EE249 Lab 1: Data Center Temperature Control

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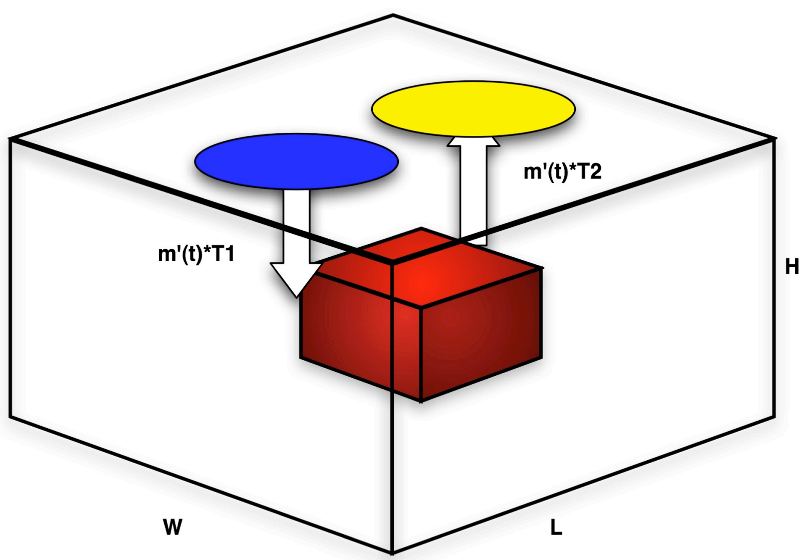
Congratulations! You have been hired to design the temperature control system for a server room at a datacenter for Google™. A temperature sensor, inflow air-cooling vent, and an outflow vent are installed in the room. In order to derive a model of the evolution of the temperature in time, it's important to understand how the heat is exchanged. The inflow vent can be on or off. When it is on, it injects an air-flow of m_1 g/sec at temperature $T1$. Air is ejected from the room through the outflow vent at a rate m_2 g/sec at temperature T_2.*(Here, $T_2=T_{room}$)* In addition, the four walls of the room must also be considered as a conducting surface for the temperature flow. The floor and ceiling surfaces may be considered as insulated surfaces, and do not contribute to temperature gain/loss.



To simplify the problem, lets assume each server rack emits heat at a constant rate of q Watt (J/sec).

Then, by balancing the cooling air that is injected, the heat that is added/lost, and the temperature increment of the room we obtain on a time interval Δt:

$$\left\{ m_1 \cdot C_{p_a} \cdot T_1 - m_2 \cdot C_{p_a} \cdot T_2 + N * q + \sum_{i=1}^{4} \alpha_i (T_i - T_{room}) \right\} \cdot \Delta t = \rho \cdot V \cdot C_{p_a} \cdot \Delta T_{\text{room}}$$

where C_{pa} is the specific heat of the air, V is the volume of the room, A_i is the area of wall i, T_i is the temperature of wall i, N is the number of server racks, and ρ is the air density. α is defined as:

$$\alpha_{in} = \frac{1}{\frac{R_{wall}}{2} + R_{in}} \qquad \alpha_{out} = \frac{1}{\frac{R_{wall}}{2} + R_{out}}$$

$$R_{wall} = \frac{l_{wall}}{h_{wall} \cdot A_{wall}},\ R_{in} = \frac{1}{h_{in} \cdot A_{wall}},\ R_{out} = \frac{1}{h_{out} \cdot A_{wall}}$$

where l_{wall} is the thickness of the wall, A is the area of the wall, and h are the conduction coefficient.

The temperatures for each of the walls are given by another balance equation:

$$\left\{\alpha_{in} \cdot \left(T_{room} - T_i\right) + \alpha_{out} \cdot \left(T_{out} - T_i\right)\right\} \cdot \Delta t = \rho_{wall} \cdot V_{wall} \cdot C_{p\,wall} \cdot \Delta T_i$$

Of course, we should never forget the initial condition T_0, which is the temperature of the room at some point in time.

Parameters:

C_{pa}	1 J/(g·K)
T_1 of inflow vent	15˚C (288K)
q	1kW (~3500 BTU/hr)
C_{pwall}(Brick)	0.84 J/(g·K)
$m_1 = m2$	300 g/sec
ρ	1184 g/m^3
h_{wall}	0.69 W/(m·K)
ρ_{wall}	2,000,000 (g/m^3)
l_{wall}	0.25m
h_{in}	0.025 W/(m·K)
h_{out}	0.025 W/(m·K)
T_0	30˚C
L	10 m
W	10 m
H	3 m
T_{out}	300K
N	1

Tasks:

1. Construct a functional model of the plant (ie. Server room) in Ptolemy II.

2. Design a simple bang-bang controller such that room temperature is kept within the range 20–25 °C.