware: ROS 2 (Robot Operating System)** for sensor fusion & navigation

– **Navigation & Control: Nav2 + RTK-GPS** for path planning

– **AI & Computer Vision: TensorFlow, OpenCV** for seed placement & soil analysis

– **Data Communication: MQTT/LoRaWAN** for IoT data transmission

– **Cloud Dashboard: Flask + Firebase** for real-time field monitoring

Real life Render of Ceres

Component	Function
Chassis & Mobility	4WD/Tracked base for rough terrain
RTK-GPS Module	High-precision navigation (±2cm accuracy)
LiDAR & Depth Camera	Obstacle detection and SLAM-based mapping
Soil Sensors	Collects real-time soil data
Seed Dispenser (Stepper Motor Controlled)	Drops seeds with precise depth & spacing
AI Processing Unit (Jetson Nano / Raspberry Pi + Coral TPU)	Runs real-time AI-based analysis
Solar Panel / Battery Pack	Provides sustainable power
IOT(ESP32/LoRa)	Sends data to cloud dashboard

Component	Specification	Estimated Cost (INR/USD)
Chassis Frame	Aluminum/Steel (50x40cm)	Rs5,000 / $60
Wheels (4WD)	3-4-inch rubber wheels	Rs5,200 / $60
DC Motors (4x)	12V 100RPM High Torque	Rs1,000 / $10
Motor Driver	L298N / Sabertooth 2x25	Rs660 / $8
Battery Pack (2X)	2200mAh 10C 3S1P Li-Ion Battery Pack	Rs3,500 / $40
NEO 7M GPS	u-blox ZED-F9P	Rs1,723.00 / $20
Gyro & Accelerometer	HW-290/GY-87 10DOF	Rs407 / $5
LiDAR Sensor	RPLIDAR A1	Rs9,000 / $103
Soil pH Sensor	Gravity Analog pH Sensor	Rs4250 / $50
Soil NPK Sensor	DFRobot NPK Sensor	Rs622 / $8
Soil Moisture Sensor	Capacitive Soil Sensor	Rs130 / $2
Seed Dispenser	Custom Hopper + Servo Motor	Rs3,000 / $40
Stepper Motor	NEMA 17	Rs471 / $6
AI Processing Unit	Raspberry Pi 4	Rs8,000 / $100
Microcontroller	Arduino Mega	Rs2,500 / $30
LoRa Module (IoT)	SX1278	Rs1,897 / $22
Wiring & Connectors	Jumper wires, PCB board	Rs110 / $2
Total:		R̃s 50K / $572

Note: Links to the purchasing can be accessed by clicking on the components. Not all the components have links for obvious reasons. The budget is subjected to change.

The cost of making a Proof of Concept would naturally be high, but once a few prototypes are built we will work on reducing the manufacturing cost of the rover. I wish to integrate it with a drone as well so that it so that it can perform other tasks too. This way we can have a whole ecosystem to aid and innovate the agriculture sector.

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