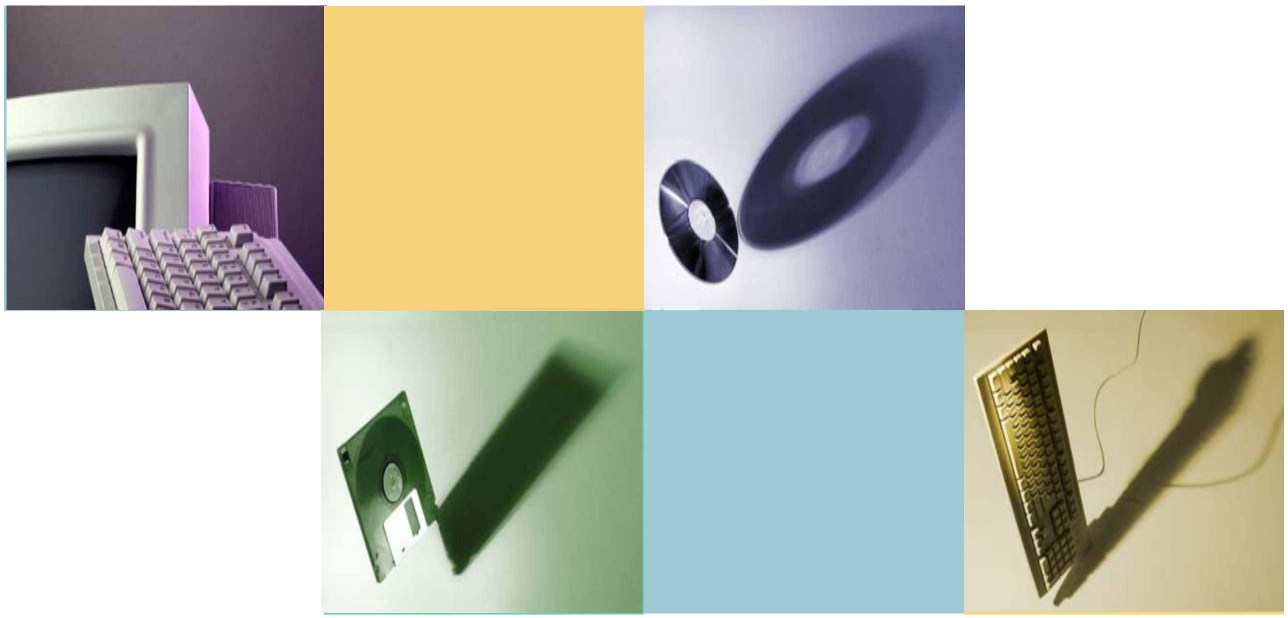
Room cooling control optimization

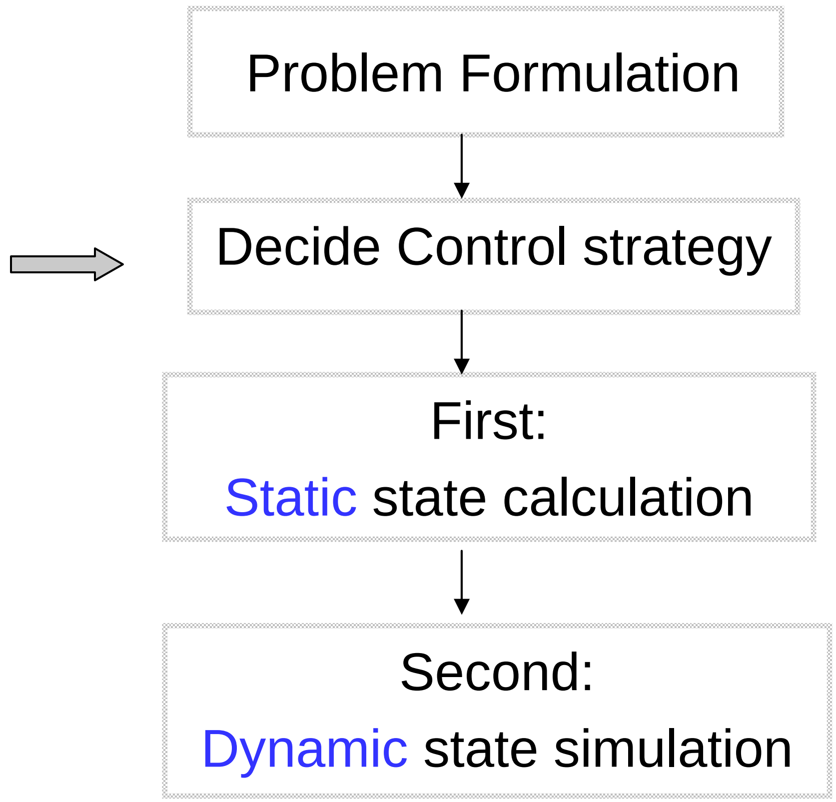


May 17 2005

So Young Koo
Project Management
Department of Civil Engineering

Overview

- Apply the optimization method to control the building thermal environment
- Want to maintaining thermal comfort and minimizing the energy cost



