Autonomous Poultry Farm Management

Software Engineering for Autonomous Systems – Project Proposal

Team: Abu Saleh, Aruzhan Amangeldina, Tesfay W. Tesfay

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1) Introduction

The Autonomous Poultry Farm Manager is a self-adaptive system designed to maintain optimal environmental and welfare conditions inside a small-scale poultry house. The system continuously monitors temperature, humidity, air quality (ammonia), feed and water availability, and basic activity indicators of the flock.

Using the MAPE-K autonomic loop, the system analyzes the collected data, plans adjustments when necessary, and executes actions through ventilation, heating, lighting, and feed/water management actuators. All components communicate using an MQTT broker, allowing loosely coupled sensor and actuator nodes.

The goal of the system is to improve bird welfare and safety, reduce human workload, and avoid harmful conditions such as overheating, poor air quality, or empty feeders/waterers. The system also records historical data for long-term monitoring and performance evaluation. Future extensions may integrate Large Language Model (LLM) reasoning for advanced behavior interpretation, but this is not part of the current implementation proposal.

2) Managed Resources

The system handles the following resources inside the poultry house:

- Environmental Control: ventilation fans, heaters, humidity control, and lighting.
- Feeding System: automated feed dispenser and feed bin.
- Watering System: water level monitoring and automated refill valve.
- Flock Activity: indicators of bird movement or potential inactivity/clustering.

3) Sensors and Effectors

Sensors

- Temperature & Humidity Sensor: monitors thermal comfort and moisture levels.
- Ammonia (NH_3) Sensor: detects poor air quality conditions.
- Feed Level Sensor (load cell): measures feed bin weight to detect shortages.
- Water Level Sensor: monitors drinking water availability.
- PIR Motion Sensor: detects flock activity or potential inactivity.

Effectors

- Ventilation Fan Actuator: turns on/off or adjusts airflow to regulate temperature and ammonia.
- Heater Actuator: maintains minimum thermal comfort levels.
- LED Lighting System: provides appropriate light cycles for bird welfare.
- Feed Dispenser Motor: distributes new feed when levels are low.
- Water Refill Valve: ensures the drinker line remains filled.

4) Architectural Pattern for the Autonomic Manager

The system follows a single autonomic manager architecture, structured according to the MAPE-K loop:

1. **Monitor**
    - Collects sensor data from MQTT topics.
    - Tags each reading with timestamp and poultry house zone (if applicable).
    - Stores all data into the Knowledge component.

2. **Analyzer**
    - Interprets sensor values and evaluates conditions such as:
        - temperature outside comfort range,
        - ammonia concentration above threshold,
        - feed or water shortage,
        - unusually low activity.
    - Produces structured status messages for the Planner.
3. **Planner**
    - Receives analyzed data and selects suitable adaptation actions.
    - Ensures priority to safety-critical decisions (e.g., overheating).
    - Determines duration and parameters of planned actions (fan level, feed amount, etc.).
    - Updates the Knowledge component with the selected plan.
4. **Executor**
    - Converts the plan into MQTT commands for effectors.
    - Triggers ventilation, heating, feeding, watering, or lighting actions.
    - Logs execution results to Knowledge.
5. **Knowledge**
    - Stores historical environmental readings, actuator states, thresholds, and configuration.
    - Supports consistent reasoning among MAPE-K components.

5) Adaptation Goals of the Autonomic Manager

The system focuses on the following adaptation goals:

Environmental Safety

- Maintain temperature within species-appropriate comfort thresholds.
  Metric: TEMP_MIN ≤ temperature ≤ TEMP_MAX

- Activate fans or heaters as needed.

Air Quality Control

- Keep ammonia levels safe to avoid stress or respiratory issues.
  Metric: $NH_3 \leq$ NH3_THRESHOLD
- Increase ventilation when exceeded.

Feed & Water Availability

- Ensure feed and water remain above minimum levels.
  Metric: feed_level ≥ FEED_THRESHOLD, water_level ≥ WATER_THRESHOLD
- Trigger feed dispenser or refill valve when necessary.

Activity Monitoring (Possibly)

- Detect abnormal flock inactivity that may indicate stress, illness, or overheating.
  Metric: activity_level ≥ ACTIVITY_MIN
- Apply corrective actions such as adjusting ventilation or lighting.

Future Extension (Not in current scope)

A future enhancement may integrate LLM-based semantic analysis for behavior interpretation, using summarized sensor data. The LLM would support complex reasoning (correlating temperature spikes with activity drops), but all critical actions would remain rule-based.

Conclusion

The Autonomous Poultry Farm Manager provides a reliable, adaptable system for maintaining poultry welfare through continuous monitoring and automated environmental control. With its MQTT-based modular design and clear MAPE-K structure, the system is well-suited for implementation and future expansion, including the possible integration of higher-level reasoning capabilities.