Technical Report: Autonomous SLAM-Based Fleet for Smart Agricultural Supervision

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Introduction - In modern agriculture, monitoring large farmlands efficiently remains a critical challenge. Traditional methods are labor-intensive, lack real-time data insights, and have limited automation, leading to inefficiencies in farm supervision. To address this issue, our team, *Nexus Numerics*, developed an integrated web and mobile application that enables the autonomous operation of SLAM-enabled agricultural robots, referred to as *Slambots*. These robots use Simultaneous Localization and Mapping (SLAM) technology for navigation, distributed monitoring, and adaptive collaboration, significantly improving farm supervision.

Project Scope and Objectives Our project aimed to develop a scalable web application for managing a fleet of Slambots, with the following key functionalities:

1. **Autonomous Navigation**: Implementing SLAM to enable efficient movement across large farmlands.
2. **Distributed Monitoring**: Collecting and analyzing real-time data on soil moisture, temperature, and crop health.
3. **Adaptive Collaboration**: Optimizing task distribution among Slambots through shared data analysis.
4. **Fail-Safe Operations**: Ensuring operational stability by handling sensor failures, communication delays, and power constraints.
5. **Remote Supervision**: Providing farmers with real-time monitoring capabilities via a web or mobile interface.

Implementation Details Our project leveraged a combination of software and hardware components to achieve the desired functionality:

- **Website Development:** We used React.js and CSS for the front-end interface, providing an intuitive dashboard for farmers to monitor and control Slambots.
- **Desktop Application:** Developed using Python, integrating Power BI for real-time data visualization and MySQL for data storage.

- **API Integration:** The application interacts with the SLAM-based fleet via API calls. Session-based isolation is implemented, requiring authentication using a session ID.
    - Start a session: POST https://fleetbots-production.up.railway.app/api/session/start
    - Retrieve fleet status: GET https://fleetbots-production.up.railway.app/api/fleet/status?session_id=<SessionId>
- **Database Management:** Sensor data from the Slambots is stored in CSV format and processed using MySQL to generate actionable insights.
- **Data Visualization:** We used Power BI to visualize real-time data collected by the Slambots, including soil moisture, temperature, and crop health metrics. This enabled farmers to gain actionable insights through interactive dashboards for better decision-making.

Challenges and Solutions Throughout the project, we faced several technical challenges:

1. **SLAM Integration:** Implementing real-time navigation required fine-tuning of SLAM algorithms. We resolved this by optimizing sensor data processing and using pre-trained models for terrain recognition.
2. **Data Synchronization:** Ensuring smooth communication among multiple Slambots was complex. We implemented adaptive task allocation based on sensor data sharing to improve coordination.
3. **System Fail-Safes:** To handle sensor failures, we introduced redundancy mechanisms and power-efficient operation strategies.

Bonus Implementation To enhance our solution, we simulated fleet behavior in Webots using sensor-based data generation. This allowed us to test navigation algorithms and optimize robot coordination before real-world deployment.

Conclusion Our project successfully demonstrated the potential of SLAM-enabled Slambots for smart agricultural supervision. By combining autonomous navigation, real-time monitoring, and adaptive collaboration, we provided an innovative solution to enhance farm productivity. The developed web and mobile applications enable farmers to efficiently manage their agricultural operations, improving both yield and sustainability. Future improvements include integrating machine learning models for predictive analytics and expanding sensor capabilities for more comprehensive data analysis.