Sustainable Greenhouse with Tomato Growth Dynamics

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[Date]

Problem Statement

Design an automated greenhouse system to optimize tomato cultivation while minimizing resource use. The system must:

- Regulate temperature (T), humidity (H), and soil moisture (W) for optimal growth.
- Maintain CO_2 levels (C) to enhance photosynthesis.
- Model tomato biomass (B) as a function of environmental conditions.

Key Features

- Linear Coupled Dynamics:
  - Environmental variables (T, H, W, C) evolve linearly with control inputs and disturbances.
  - Tomato growth rate depends proportionally on T, H, C, and light exposure.
- Sustainability Focus:
  - Rainwater recycling reduces freshwater consumption.
  - Energy-efficient HVAC and lighting systems.
- Actuators:
  - PID-controlled heaters, humidifiers, and CO_2 injectors.
  - Relay-controlled irrigation and ventilation.

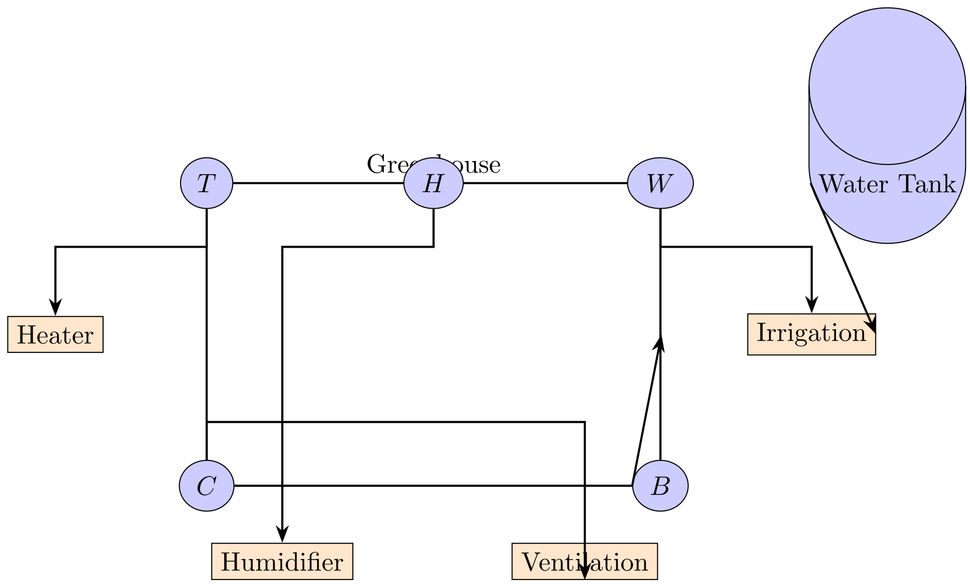

Figure 1: Greenhouse system with sensors (T, H, W, C, B) and actuators. Rainwater tank supports sustainable irrigation.

Tasks

1. Modeling

Derive five interconnected linear ODEs by:

- **Temperature (T)**: Balance heating input, convective/conductive losses, and solar gain (linear in T).
- **Humidity (H)**: Model irrigation and transpiration effects (linear in H and W).
- **Soil Moisture (W)**: Relate irrigation rate, drainage, and plant uptake (linear in W).
- **CO_2 (C)**: Include injection, plant uptake, and air exchange (linear in C).
- **Biomass (B)**: Assume growth proportional to T, H, C, and light (linear in B).

2. Discretization

- Convert to discrete-time using Forward Euler with $\Delta t = 1$ hour.
- Validate consistency with continuous simulations.

3. Control Design

- PID for T, H, C: Track setpoints for optimal growth.
- Relay for Irrigation/Ventilation: Activate based on W and C thresholds.
- Energy Optimization: Prioritize renewable energy sources.

4. Sustainability Analysis

Evaluate:

- Water savings: $\frac{\text{Recycled Water}}{\text{Total Irrigation}}$.
- Energy efficiency: $\frac{\text{Biomass Yield (kg)}}{\text{Energy Used (kWh)}}$.

Deliverables

Submit:

- A PDF report with:
  - Model derivation methodology (emphasize linear relationships).
  - Controller tuning and stability analysis.
  - Sustainability metrics under varying conditions.
- MATLAB/Simulink files:
  - `init.m`: Parameters (heat transfer coefficients, growth rates).
  - Simulink model with PID/relay logic.

Guidelines

- Ensure all equations are strictly linear (no T^2, $H \cdot C$, etc.).
- Validate parameters using agricultural data (e.g., tomato growth rates).
- Explicitly couple variables: e.g., W affects H, H affects B.