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Evaluation of Hybrid GNSS/RTK and ROS 2 Nav2 Navigation Architectures for Autonomous Agricultural Robots

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Abstract.

Global Navigation Satellite Systems (GNSS), particularly when combined with Real-Time Kinematic (RTK) corrections, are widely used in precision agriculture to provide accurate global positioning for autonomous field operations. However, although GNSS-based systems enable georeferenced navigation, they offer limited capabilities for dynamic obstacle avoidance and local path optimization. Conversely, modern robotic navigation frameworks such as the ROS 2 Navigation Stack (Nav2) integrate multiple sensors and path-planning algorithms, including A and Dijkstra, to generate adaptive trajectories in complex environments. This work evaluated a hybrid navigation architecture that combines GNSS/RTK localization with Nav2 local planning for autonomous agricultural robots. The proposed approach was implemented in ROS 2 Jazzy and validated in a simulated agricultural environment using a Clearpath Husky robot. Six navigation configurations were evaluated, including GNSS-only, GNSS with RTK, GNSS combined with Nav2, and GNSS with RTK integrated with Nav2. Experiments were conducted using georeferenced waypoint missions and repeated under multiple navigation scenarios. Results showed that GNSS-only navigation achieved 4 of 5 waypoints with a mission time of 8 min 34 s, while the best-performing configuration, GNSS + RTK + Nav2 using the A* planner, successfully reached all waypoints and reduced mission time to 3 min 57 s, representing a 54% improvement. The findings indicate that integrating global localization and local sensor-based planning can improve navigation efficiency, robustness, and obstacle-aware operation, demonstrating the potential of hybrid navigation architectures for autonomous agricultural robotics applications.*

Keywords.

autonomous navigation, GNSS, precision agriculture, ROS 2, Nav2, SLAM, agricultural robotics, waypoint navigation.

Introduction

Global Navigation Satellite Systems (GNSS) are widely adopted in precision agriculture to provide absolute positioning for autonomous field operations. When combined with Real-Time Kinematic (RTK) corrections, GNSS-based systems can achieve centimeter-level accuracy, enabling applications such as auto-steering, planting, spraying, and autonomous logistics *(Carvalho, 2026)*. Modern agricultural guidance systems can follow complex trajectories over large areas and have become a key component of precision farming technologies.

Despite their high positioning accuracy, GNSS-based navigation systems generally focus on global localization and path tracking, offering limited capabilities for dynamic obstacle avoidance and local path adaptation. In contrast, robotic navigation frameworks such as the ROS 2 Navigation Stack (Nav2) integrate multiple sensors, including LiDAR, odometry, and inertial measurement units, to generate environmental representations and compute optimized trajectories using path planning algorithms such as A* and Dijkstra.

The integration of global GNSS/RTK localization with local sensor-based planning has the potential to improve the operational flexibility of agricultural robots operating in partially structured environments, including crop-row navigation, field scouting, and autonomous transportation tasks *(Bengochea-Guevara et al., 2025)*. Therefore, this work evaluated a hybrid navigation architecture combining GNSS/RTK positioning and ROS 2 Nav2 planning in a simulated agricultural environment.

Materials and Methods

A hybrid navigation architecture was implemented using ROS 2 Jazzy and evaluated in the Gazebo simulation environment using a Clearpath Husky unmanned ground vehicle. The proposed architecture combined global localization provided by GNSS or RTK with local path planning and obstacle avoidance capabilities provided by Nav2 *(Macenski et al., 2023)*.

Georeferenced waypoints defined in the WGS84 coordinate system were transformed into a local Cartesian reference frame and used as navigation goals. Nav2 planners generated optimized trajectories between waypoints while incorporating obstacle information obtained from simulated onboard sensors.

The evaluation considered six navigation configurations:

1. GNSS-only navigation;
2. GNSS with RTK corrections;
3. GNSS combined with Nav2 using the A* planner;
4. GNSS combined with Nav2 using the Dijkstra planner;
5. GNSS with RTK and Nav2 using the A* planner;
6. GNSS with RTK and Nav2 using the Dijkstra planner.

Experiments were conducted in a simulated agricultural environment containing navigation corridors and obstacles representative of field conditions. Two waypoint sets were defined, with approximately 15 m between consecutive waypoints. Each configuration was executed six times, corresponding to three repetitions for each waypoint set.

Results and Discussion

Table 1. Results of simulation tests considering only the best score of each

Configuration	Waypoints Reached	Obstacle Avoidance Events	Mission Time
GNSS	4/5	12	08:34
GNSS + RTK	5/5	14	06:22

GNSS + Nav2 (A*)	5/5	N/A	04:40
GNSS + Nav2 (Dijkstra)	5/5	N/A	04:15
GNSS + RTK + Nav2 (A*)	5/5	N/A	03:57

The GNSS-only configuration produced the lowest overall performance, reaching only four of the five waypoints and requiring the longest mission execution time. Adding RTK corrections improved localization accuracy and enabled successful completion of all navigation goals, reducing mission time by approximately 26%.

The integration of Nav2 produced the largest performance gains. Both A* and Dijkstra planners generated more efficient trajectories than those obtained using GNSS-based navigation alone. Among the non-RTK scenarios, the Dijkstra planner achieved the shortest mission time, reducing total execution time by approximately 50% compared to the GNSS-only configuration.

The best overall result was obtained using the GNSS + RTK + Nav2 (A*) architecture, which completed the mission in 3 min 57 s. This configuration reduced mission time by approximately 54% relative to GNSS-only navigation while maintaining 100% waypoint completion. These results suggest that RTK primarily improves localization reliability, whereas Nav2 contributes to trajectory optimization and obstacle-aware navigation.

Conclusion

Experimental results demonstrated that Nav2 significantly reduced mission execution times compared to GNSS-only navigation, while RTK improved waypoint completion reliability. The best-performing configuration, combining RTK and Nav2 with the A* planner, reduced mission time by approximately 54% while successfully reaching all waypoints.

These findings indicate that hybrid global-local navigation architectures can enhance the operational capabilities of autonomous agricultural robots by combining accurate georeferenced positioning with adaptive path planning. Future work will focus on field validation using real GNSS and RTK receivers and on evaluating navigation performance in crop-row environments and larger agricultural scenarios.

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