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A Fuzzy Logic Controller for Temperature Control of Air Handling Plant

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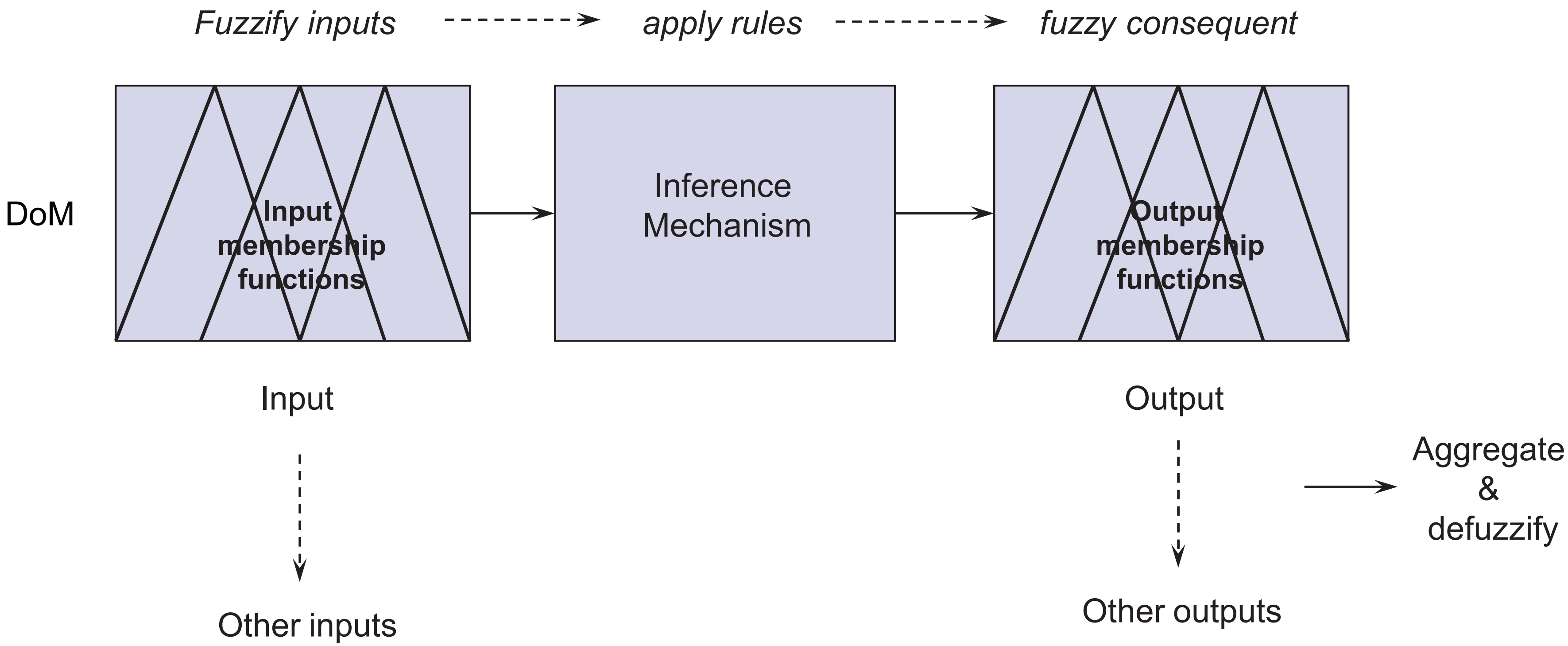
Summary of This Work

- In this work the development of a three-channel fuzzy temperature controller for air handling plant is considered
- Sugeno inference mechanisms are used and their advantages for control type problems are highlighted
- The fuzzy controller is benchmarked against conventionally-tuned PID control
- It is demonstrated that the fuzzy controller is easier to set up than the PID controller whilst offering superior control tracking performance
- The work has made use of Matlab/Simulink as well as the Matlab Fuzzy Logic Toolbox

Background: Fuzzy Inference



Background: Fuzzy Inference Methods

- **Mamdani** inference (the most common method) outputs to fuzzy sets
- Examples (*T* = temperature)*….*

If (*T* is high) ***Then*** (Valve is low)

If (*T* is high) ***And*** (d*T*/d*t* is negative) ***Then*** (Valve is medium)

<u>Combinatorial rule setting examples:</u>

AND = *min* or *product*
OR = *max* or *probabilistic*

- **Sugeno** (or Takagi-Sugeno) inference outputs to numerical values
- Examples (*u* = valve signal)…

If (*T* is high) ***Then*** *u* = 0

If (*T* is low) ***Then*** *u* = 1

If (*T* is high) ***And*** (d*T*/d*t* is negative) ***Then*** *u* = 0.5*input

i.e. Sugeno inference can output to some mathematical function of the fuzzy input(s)

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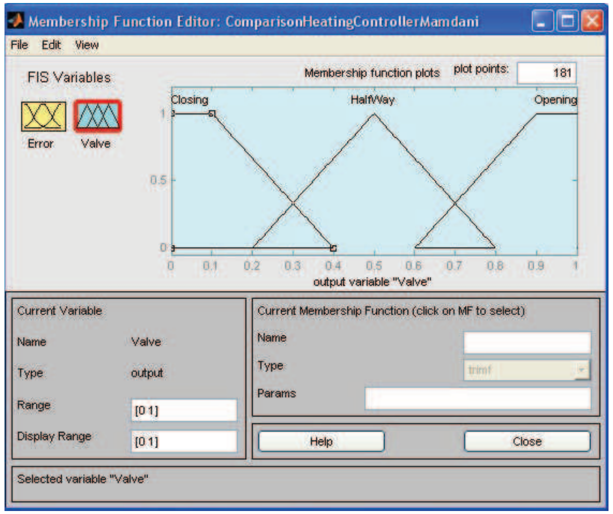
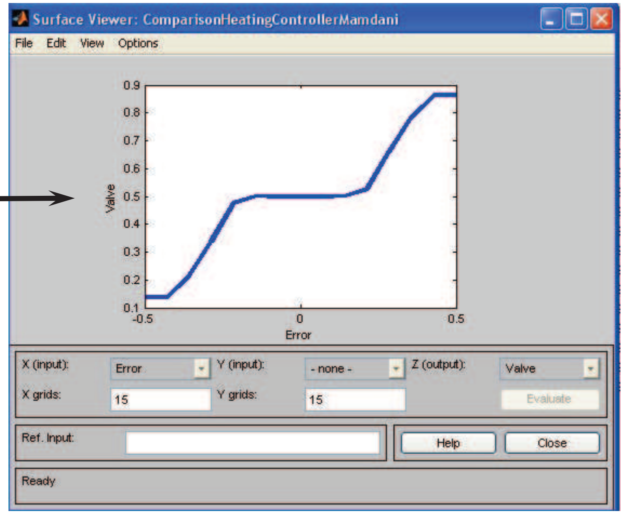
Simple Comparison of Inference Methods: Heating Coil Control