Functions & Parameters

- Thermal comfort index
  - PMV
  - 'predicted mean vote' on the thermal sensation scale
    - PMV = (-8.6479 + 0.2431*C) + (0.3422-0.0073*C)*T
    - C: Relative humidity
    - T: Air temperature
  - PPD
  - the predicted percentage of dissatisfied people
    - PPD = 100 – 95*exp[-{0.03353*PMV^4 + 0.2179*PMV^2}]

Functions & Parameters

- Heat balance equation

a* C air * V room*(T p+1- T p)/ Δt = Σ h*Ai*(Tp - Tsi) + Q1 + Q2

a: Air density of room [kg/㎥]
C air: Specific heat of the air [J/kg℃]
V room : Volume of room (㎥)
T p+1: The room air temperature (℃)
T p : The room air temperature before Δt second (℃)
Ts : The surface temperature of room (℃)
Δt: Time step(sec)
hi: heat transfer coefficient of wall i (Kcal/㎡h℃)
Q1: cooling load by infiltration (W)
Q2: generated heat in room (W)
Ai: area of wall i (㎡)
hi = 2.63**(Tsi - Ti p)^(1/4)

Problem Formulation

 # Objective function: Multi objective nonlinear

- ✓ Min f1 + f2
- ✓ f1 = Vi *(**Ti p+1** - Ti p) / Δt
- ✓ f2 = 100 – 95*exp[-{0.03353*PMVi^4 + 0.2179*PMVi^2}]
- ✓ PMV = (-8.6479 + 0.2431***Ci**) + (0.3422-0.0073***Ci**)* **Ti p+1**
- ✓ **Consider Ti p+1 unique control variable for dynamic simulation**

 # Problem variables

Ti p+1: The optimal air temperature of room i (℃)

Ti p : The air temperature of room i before Δt second (℃)

Δt : Time step(sec)

Ci : The relative humidity of room i (%)

Tsi : The floor surface temperature of room i (℃)

Ai : The floor area of room i (㎡)

Vi : The volume of room i (㎥)

Problem Formulation

- Constraints
  - Minimum cooling load should be satisfied
  - F1 >= 2.63*(Tsi - Ti p)* Ai *(Ti p - Tsi)/(V*10/ Δt)

    ↓
  - **Linear constraint**
  - Maximum thermal discomfort should be 10%
  - F2<=10%

