



SWAYAM : The Autonomus tractor

Use case :

Traditional farming methods are labor-intensive and inefficient, resulting in escalating costs and significant challenges in sustaining productivity. In contrast, autonomous tractors can perform a variety of agricultural tasks such as plowing, planting, and harvesting continuously without the need for breaks, significantly enhancing the speed and efficiency of these processes while revolutionizing modern farming practices.

Features :

- **360-Degree Field Awareness:** Uses multiple cameras for real-time monitoring and obstacle detection.
- **Autonomous Navigation:** Powered by the Nvidia Jetson Xavier and ROS for real-time decision-making can also be remotely operated.
- **Precision Plowing:** Utilizes RTK GPS and steering encoders for accurate plowing depth and coverage.
- **Automated Seeding:** Features a mechanical seeder for optimal seed placement and spacing.

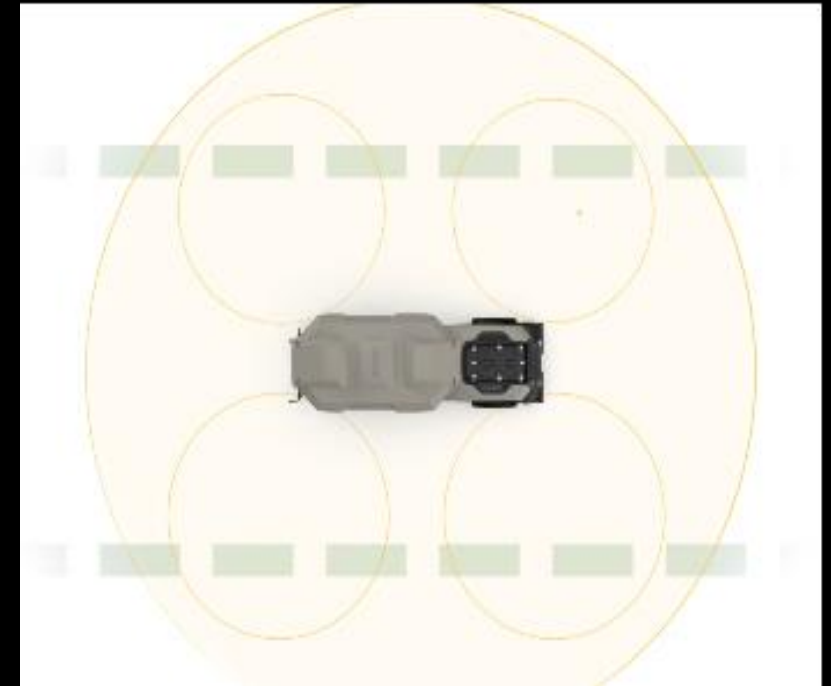


Fig 1: Field Of View

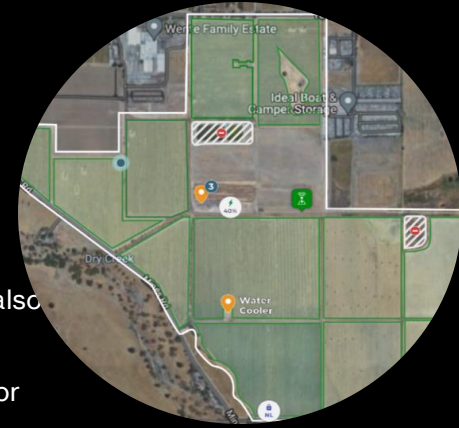
Power

- **Weight Assumption** : ~ 3727kg (with frame and all components)
- **Dimension of Swayam** :
Length: ~3.8 meters
Width: ~2.5 meters
Height: ~2.6 meters
- **Battery charger** :Delta-Q QuiQ Charger
- **Conncectors** :Type 2 connector male and female
- With plow tractor last 7.5hrs plow ~8 hectors of land
- With seeder tractor last 11 hrs seeds 15 hectors of land as seeder is mechanical

