A Strategy for Designing a Numerically Reliable Switching Algorithm for Cooling Coil Application

Donghun Kim

08/20/2019

Review of Previous Switching Algorithm

Unknown

1. If the coil surface temperature at the air inlet section is lower than the dew-point temperature at inlet to the coil, then the cooling coil surface is "all wet" (the right part of the coil).

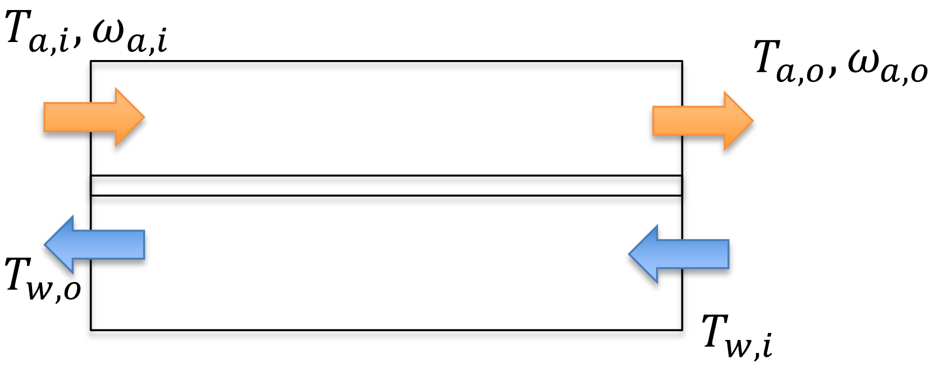
2. If the surface temperature at the air outlet section is higher than the dew-point temperature of air at inlet, then the cooling coil surface is "all dry," (the left part of the coil as shown in Fig. 1).

3. If any of the conditions in 1 or 2 is not satisfied, then the cooling coil is "partially wet-partially dry."

R1: If $T_{w,o} < T_{dp,i}$, then $y = F_{FW}(x)$

R2: If $T_{w,i} > T_{dp,o}$, then $y = F_{FD}(x)$

R3: Otherwise , then $y = F_{PW}(x)$



Counter flow HX

where,

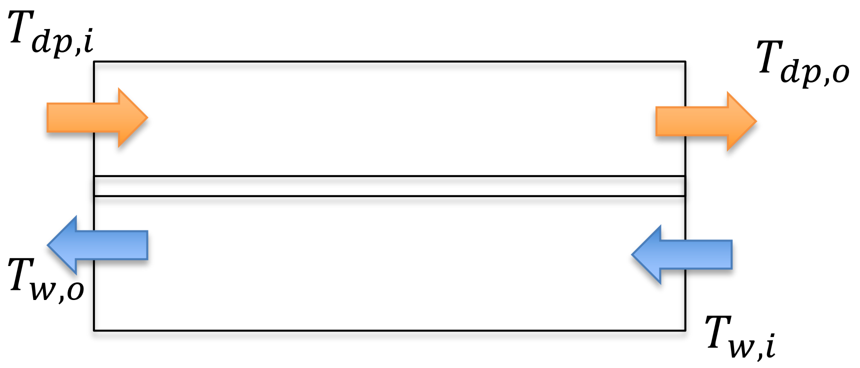
$x = [T_{w,i}, T_{a,i}, \omega_{a,i}, \dot{m}_a, \dot{m}_w]$

$y = [T_{a,o}, \omega_{a,o}, T_{w,o}]$

(Assume coil surf temp ≈ water temp at a point, EnergyPlus)

* E lma h d y , A . H . ; M i t a l a s , G . P ., 1977, A simple model for cooling and dehumidifying coils for use in calculating energy requirements for buildings", ASHRAE Transactions, 83, (2)

Review of Previous Switching Algorithm, Conti.



Counter flow HX

1. Assume the fully wet condition and calculate $T_{w,o}$ & $T_{dp,o}$. That is, get estimations using $\hat{y} = F_{FW}(x)$.
2. Then, find an appropriate rule using the estimation.

Note the criteria of each rule has a following form.