Resulting in sub-saturated valve positioning



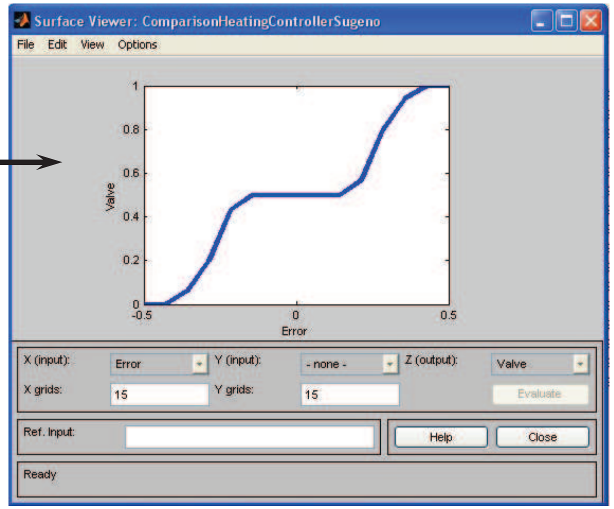
Can alleviate by working on the MFs or use Sugeno inference

Sugeno case:

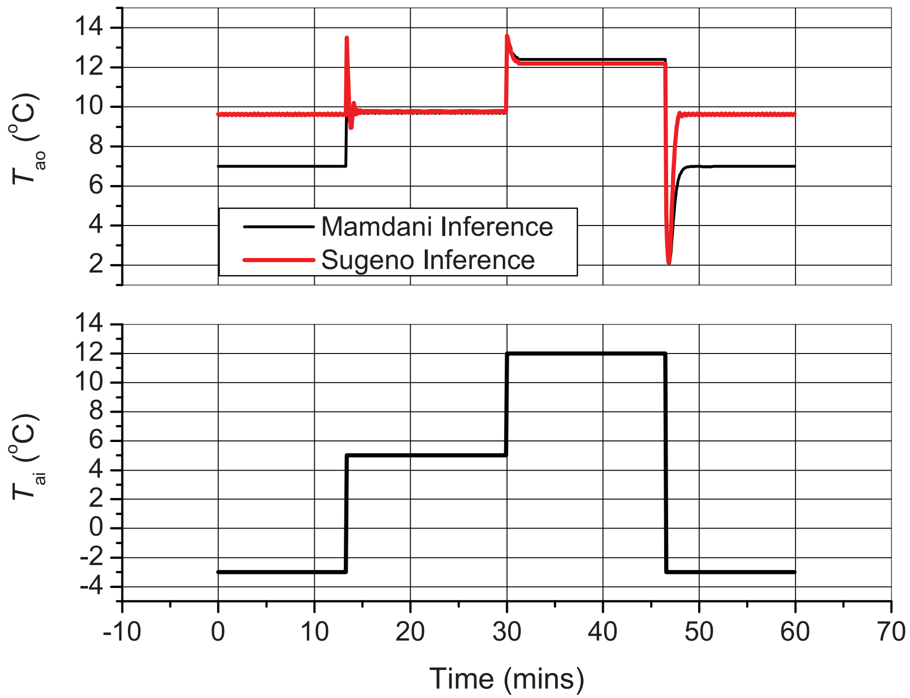
If (*T* is low) Then: Valve = 1

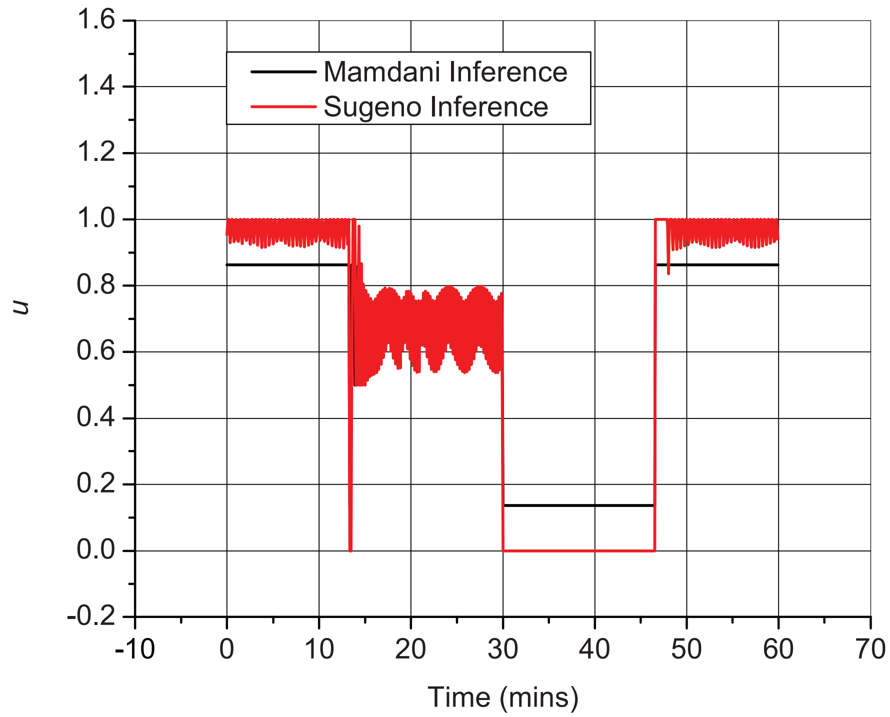
If (*T* is OK) Then: Valve = Constant*Input