Power Estimate

Component	Model Number	Power Consumption (W)	Weight	Working Temperature
Li-ion Battery (1000 kWh)	Custom High-Capacity Battery	12 hours approx depending on attachments.	1500-1800 kg	-20°C to 60°C
Electric Motor (35 kW)	Kollmorgen AKM54	35,000	70 kg	-40°C to 85°C
Hydraulic System	Parker Hannifin PGP 500	15,000	80 kg	-40°C to 90°C
RTK GPS Module	Trimble AG-372	10	1 kg	-40°C to 70°C
IMU	VectorNav VN-100	0.5	0.5 kg	-40°C to 85°C
360 Vision Cameras (4)	ZED 2i Stereo Camera	18 (4.5 W each)	0.8 kg each	-20°C to 55°C
Ultrasonic Sensors (4)	MaxBotix	2 (total)	0.8 kg	-40°C to 65°C
Plow (4-furrow)	Lemken VariOpal 8	74600 (for ploughing)	400 kg	-20°C to 60°C
Mechanical Seeder	EarthWay Precision Seeder	7500(for seeding)	50 kg	-15°C to 55°C
Steering	Novotechnik RSC3200	2	0.4 kg	-40°C to 85°C
Wheel Encoders (4)	Sick DFS60 or similar (IP65-rated)	8 (2 W each)	1 kg total	-40°C to 85°C
Power Management Unit (PMU)	Victron Energy Multiplus	1,500	15 kg	-25°C to 60°C
Onboard Computer (ROS)	Nvidia Jetson Xavier NX	50	5 kg	0°C to 50°C
Cooling System	Rittal TopTherm	1,000	50 kg	-20°C to 55°C

Navigation



1. Field Mapping and Localization

- **RTK GPS:** Provides high-precision GPS data, achieving centimeter-level accuracy essential for defining field boundaries and plotting efficient paths.
- **ZED 2i Cameras:** Capture high-resolution, 3D imagery of the environment, which is combined with GPS data to build detailed field maps. The stereo cameras also provide depth perception, essential for spatial awareness.
- **Data Integration:** By merging GPS coordinates with 3D camera images, the tractor creates a comprehensive, high-resolution map of the field, marking areas for plowing, seeding, and other tasks.

2. Position Estimation and Tracking

- **Multi-Sensor Fusion:** GPS coordinates, ZED camera data, and encoder feedback are combined to achieve precise position estimation and path tracking.
- **Encoders (Wheel and Steering):** Measure wheel rotations and steering angles in real-time, refining positioning accuracy and allowing the tractor to make minor adjustments to maintain its path.
- **Continuous Updates:** This integrated system continuously recalculates the tractor's position to adapt to small deviations caused by uneven terrain or soil conditions.

3. Obstacle Detection and Avoidance

- **Ultrasonic Sensors:** Short-range sensors that detect nearby obstacles, even in low visibility conditions, ensuring safe operation around equipment, livestock, or people.
- **ZED 2i Cameras:** Provide long-range depth perception, enabling early detection of larger obstacles and providing additional safety when moving at higher speeds.
- **Real-Time Decision-Making:** The sensor data is processed to make immediate adjustments, rerouting the tractor's path when an obstacle is detected.

4. Adaptive Navigation and Control

- **Speed and Trajectory Adjustment:** The tractor modulates its speed and trajectory using feedback from the encoders, cameras, and ultrasonic sensors. This adaptive control helps maintain efficiency during tasks like plowing or seeding, even on challenging terrain.
- **Dynamic Path Planning:** Uses real-time data to make on-the-fly adjustments in speed and steering, ensuring optimal coverage and avoiding missed areas.

5. Data Logging and Performance Analysis

- **Operational Data Collection:** Continuously logs GPS coordinates, sensor readings, and control inputs for analysis.
- **Optimization and Efficiency Tracking:** This data helps optimize future tasks, ensuring accurate coverage and tracking areas of improvement for operational efficiency.

- **ZED 2i Stereo Cameras (4)**

Location: Mounted at front, back, and sides around the tractor's roof for 360° vision coverage.

Purpose: These cameras provide stereo vision for obstacle detection and terrain mapping, helping with navigation and precise operation. They generate real-time depth maps to detect obstacles in the tractor's path ensuring safe navigation.