    ↓
  - **Nonlinear constraint**

Control Strategy

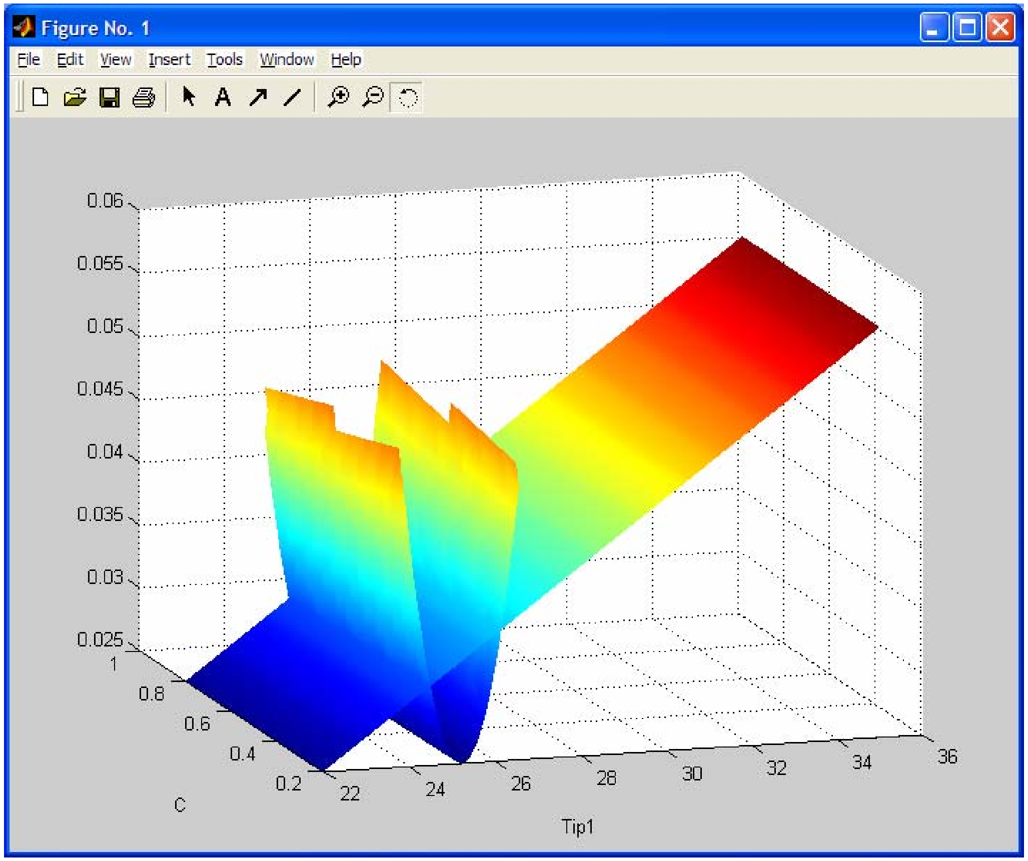
If Ti p+1 < Ti p then ON the cooling for ith room

If Ti p+1 > Ti p then OFF the cooling for ith room

```
For i = 1 To N
      IsItOn(i) = WasItOn(i)
      If (Ti p > (Ti p+1 - Range)) Then
          IsItOn(i) = True
      ElseIf (Ti p < (Ti p+1 + Range)) Then
          IsItOn(i) = False
      End If
Next i
```

Static State Calculation

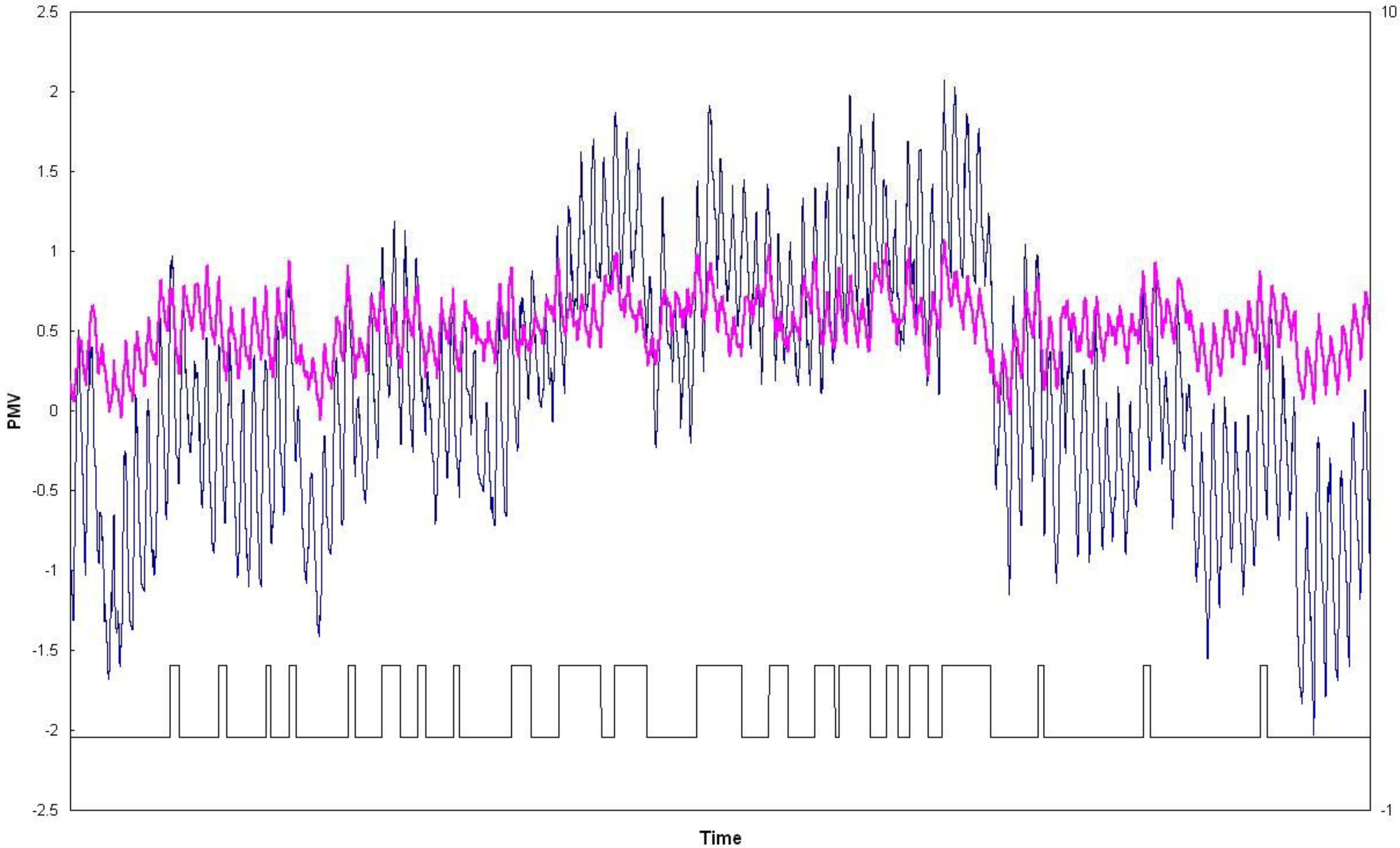
- Ignore Δt(timestep)
- Variable: humidity, temperature