If (*T* is high) Then: Valve = 0



Results: Alternative Inference Methods (Simple Heating Coil Test Case)

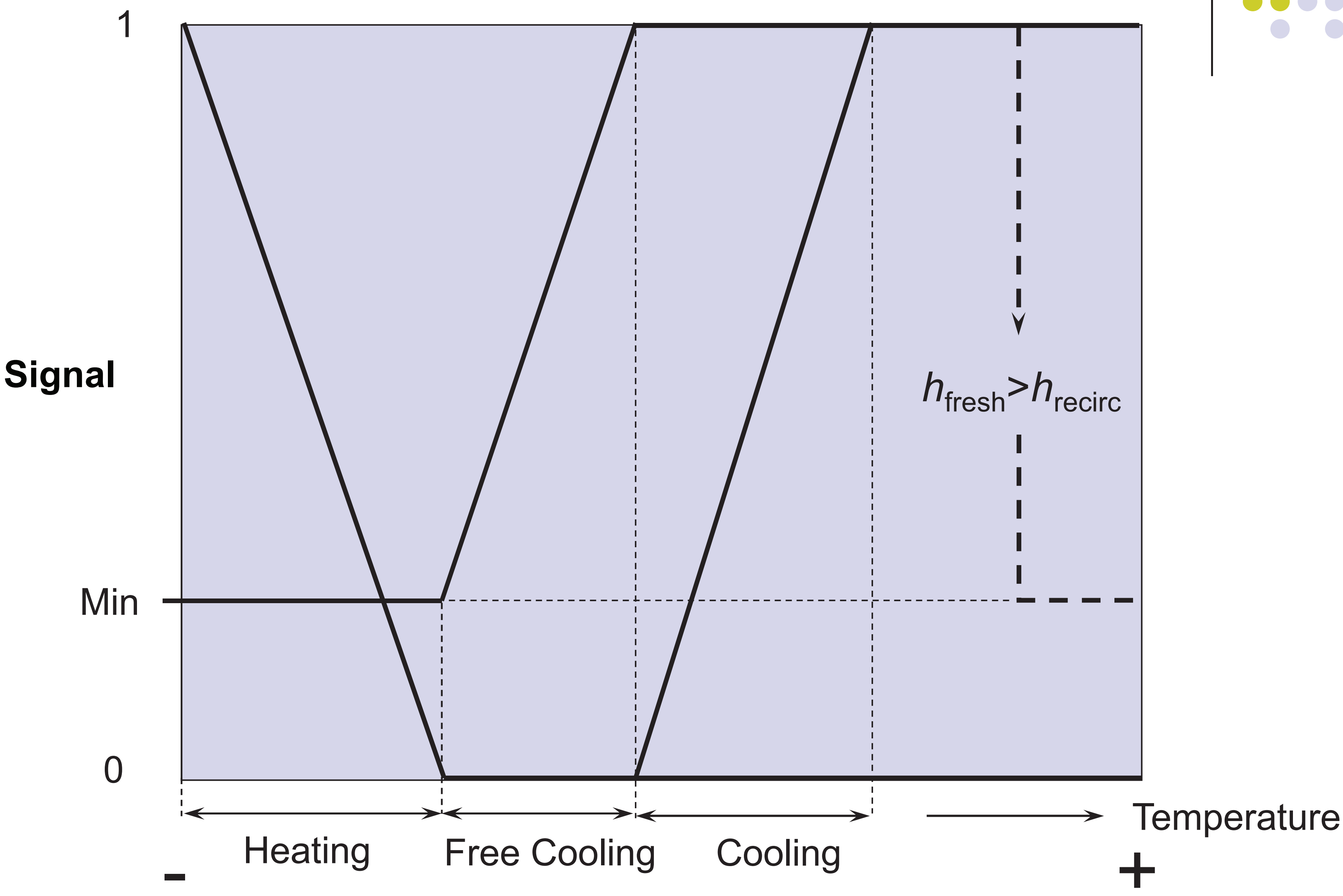




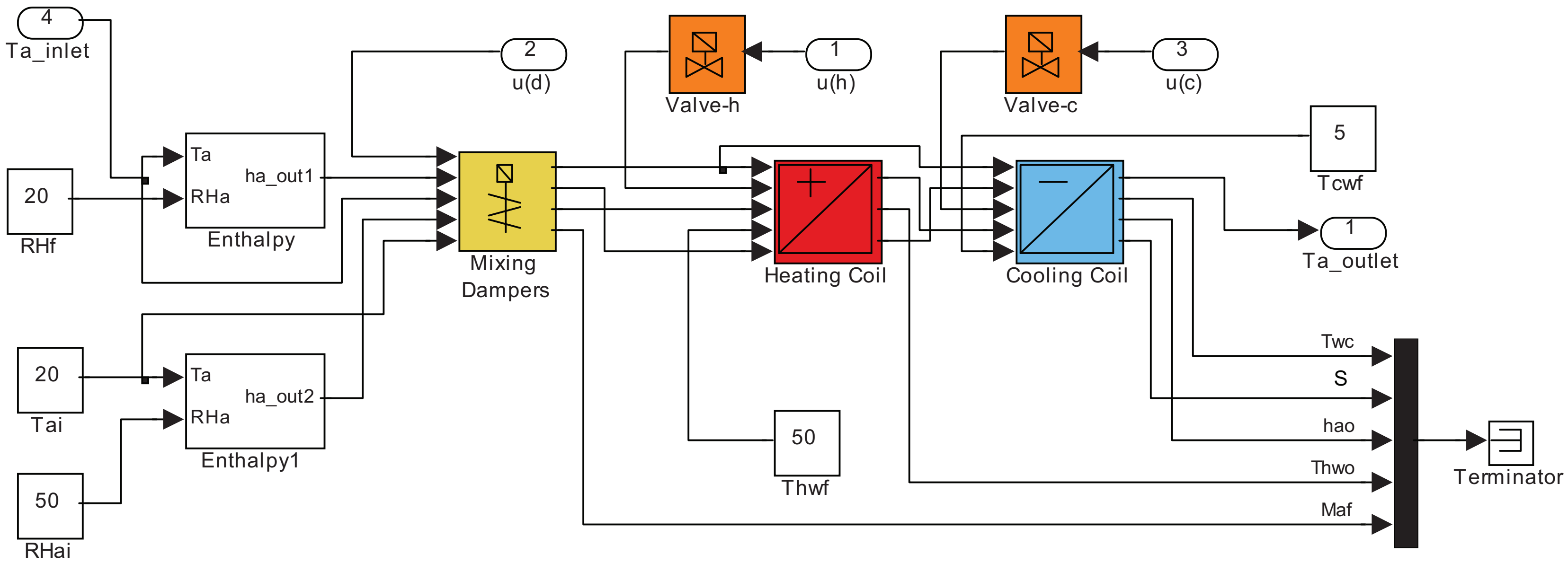
Outlet temperature set point: 10°C

T_{ao} = air outlet temperature T_{ai} = air inlet temperature

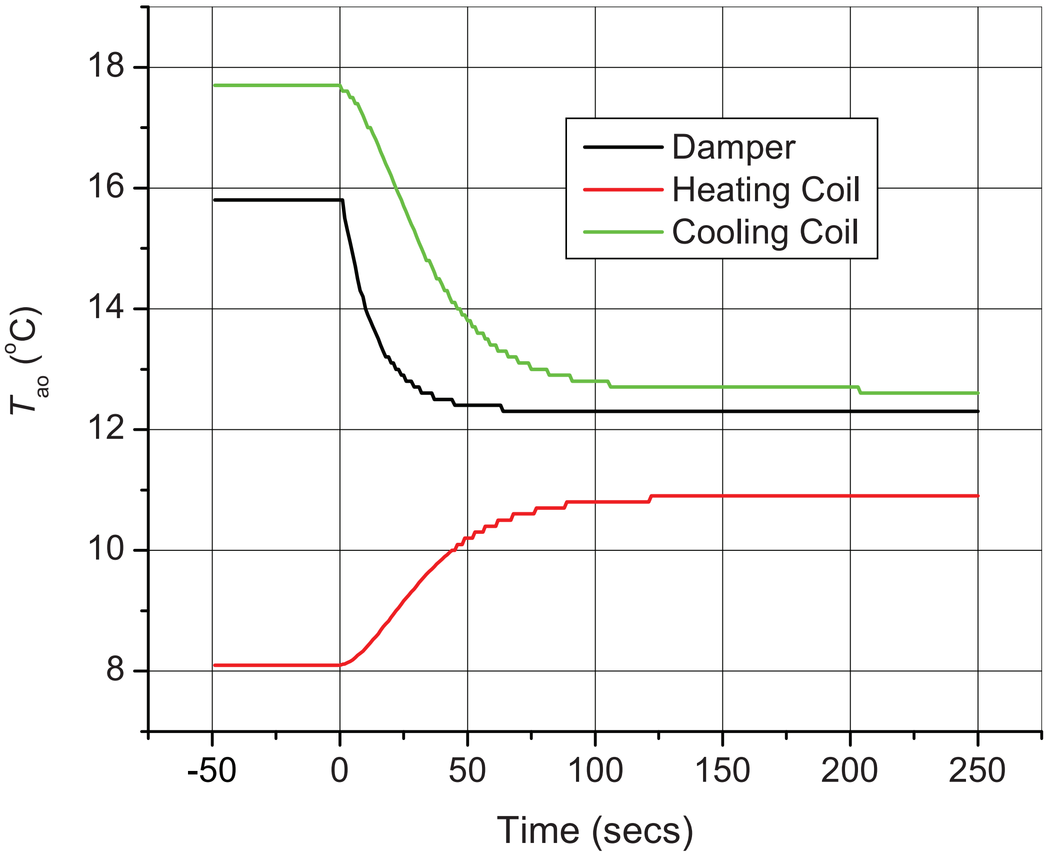
The Problem: Sequencing Temperature Control of AHP



Vehicle – Simulink Air Handler Model



PID Control: Ziegler-Nichols Tuning Parameters Fitted to Open Loop Step Response "Tests"



PID tuning parameters:

Loop	K_c	K_i
Damper	-2.620	-3.490
Heating Coil	0.188	0.006
Cooling Coil	-0.108	-0.004