- **GPS + RTK Module**

Location: Centrally mounted on the tractor roof.

Purpose: Provides highly accurate positioning for field navigation, ensuring the tractor stays on a pre-planned route for ploughing and seeding tasks.

- **Ultrasonic Sensors (x4)**

Location: Mounted at the front, back, and sides of the tractor.

Purpose: Detects nearby obstacles in real time. These sensors create warning and stop zones based on the tractor's speed and direction, ensuring safe navigation during operation.

- **Wheel and Steering Encoders**

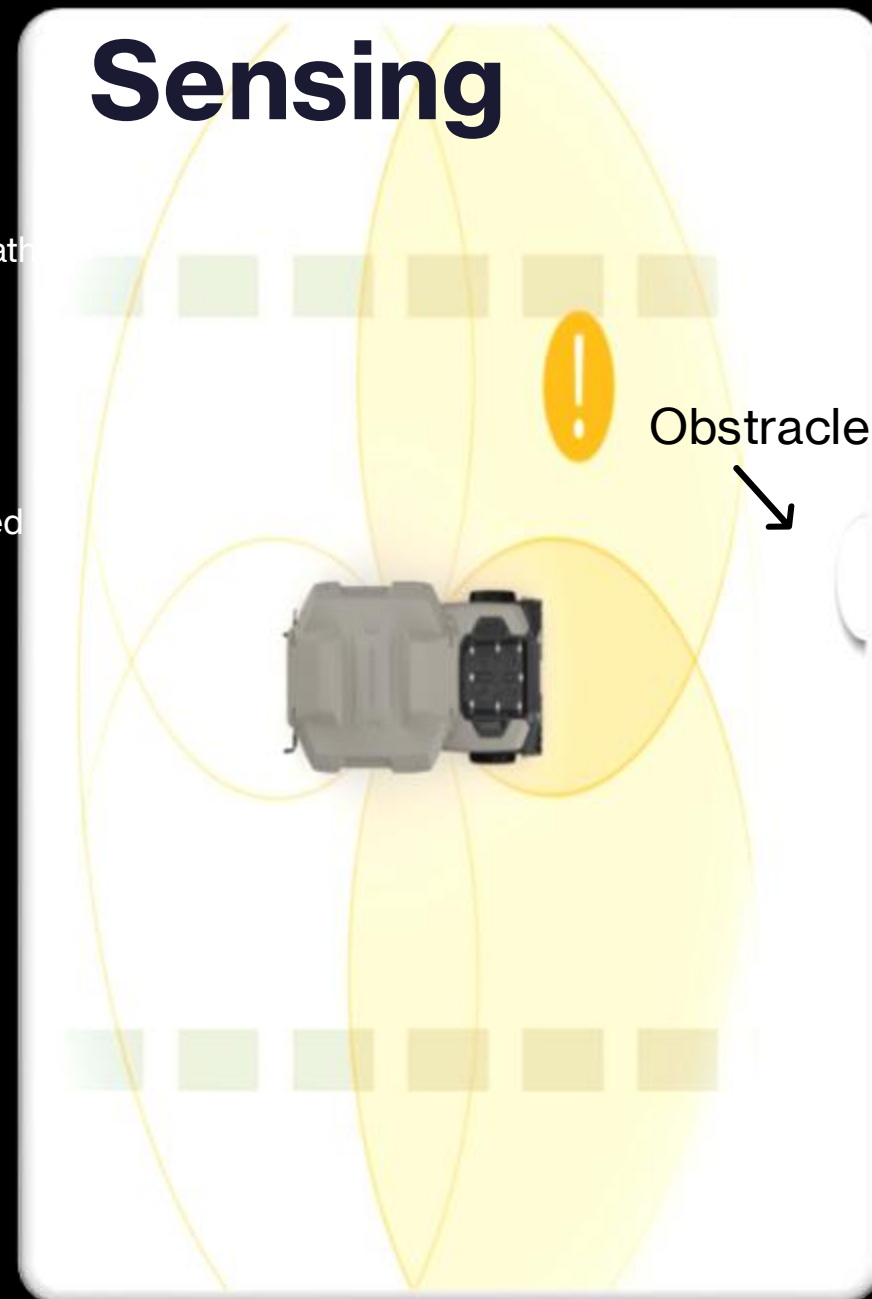
Location: Integrated with wheels and steering mechanism.

