Project 5: Over-Rack Inventory Scan – PX4 Vision

Topics: aerial inspection • vision-based monitoring • simulation • abnormal-state detection • autonomous flight

Objective

The objective of this project is to design a drone-based system capable of autonomously scanning and verifying inventory over shelving racks. The drone will follow a predefined mission path, stabilize above designated hover points, capture high-resolution images, and extract barcode data in real time. The system must detect and respond to conditions such as scan failures, optical-flow instability, or thermal stress.

Description

The quadrotor will execute a rectangular flight pattern over a simulated or physical shelving rack, flying at an altitude of approximately 2.5 meters. At each waypoint, it will enter a **hover mode**, capture a downward-facing image using a 12-MP camera, and process the frame onboard to decode barcodes using the **ZXing library**.

The decoded barcode IDs and **hover variance** will be transmitted to a ground station (e.g., a tablet) for live monitoring. The barcode detection rate will be used to assess scan coverage and detect blind spots.

The system will transition between the following **states**:

- *Take-off*: mission initialization and vertical ascent
- *Transit*: movement between scan points
- *Hover-Scan*: precise hovering and image capture
- *Descend-Land*: controlled landing at the end of the mission
- *Alarm*: triggered when scan quality or flight stability degrades

Fault conditions include:

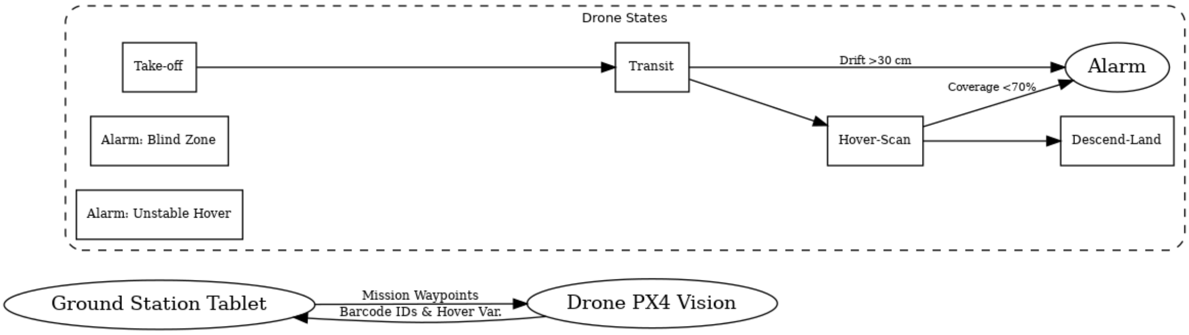
- < 70% of expected barcodes decoded at a scan point
- optical-flow drift exceeding 30 cm during hover
- CPU temperature exceeding 80 °C

These conditions will result in the system entering a local *Alarm* state and logging the anomaly.

Simulated disruptions may include temporary loss of lighting, GPS jamming (indoor use case), and intermittent Wi-Fi dropout. Recovery strategies will rely on local vision-based positioning and onboard data buffering.

Diagram

The diagram below illustrates the state machine managing the drone's scanning behavior and response to faults:



Key transitions:

- *Transit* → *Hover-Scan* for image acquisition
- *Hover-Scan* → *Alarm* if barcode coverage is insufficient or hover is unstable
- *Hover-Scan* → *Descend-Land* when scan is complete and stable
- Operator supervision remains active throughout via the tablet

Methods and Tools

The project will be developed using:

- **PX4 Autopilot firmware** with the kit's integrated vision-based positioning
- **Onboard NVIDIA Jetson (or Xavier/Nano)** for real-time image capture and processing
- **ZXing (Zebra Crossing)** for barcode decoding from captured frames
- **MAVSDK-Python** to script state transitions and telemetry monitoring
- **QGroundControl** for mission upload and status feedback
- **Gazebo** for simulation, using a model of an indoor rack environment

Optional tools include:

- thermal monitoring via on-chip sensors
- CSV export of barcode statistics and hover performance metrics
- plot-based comparison of nominal vs fault-induced behavior

Expected Outcome

The final system will be capable of:

- performing a stable, autonomous inventory scan mission over a rack
- capturing and decoding barcodes at each waypoint with a success rate ≥ 70%
- detecting and logging scan or flight anomalies such as drift or blind zones
- comparing run metrics between normal and disrupted conditions

Deliverables will include:

- a fully working mission FSM and onboard vision processing code
- barcode logs and hover-variance metrics
- a set of mission flight logs (normal vs disturbed)
- a concise technical report documenting outcomes and observations

Project Phases and Workload Distribution

First phase – Industrial IoT course (simulation and barcode pipeline):
The mission FSM will be designed and implemented using Gazebo and MAVSDK.
A barcode detection pipeline will be tested using static images or pre-recorded frames.
Simulated fault conditions (blind spots, drift injection) will be introduced to verify fault detection logic.
A prototype dashboard or data log visualizer will be developed.

Second phase – Internship (real flight tests and integration):
The FSM and barcode logic will be deployed on the real PX4 Vision kit.
Test flights will be conducted over a mock shelving rack with printed barcodes.
Scan performance and hover precision will be evaluated in real conditions, including in low-light or low-GPS indoor setups.
Alarms and flight logs will be collected for each session.

Third phase – Thesis (evaluation, optimization, analysis):
This phase will focus on system refinement and detailed analysis.
Detection thresholds will be optimized, and new metrics (e.g., scan duration per station, image blur analysis) may be added.
All results will be documented in a thesis, including diagrams, mission logs, and comparative evaluations between different test conditions.