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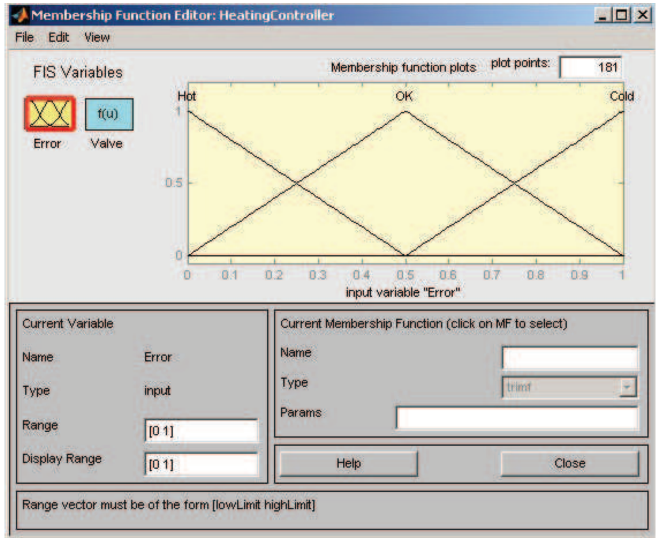
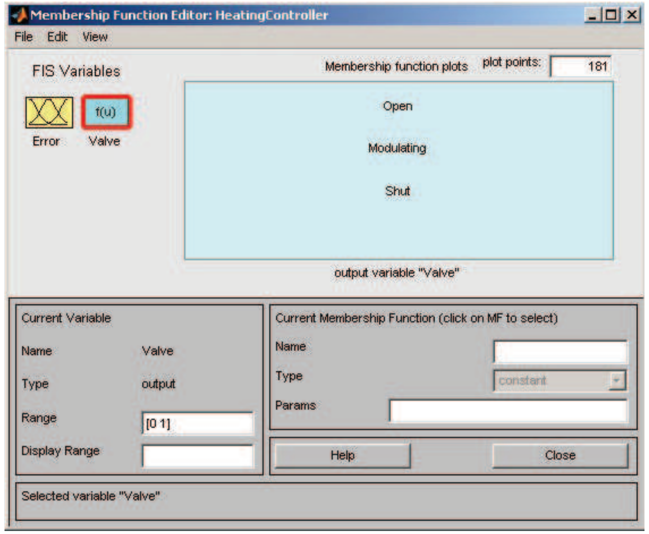
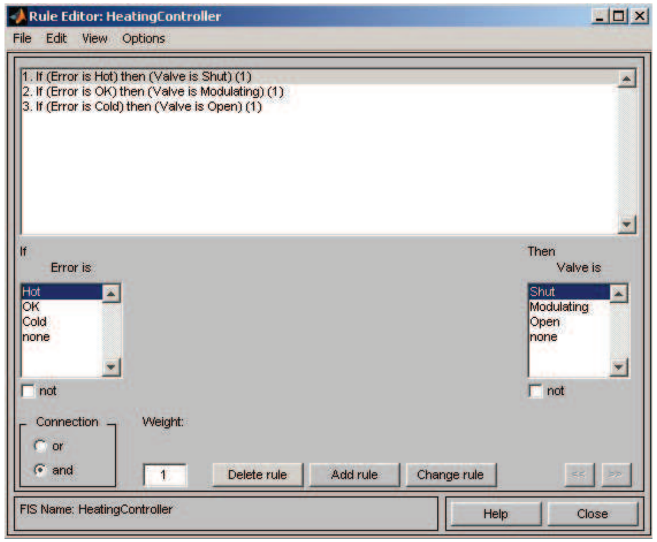
Fuzzy Heating Controller



