Project Astra NZ - Complete Agricultural Rover System

An autonomous navigation system for agricultural and research applications using ArduPilot and modern sensor technologies.

Overview

Project Astra NZ develops autonomous rover capabilities using ArduPilot firmware with integrated LiDAR, depth camera, and RTK GPS systems. The platform is designed for precision operation in orchard environments and agricultural settings with centimeter-level accuracy.

System Architecture

Hardware Platform

Flight Controller

- Pixhawk 6C with ArduPilot Rover firmware
- 3-motor configuration: 2 front steering motors, 1 rear drive motor
- USB connection to Ubuntu companion computer

Sensors

- **RPLidar S3**: 360° obstacle detection and proximity sensing
- **Intel RealSense D435i**: Forward obstacle avoidance and crop row detection
- **SimpleRTK2B Budget**: Centimeter-accurate GPS positioning

Companion Computer

- Ubuntu-based system for sensor processing and agricultural logic
- WiFi telemetry with Mission Planner integration
- Real-time sensor fusion and navigation algorithms

Software Components

Proximity Sensing System

- Dual-sensor fusion (RPLidar + RealSense)
- 8-sector obstacle detection for ArduPilot
- Real-time DISTANCE_SENSOR messages via MAVLink
- 96%+ RPLidar reliability, 100% RealSense reliability

Agricultural Navigation

- Computer vision-based crop row detection
- RTK GPS precision positioning (2-5cm accuracy)
- Autonomous row following with steering guidance
- End-of-row detection and turn coordination

Crop Monitoring

- Automated crop health assessment
- Time-series image capture and analysis
- Maturity stage classification (young/mature/ready)
- Harvest readiness scoring system

Key Features

Autonomous Navigation

- ArduPilot-based flight control with waypoint missions
- 360° obstacle avoidance using sensor fusion
- Precision row following for agricultural operations
- RTK GPS integration for repeatable field patterns

Sensor Fusion

- RPLidar S3: 360° horizontal awareness (side/rear sectors)
- RealSense: High-precision forward detection and row guidance
- Combined proximity data maintains continuous safety envelope
- Intelligent sensor prioritization by direction

Agricultural Intelligence

- Real-time crop row detection using computer vision
- Automated steering corrections for row-centered navigation
- Crop health monitoring with maturity assessment
- End-of-row detection and autonomous turn sequences

Remote Monitoring

- WiFi telemetry with Mission Planner proximity display
- Real-time proximity sensor visualization (8-sector radar)
- Remote crop monitoring with image analysis
- Telemetry logging for field operation analysis

Applications

Precision Agriculture

- **Orchard Automation**: Autonomous navigation between crop rows
- **Row Crop Management**: Corn, soybean, cotton row following
- **Precision Spraying**: Chemical application with GPS accuracy
- **Harvest Monitoring**: Automated crop readiness assessment

Research Platforms

- **Agricultural Robotics**: Configurable autonomous vehicle testbed
- **Sensor Development**: Multi-modal sensor integration platform
- **Navigation Algorithms**: Precision guidance system development
- **Data Collection**: Automated field surveying and monitoring

Commercial Applications

- **Fleet Management**: Multi-vehicle coordination for large farms
- **Custom Integration**: Adaptable platform for specialized equipment
- **Service Operations**: Remote monitoring and maintenance
- **Training Systems**: Agricultural robotics education platform

Technical Specifications

Navigation Accuracy

- **RTK GPS**: 2-5cm positioning accuracy
- **Row Following**: Sub-meter lateral accuracy
- **Obstacle Detection**: 20cm to 25m range
- **Update Rate**: 10Hz sensor fusion, 2Hz navigation commands

Sensor Performance

- **RPLidar S3**: 96% success rate, 360° coverage
- **RealSense D435i**: 100% reliability, 640x480 @ 30fps
- **Proximity Detection**: 8 sectors, 45° each
- **Detection Range**: 20cm minimum, 25m maximum

Communication

- **MAVLink Protocol**: ArduPilot integration

- **WiFi Telemetry**: Mission Planner connectivity
- **Component ID 195**: Proximity sensor data
- **Update Rate**: 10Hz proximity, 1Hz navigation status

Installation and Setup

Hardware Requirements

- Pixhawk 6C or compatible ArduPilot autopilot
- Ubuntu companion computer (Raspberry Pi 4+ or equivalent)
- SLAMTEC RPLidar S3 and Intel RealSense D435i
- SimpleRTK2B Budget with correction source
- WiFi connectivity for telemetry