Dynamic State Simulation

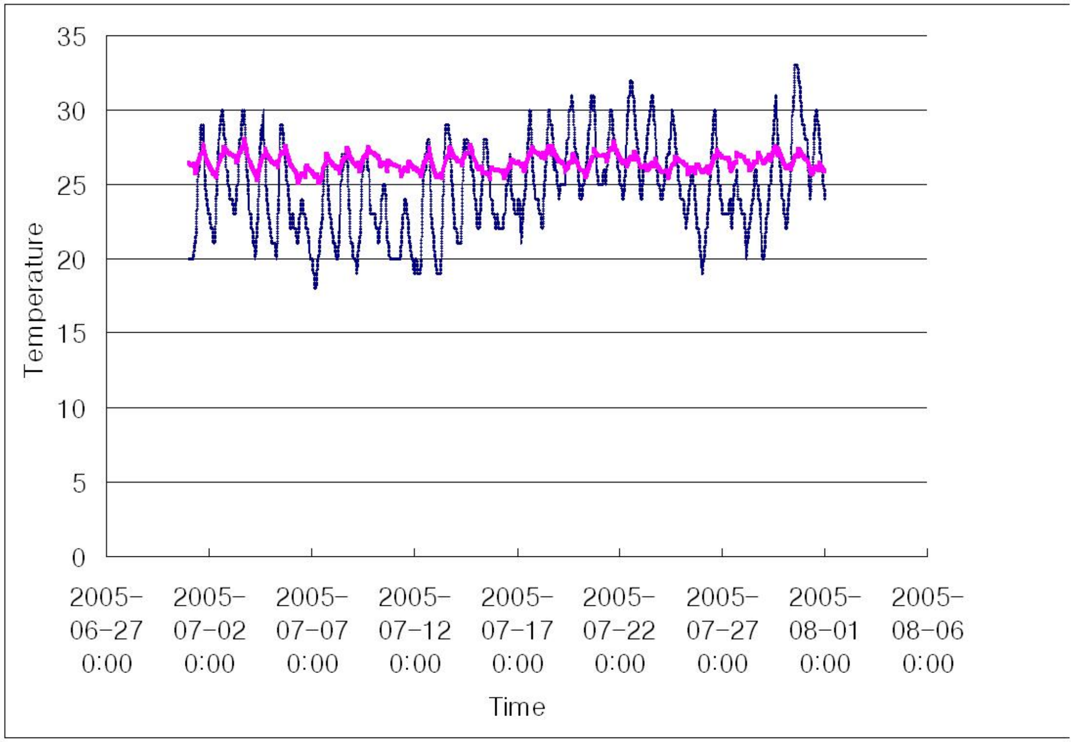
- Link Matlab to VB program for simulation and use function fmincon() for optimization
- Input Data: Weather data, Room modeling
- June~September

Result



Result

- PMV is within the comfort range
- Room thermal environment is well controlled by optimization method



Future Work

- Apply the whole building with multiple rooms
- Examine the effect of the number of sensors to control the building thermal environment
- Consider weighting sum approach
- Compare to other control method

Thank you !