Designing a Virtual Smart Home System for Adaptive Environment Management

Jasser Abdelfattah
UH ID: 21033101

March 19, 2025

Part 1: Defining the System Context

1. Problem Domain Analysis

- **Intelligent Components:** Machine learning-driven decision engine analyzing real-time sensor data (CO_2, temp, humidity)
- **Adaptive Mechanisms:** Priority-based actuator control with ventilation override capability
- **System Constraints:** 15-min response delay for ventilation, 2x daily heater limit

2. Stakeholder Requirements

- **Primary Users:**
  - Residents: Comfort optimization (20-22°C target)
  - Facility Managers: Energy consumption monitoring
- **Success Metrics:**
  - 85%+ satisfaction score maintenance
  - Heater usage $\leq$ 2 activations/day
  - Ventilation efficiency ($CO_2 < 250$ppm within 15min)

3. System Boundaries

- **Included:** Core environmental parameters, actuator priority rules
- **Excluded:** Non-essential subsystems (lighting/security)
- **Data Scope:** Limited to provided 6FTC2088.csv dataset parameters

Part 2: Conceptual Model Development

2.1 Modeling Technique Selection

- **UML Class Diagram:** Static structure representation
- **Activity Diagram:** Process flow visualization
- **State Chart:** Device behavior modeling

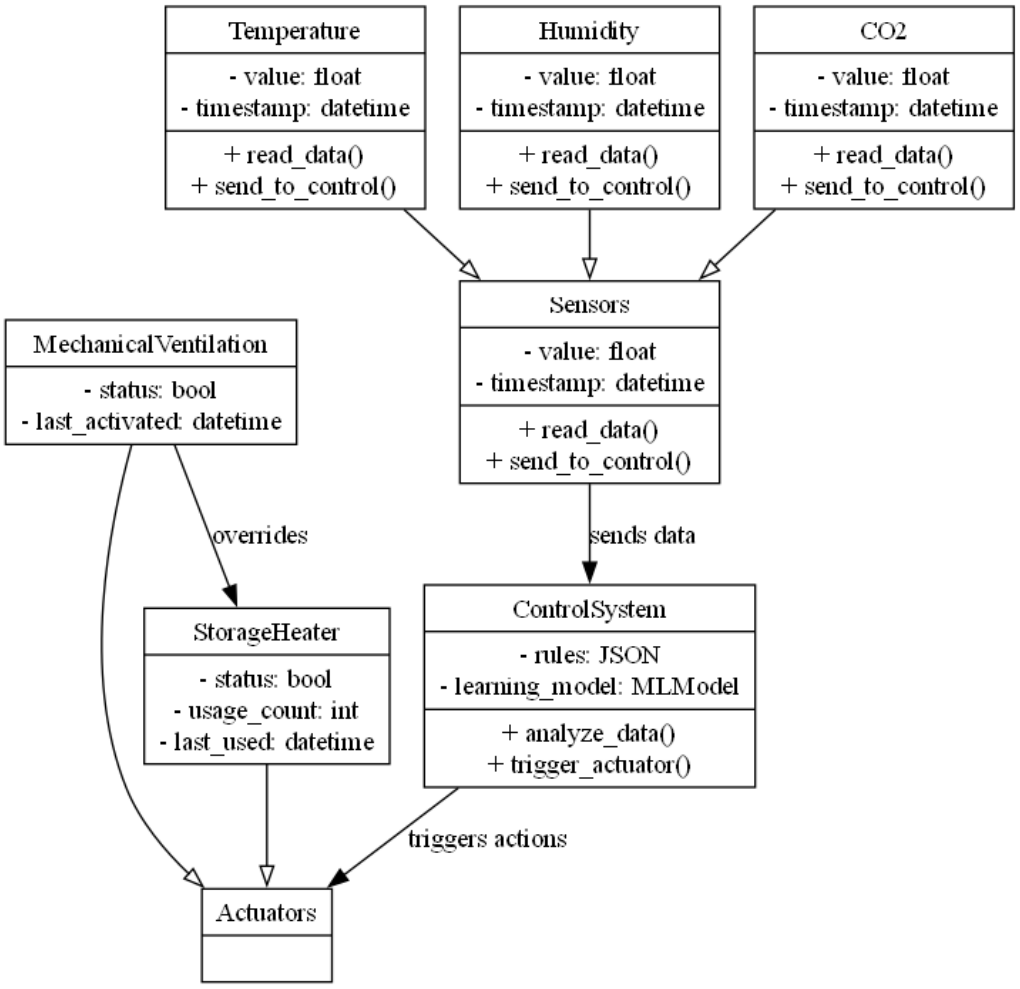

Figure 1: UML Class Diagram showing core system components and relationships. Key classes include `Sensor`, `Actuator`, and `Controller` with inheritance for specific device types.

