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Autonomous Navigation Systems for UAVs and UGVs in Vineyard Environment: Path Planning, Localization, and Obstacle Avoidance

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ABSTRACT

In recent years, unmanned ground vehicles (UGVs) and Unmanned aerial vehicles (UAVs) have been widely adopted in agriculture, reducing human labor and enhancing operational safety. Autonomous navigation systems are essential to support UGVs and UAVs in diverse field conditions, enabling automated tasks such as planting, spraying, fertilizing, harvesting, thinning, weeding, and inspection. Advances in technology have led to more intelligent and adaptable navigation systems capable of long-term autonomous operation while executing specific field tasks.

This study presents a navigation system for UGVs and UAVs in vineyard environment, enabling seamless bidirectional communication between a Farm Management Information System (FMIS) and autonomous vehicles within smart farming applications. The system integrates advanced route-planning algorithms within the FMIS and is compatible with agricultural vehicles via the Robot Operating System (ROS) and MAVLink protocols. It also includes a communication and computation unit (CCU) that links the FMIS algorithms, user interface, and vehicles. The system integrates advanced path planning, real-time localization, and obstacle avoidance techniques to ensure optimal performance. Key components include dynamic autonomous navigation, motion planning algorithms, sensor fusion using GNSS, LiDAR, and computer vision.

The system was validated through field deployment of two ground robotic vehicles (Thorvald - Saga Robotics and Husky A200 - Clearpath Robotics) and two drones (S1000 – DJI and Farm4Drone – Acceligence) for executing route tasks in a vineyard. Case studies demonstrated

over 80% efficiency in field traversal, while optimal route-planning improved field efficiency by up to 9.5%. These results highlight the potential of autonomous navigation in enhancing the efficiency and productivity of precision viticulture.

Keywords: agri-robots; farm management information system; operations planning; UAV; UGV; vineyard.