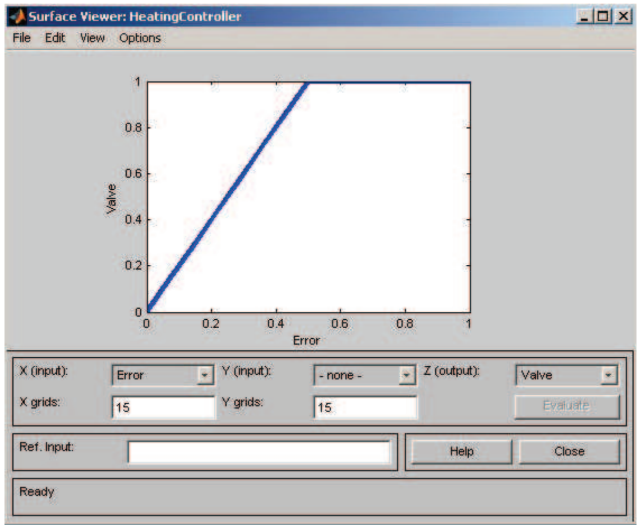
1. Input MFs



2. Output MFs

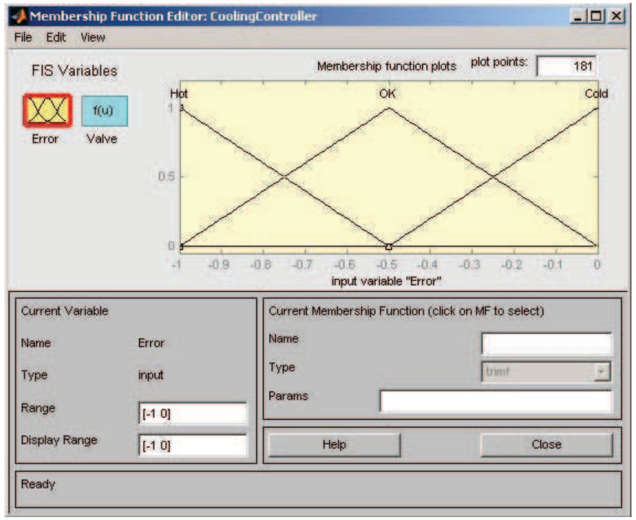


3. Rules

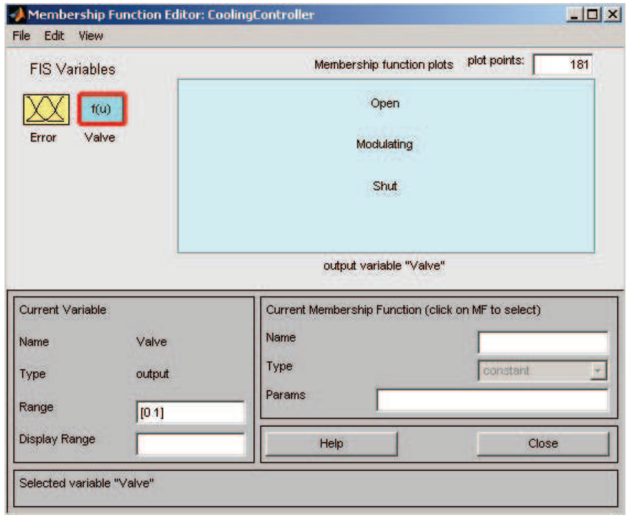


4. Surface

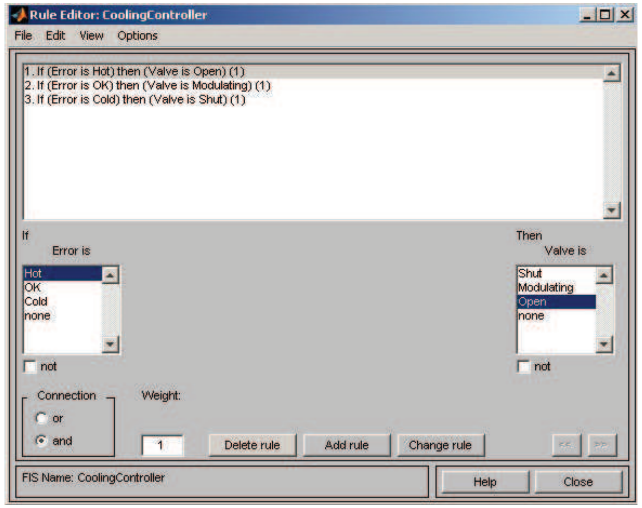
Fuzzy Cooling Controller



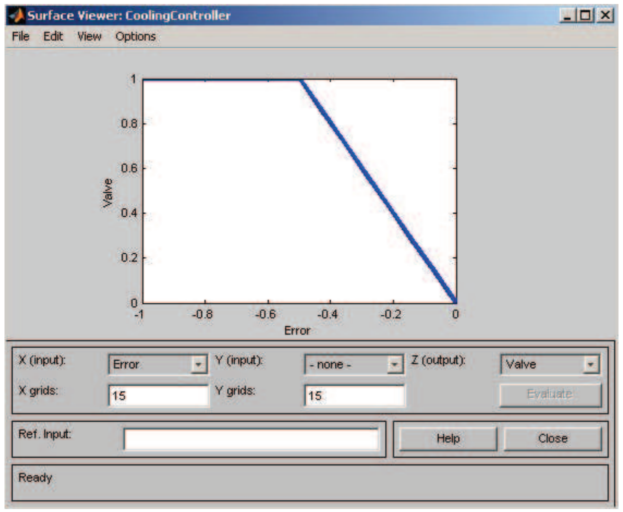
1. Input MFs



2. Output MFs

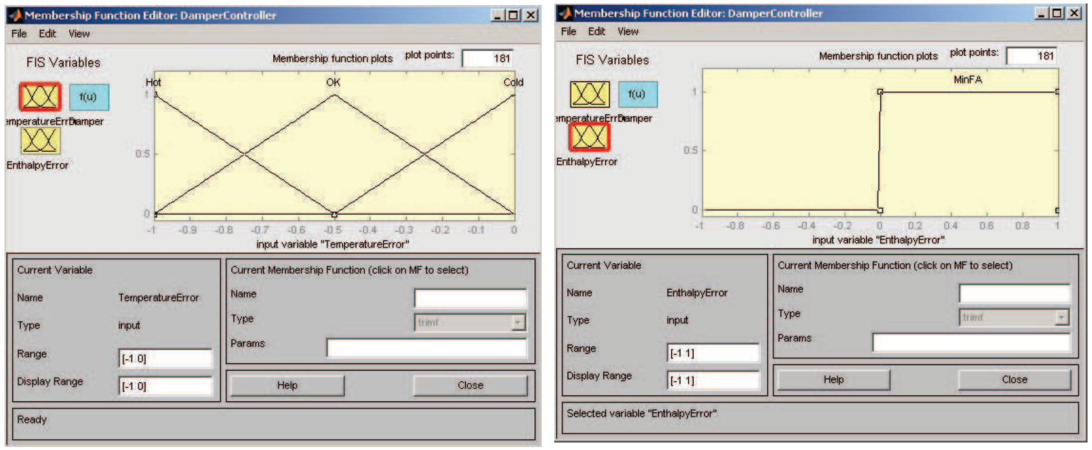


3. Rules

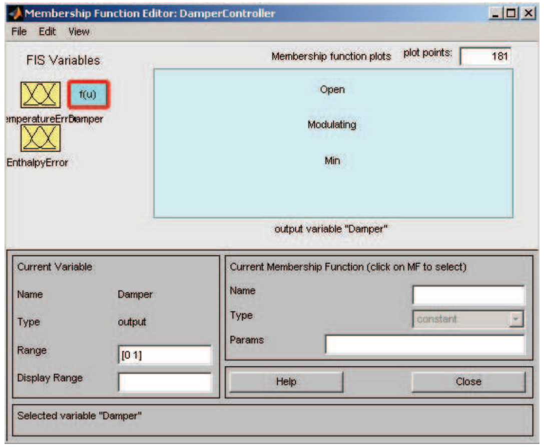


4. Surface

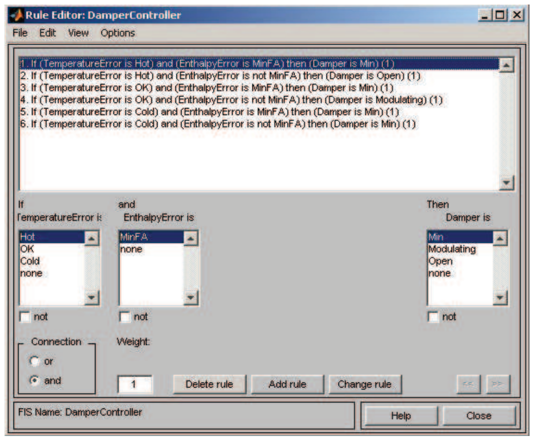
Fuzzy Damper Controller



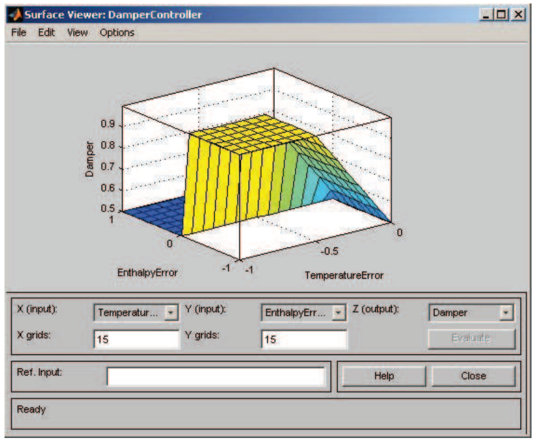
1. Input MFs (2 inputs)