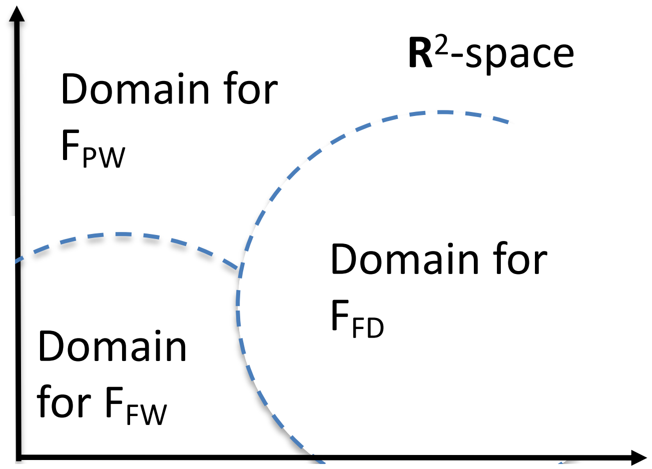
$g_i(x, \hat{y}) < 0$ or $f_i(x) < 0$, where $f_i(x) \coloneqq g_i\big(x, F_{FW}(x)\big)$

e.g. R2: $T_{w,i} > T_{dp,o} \Rightarrow T_{dp,o}\big(T_{w,i}, T_{a,i}, \omega_{a,i}, \dot{m}_a, \dot{m}_w\big) - T_{w,i} < 0$

$\in x$ $\in \hat{y}$

➔ This forms a complex switching surface in x on which the cooling coil model is likely discontinuous.

Approach to Handle Complex Mode Switching



Conceptual example of switching surfaces

Objective: develop a cooling coil model in the form of $y = F(x)$,

s.t.

1) F is mode-independent
2) F is at least continuously differentiable.

A key method: T-S (Takagi-Sugeno) Fuzzy modeling

Application of T-S Fuzzy Modeling Approach to Cooling Coil Modeling

Final model structure (according to the TS fuzzy modeling)

$$y = \omega_1(x)F_{FW}(x) + \omega_2(x)F_{FD}(x) + \omega_3(x)F_{PW}(x)$$

Membership function for "Low coil temp at the air inlet"

$$\mu_1(x) := \mu_{i,L}(x)$$

Membership function for "High coil temp at the air outlet"

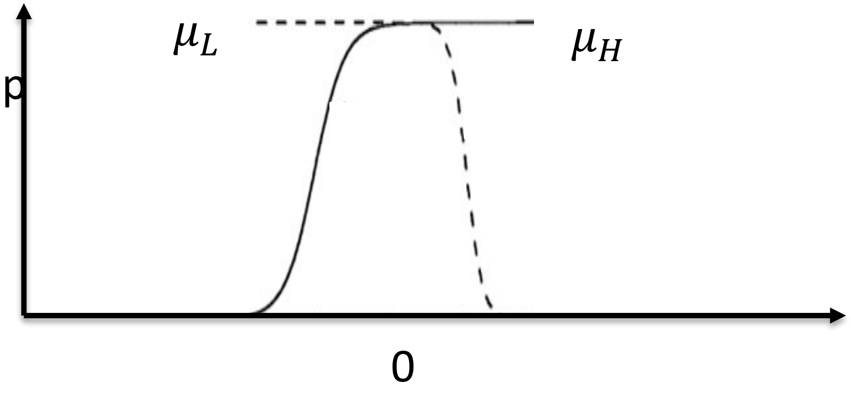
$$\mu_2(x) := \mu_{o,H}(x)$$

$$\mu_3(x) := \mu_{i,H}(x) \times \mu_{o,L}(x)$$

$$\omega_j(x) := \frac{\mu_j(x)}{\sum \mu_j(x)}$$

Obtained from applying the fuzzy-inference to Rule 3

Sigmoid-Membership functions (example)



- ❖ The fuzzy variables of coil temperatures at the air outlet and inlet are defined as $T_{w,o} - T_{dp,i}$ and $T_{w,i} - T_{dp,o}$, respectively.
- ❖ $x = [T_{w,i}, T_{a,i}, \omega_{a,i}, \dot{m}_a, \dot{m}_w]$, $y = [T_{a,o}, \omega_{a,o}, T_{w,o}]$

- Note if $F_i(.)$ and $\mu_i(.)$ are continuous, so is the fuzzy model. If they are k^{th} order differentiable, so is the fuzzy model.
- Note also the fuzzy-modeling approach systematically generates a smoother function on the complex switching surfaces.

Future Work

- Investigate function properties of F_{FW}, F_{FD}, F_{PW} $(\in C^1?)$

- Case study that demonstrates improved numerical performance compared to the conventional IF-THEN based cooling coil model