2.2 System Component Specification

- **Entities:** Sensors (Temp/Humidity/CO2), Actuators (Vent/Heater)
- **Attributes:** Timestamps, measurement values, device status
- **Relationships:** Controller-mediated sensor-actuator communication

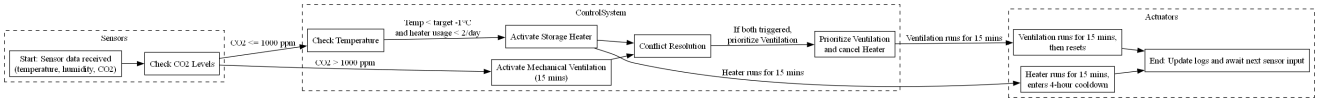

Figure 2: Activity diagram of the environmental control workflow. Diamond nodes represent decision points for ventilation/heater activation based on sensor thresholds.

2.3 Adaptive Control Mechanisms

- **Priority System:** Ventilation override protocol
- **Learning Component:** Usage pattern analysis for predictive control
- **Fallback States:** Default safe-mode configurations

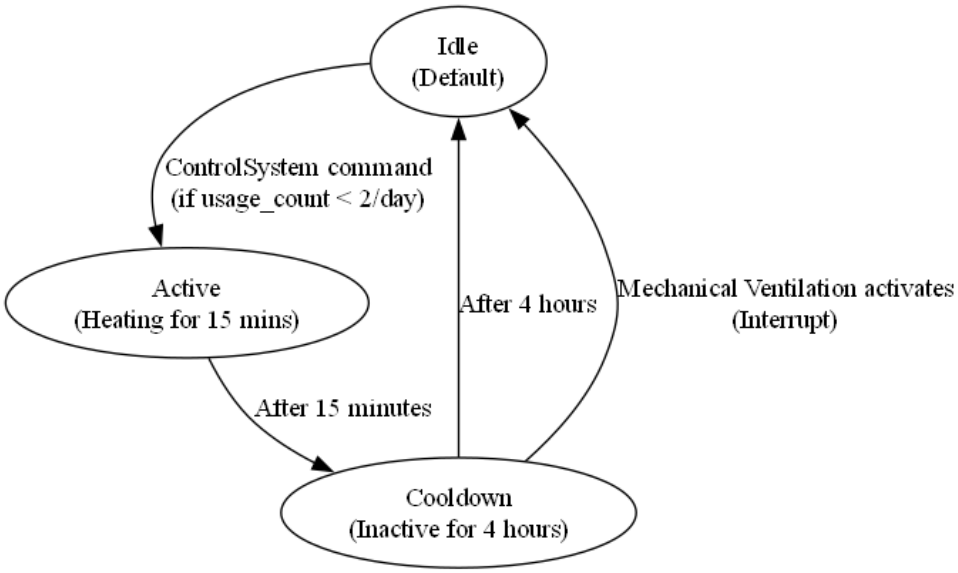

Figure 3: State chart diagram of heater control logic, showing daily usage limits and ventilation override conditions. Transition triggers include timeouts and priority interrupts.

2.4 Validation Strategy

- **Metrics:** Response time, satisfaction score, energy consumption
- **Testing:** Historical data replay (6FTC2088.csv)
- **Benchmarking:** Comparison against rule-based baseline

References

[Kaggle, 2022] Kaggle (2022) 'Smart home's temperature - time series forecasting'. Available at: `https://www.kaggle.com/competitions/smart-homes-temperature-time-series-forecasting/overview` (Accessed: 19 March 2025).

[Selvin et al., 2020] Selvin, S., Vinayakumar, R., Gopalakrishnan, E. A., Menon, V. K. and Soman, K. P. (2020) 'Deep learning-based stock price prediction using LSTM and bi-directional LSTM model', *IEEE Xplore*. Available at: https://ieeexplore.ieee.org/abstract/document/9257950/ (Accessed: 19 March 2025).

[Grand, 2002] Grand, M. (2002) 'Design patterns application in UML', in *Advanced Object-Oriented Design Using UML*. Springer, pp. 35–56. DOI: https://doi.org/10.1007/3-540-45102-1_3.

[Alhafidh, 2016] Alhafidh, B. (2016) 'Design and simulation of a smart home managed by an intelligent self-adaptive system', *ResearchGate*. Available at: https://www.researchgate.net/publication/311374442_Design_and_Simulation_of_a_Smart_Home_managed_by_an_Intelligent_Self-Adaptive_System (Accessed: 19 March 2025).

[Esko K. Juuso, 2003] Esko K. Juuso. (2003) 'Integration of intelligent systems in development of smart adaptive systems'. *ScienceDirect*. Available at: https://www.sciencedirect.com/science/article/pii/S0888613X03001075 (Accessed: 19 March 2025).

[Henry Muccini and Karthik Vaidhyanathan, 2019] Henry Muccini and Karthik Vaidhyanathan (2019) 'A machine learning-driven approach for proactive decision making in adaptive architectures'. *IEEE Xplore*. Available at: https://ieeexplore.ieee.org/abstract/document/8712155/ (Accessed: 19 March 2025).