Hive Monitor - Learning Module Concept Overview

1. Overview

This document outlines the learning module of the hive monitor system.

The learning system observes environmental, motion, light, weight, and acoustic data over time to dynamically establish baseline behaviors and thresholds. This allows the system to adapt to each hive's environment and avoid false alarms from static thresholds.

2. Core Features

- Learns normal temperature, humidity, pressure, and weight levels
- Tracks daily and seasonal patterns using hour/season index
- Monitors energy across 4 frequency bands for sound pattern classification
- Uses running statistics to avoid excessive memory usage
- Detects anomalies using z-scores and adaptive thresholds
- Stores and loads learned data from SD card

3. Data Structures

- SensorBaseline: Holds learned mean/std dev for each sensor type
- DailyPattern: Tracks hour-by-season offsets and activity levels
- RunningStats: Tracks mean and variance with low memory overhead

4. Learning Logic

- Learns from 100+ samples to establish initial baseline
- Periodically updates baseline adaptively to adjust for seasonal drift
- Calculates activity from acoustic and motion data
- Tracks 24-hour x 4-season daily pattern for fine-grained behavior modeling
- Applies z-score comparison to detect anomalies in real time

5. Persistence and Storage

- Binary file format for compact on-device saves

- Optional JSON export for human-readable summaries

- Parameters saved and loaded at startup from SD card

- Periodic saves occur every 50-100 samples or on threshold triggers

6. Anomaly Detection and Thresholds

- Temperature/humidity anomaly = deviation from time-of-day seasonal baseline

- Audio anomaly = energy shift in frequency bands beyond expected range

- Weight anomaly = short-term delta and long-term deviation checks

- Each anomaly type can be tuned using configuration or field-calibrated multipliers

7. Customization and Configurability

- All thresholds and adaptation rates can be overridden via config

- Daily pattern learning can be frozen, reset, or bootstrapped

- Configurable minimum sample count for baseline confidence

- Mode support: BASELINE_ONLY, ADAPTIVE, FROZEN (planned)