Purpose: Provide precise movement and orientation feedback to help control vehicle speed, adjust steering, and ensure accuracy in following a plotted path.

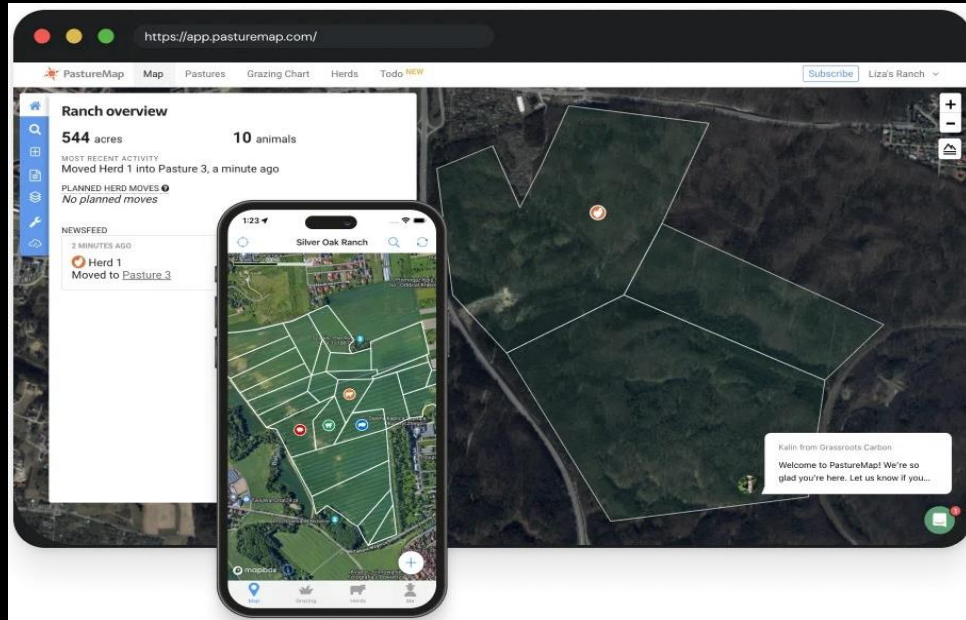
- **IMU (Inertial Measurement Unit)**

Location: in the centre of tractor

Purpose: Measures the tractor's orientation and movement, ensuring accurate control of its heading and trajectory while navigating uneven terrain.



Software



- **Advanced Navigation & Path Planning:** The tractor autonomously navigates using GPS, ZED cameras, IMU, and wheel/steering encoders, executing optimized routes for ploughing and seeding. Path planning ensures maximum field coverage with minimal overlap, improving operational efficiency.
- **Real-Time Sensor Fusion & Decision-Making:** Data from GPS, stereo cameras, IMU, and ultrasonic sensors are fused in real time for precise localization, obstacle detection, and environment mapping. Wheel and steering encoders ensure accurate tracking of position and motion control.
- **ROS-Based Modular Control System:** The tractor operates on ROS, with separate nodes handling sensor data processing, motor control, hydraulic actuation, and real-time decision-making. The system allows for dynamic adjustments in response to field conditions and obstacles.
- **Mobile App Integration for Remote Control:** A dedicated mobile app (built using platforms like **Flutter** or **React Native**) enables live monitoring, task adjustments, route setting, and real-time alerts. It also offers maintenance notifications and performance stats.
- **Safety & Obstacle Avoidance System:** The tractor employs ultrasonic sensors and 360° ZED cameras to create dynamic safety zones, automatically adjusting speed or halting operations when obstacles are detected.
- **Cloud-Based Mission Logging & Analytics:** All mission data is logged in the cloud, allowing for performance analysis, remote diagnostics, and predictive maintenance. Operators can review past missions and make data-driven decisions for future operations.