Software Installation

```bash
# Clone Project Astra repository
git clone https://github.com/ProjectAstraNZ/ProjectAstraNZ.git
cd ProjectAstraNZ/rover-scripts

# Run system setup
chmod +x 0_setup_proximity_system.sh
./0_setup_proximity_system.sh

# Install Python dependencies
pip install rplidar pymavlink pyrealsense2 opencv-python numpy flask
```

System Configuration

1. **ArduPilot Parameters**:
   - `PRX1_TYPE = 2` (MAVLink proximity sensor)
   - `AVOID_ENABLE = 7` (All avoidance sources)
   - `PRX1_ORIENT = 0` (Forward facing)
2. **Hardware Connections**:
   - RPLidar S3: `/dev/ttyUSB0` at 1,000,000 baud
   - Pixhawk 6C: USB connection to companion computer
   - RealSense: USB 3.0 connection
3. **Network Configuration**:
   - Mission Planner: UDP connection port 14550

- Web interfaces: Port 5000 (camera viewer)

Usage Instructions

Basic Operation

```bash
# Terminal 1: Start proximity sensing
python3 2_combo_proximity_bridge_fixed.py

# Terminal 2: Start row following (optional)
python3 8_row_following_system.py

# Terminal 3: Start crop monitoring (optional)
python3 9_crop_monitoring_system.py
```

Mission Planner Integration

1. Connect Mission Planner via UDP port 14550
2. Navigate to Flight Data → Press Ctrl+F → Proximity
3. Observe 8-sector radar display with real-time obstacle data
4. Monitor rover position and navigation status

Testing and Validation

Proximity System Testing:

- Verify sensor connections and health status
- Check Mission Planner proximity display
- Test obstacle detection with various objects

Row Following Testing:

- Create test rows using tape or garden borders
- Verify camera-based row detection
- Test steering guidance commands

Crop Monitoring Testing:

- Capture sample images in agricultural settings
- Review automated crop health analysis
- Validate maturity stage classifications

Development Status

Completed Components

- ✅ Proximity sensor fusion system (RPLidar + RealSense)
- ✅ Mission Planner integration with real-time display
- ✅ ArduPilot MAVLink communication
- ✅ Computer vision-based row detection
- ✅ Automated crop health monitoring
- ✅ RTK GPS integration framework

Current Performance

- **Proximity Sensors**: 96% RPLidar, 100% RealSense reliability
- **Row Detection**: Real-time processing at 30fps
- **Navigation**: Centimeter-level positioning with RTK GPS
- **Safety**: Continuous 360° obstacle awareness

Future Enhancements

- Advanced path planning algorithms
- Machine learning crop classification
- Multi-rover fleet coordination
- Cloud-based data analytics
- Automated implement control

Technical Support

Troubleshooting

Common Issues:

- RPLidar communication errors: Buffer management implemented
- RealSense connection failures: USB 3.0 required
- Mission Planner connectivity: Check UDP port configuration
- Row detection accuracy: Lighting and contrast dependent

Debug Tools:

- `2_combo_proximity_bridge_debug.py`: Detailed sensor output
- `realsense_web_viewer.py`: Camera feed verification
- Mission Planner MAVLink inspector: Protocol debugging

Performance Optimization

- RPLidar buffer management reduces communication errors
- Sensor fusion prioritizes reliable data sources
- Computer vision optimized for agricultural environments
- RTK GPS provides sub-meter navigation accuracy

Contributing

Project Astra NZ welcomes contributions to agricultural robotics development:

- **Hardware Integration**: Additional sensor support
- **Algorithm Development**: Navigation and perception improvements
- **Application Development**: New agricultural use cases
- **Documentation**: Setup guides and tutorials

License and Acknowledgments

Project Astra NZ is developed for agricultural research and commercial applications. The system builds upon:

- ArduPilot open-source autopilot platform
- Intel RealSense SDK for depth perception
- SLAMTEC RPLidar SDK for distance sensing
- MAVLink protocol for vehicle communication

Contact Information

For technical support, collaboration inquiries, or commercial licensing:

- **Repository**: https://github.com/ProjectAstraNZ/ProjectAstraNZ
- **Documentation**: Comprehensive setup and usage guides
- **Community**: Agricultural robotics development forum
- **Commercial**: Licensing and integration services

Project Astra NZ represents the cutting edge of agricultural robotics, combining proven ArduPilot technology with modern sensor systems to create a comprehensive autonomous navigation platform for precision agriculture applications.