2. Output MFs

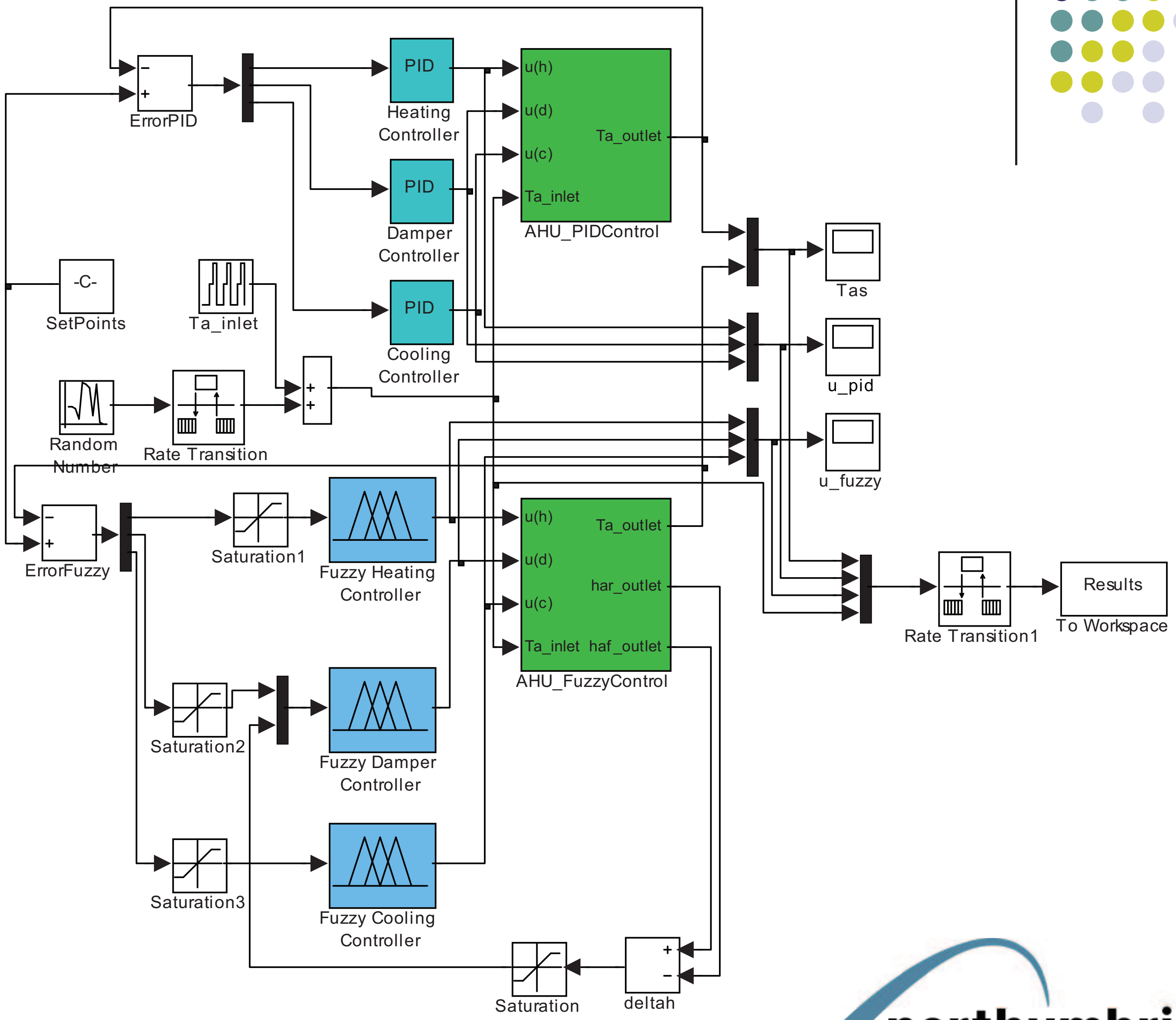


3. Rules

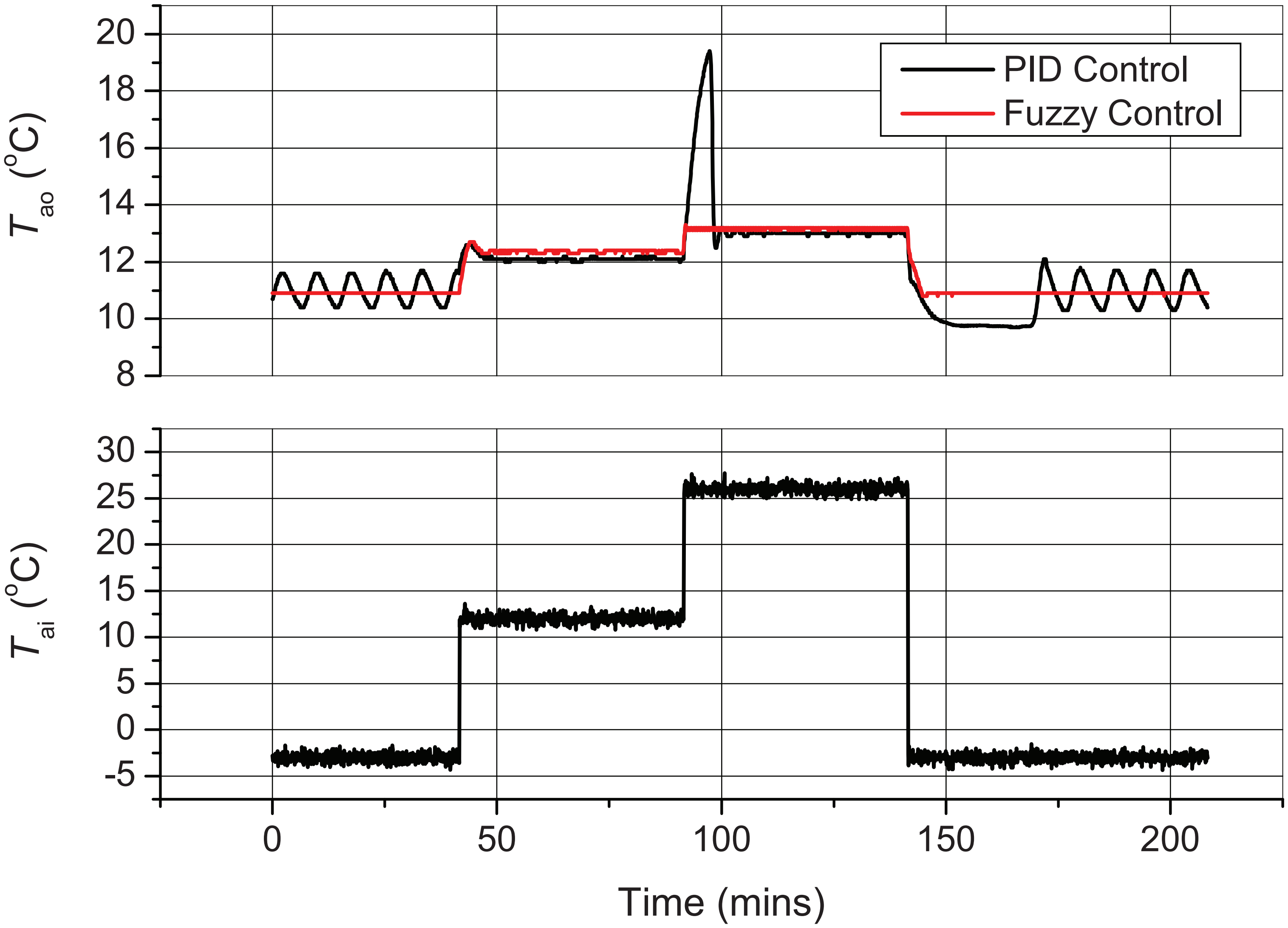


4. Surface

Simulink Model Adapted for Controller Comparisons

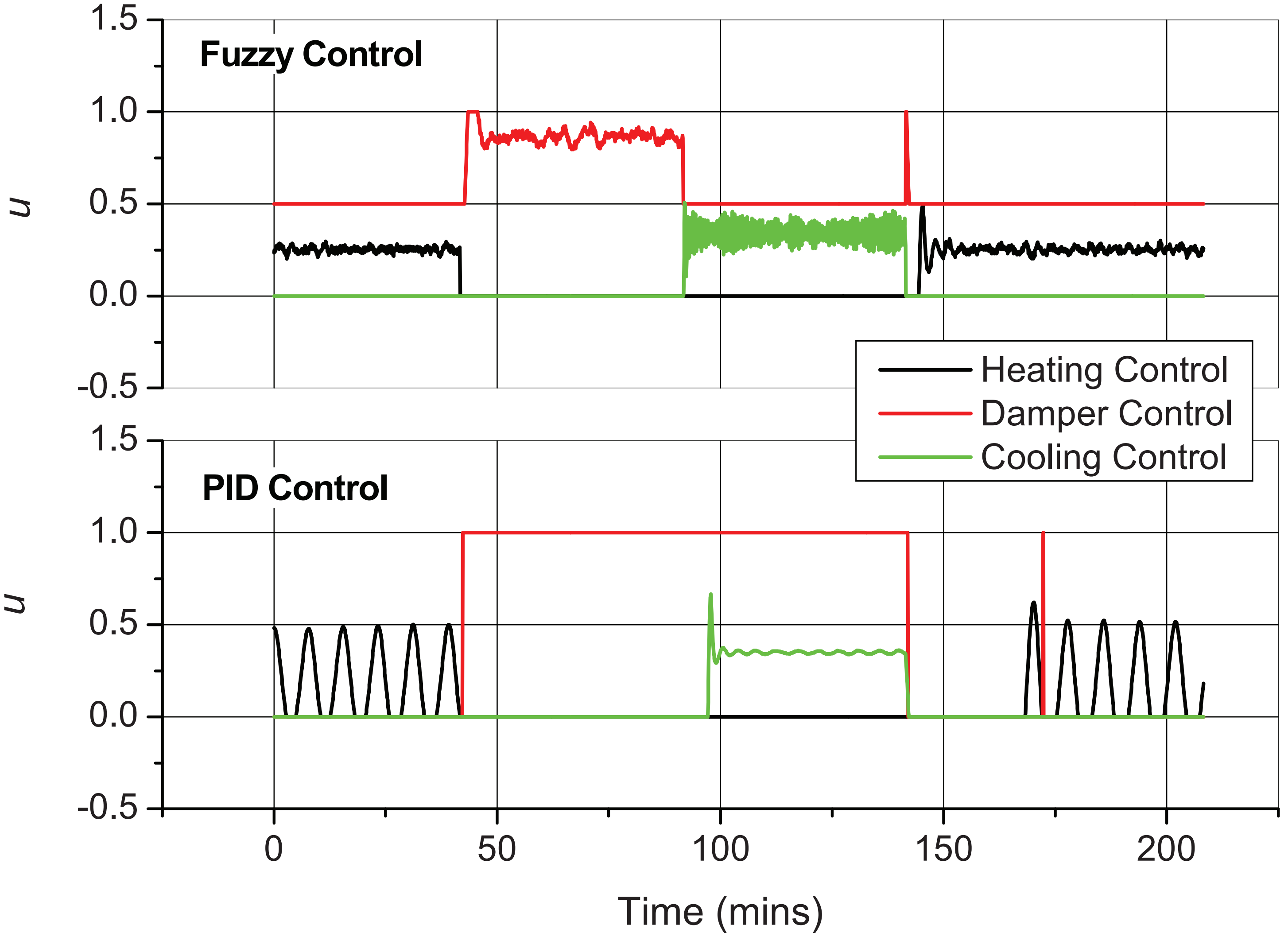


Comparative Results: Controlled Variable



Set points: 11°C (heating); 12°C (free cooling); 13°C (cooling)   (50% min F/A)

Comparative Results: Signal



CONCLUSIONS

- Fuzzy control over air handling plant temperatures requires no tuning and offers better tracking performance than conventionally-tuned PID control
- Sugeno inference has greater flexibility than conventional Mamdani inference for fuzzy controllers especially at signal saturation and requires no experience/intuition to apply it
- The well known “chatter” around the set point that can arise with fuzzy control has been noted in the present work and needs robust procedures to remove it (conventionally, introducing an additional rate variable can help)