Sustainable Automated Food Production System

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[Date]

1 Problem Statement

Design an automated food production system that ensures optimal crop growth conditions while minimizing resource waste and energy consumption. The system must:

- Regulate nutrient concentration (N) in a hydroponic solution.
- Control greenhouse temperature (T) for optimal plant growth.
- Maintain water level (L) to ensure continuous nutrient delivery.

1.1 Key Features

- **Coupling Effects:**
  - Temperature influences nutrient uptake efficiency.
  - Water level affects nutrient concentration stability.
- **Actuators:**
  - PID-controlled heating/cooling for T.
  - Relay-controlled nutrient injection for N regulation.
  - PID-controlled water inflow to maintain L.

2 Tasks

2.1 1. Modeling

Develop a set of up to three nonlinear ordinary differential equations (ODEs) describing the system dynamics. These should be derived considering:

- The heat balance governing temperature changes due to heating, cooling, and external conditions.

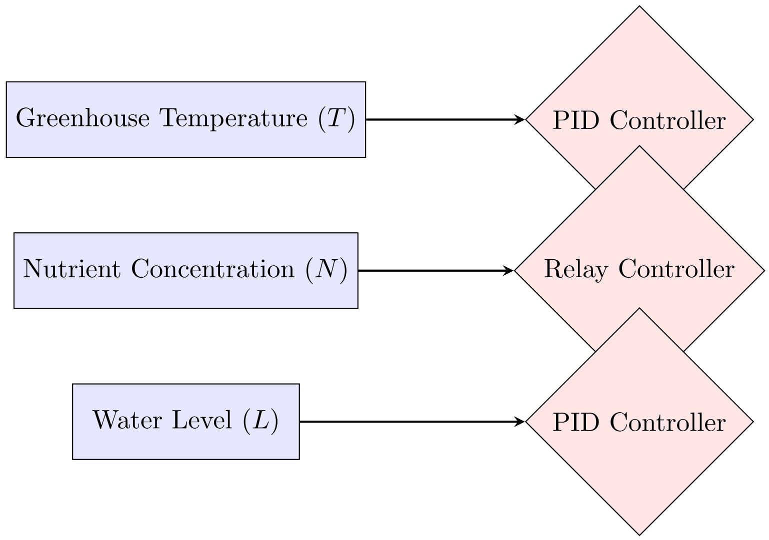

Figure 1: Schema summarizing the problem, showing interactions between system variables and controllers.

- The nutrient dynamics affected by injection, plant uptake, and dilution effects.
- The water balance maintaining a steady water level despite consumption and evaporation.

2.2 2. Discretization

Discretize the system equations using the Euler method and validate against numerical integration.

2.3 3. Control Design

- PID for Temperature: Maintain $T = 22°C \pm 2°C$.
- Relay for Nutrient Injection: Activate if N drops below the optimal level.
- PID for Water Level: Regulate inflow to ensure continuous nutrient delivery.

2.4 4. Sustainability Analysis

Compare:

- Water efficiency: $\frac{\text{Water Used}}{\text{Crop Yield}}$.
- Energy efficiency: $\frac{\text{Heating/Cooling Energy}}{\text{Growth Output}}$.

- Nutrient efficiency: $\frac{\text{Nutrient Added}}{\text{Plant Absorption}}$.

3 Deliverables

Submit:

- A PDF report including:
  - Model derivation steps.
  - Controller tuning results.
  - Time-domain plots for $T(t)$, $N(t)$, and $L(t)$.
- MATLAB files:
  - `init.m`: System parameters (e.g., heat transfer coefficients, uptake rates).
  - Simulink model implementing continuous/discrete control.

4 Guidelines

- Maintain system coupling in equations.
- Use empirical data where applicable.
- Ensure stability in control design.