

# Northumbria Research Link

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## Northumbria Research Link

**Underwood, C. P. (2005) 'A fuzzy logic controller for temperature control of air handling plant', CSTB Matlab / Simulink Building and HVAC Simulation Workshop, 3-4 November, SIMBAD.**

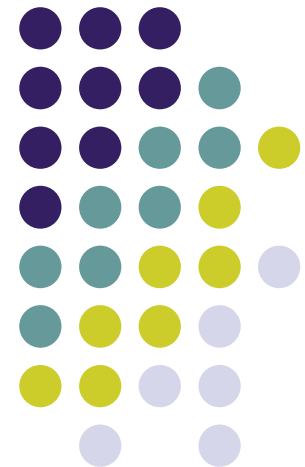
**CSTB 3<sup>rd</sup> Matlab/Simulink Building and  
HVAC Simulation Workshop  
3-4<sup>th</sup> November 2005, Paris**

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**A Fuzzy Logic Controller for  
Temperature Control of Air  
Handling Plant**

**C P Underwood**

Northumbria University, United Kingdom

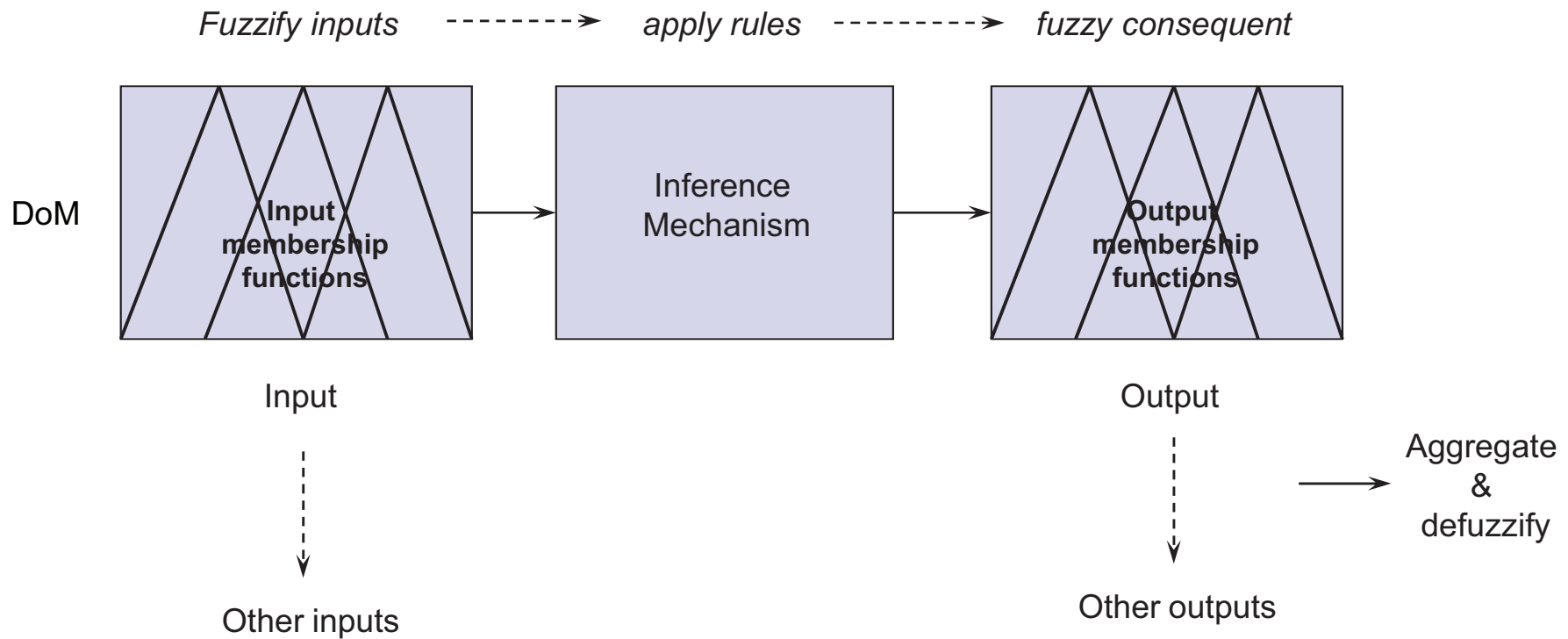


## *Summary of This Work*



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

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

***If*** ( $T$  is high) ***And*** ( $dT/dt$  is negative) ***Then*** (Valve is medium)

Combinatorial rule setting examples:

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

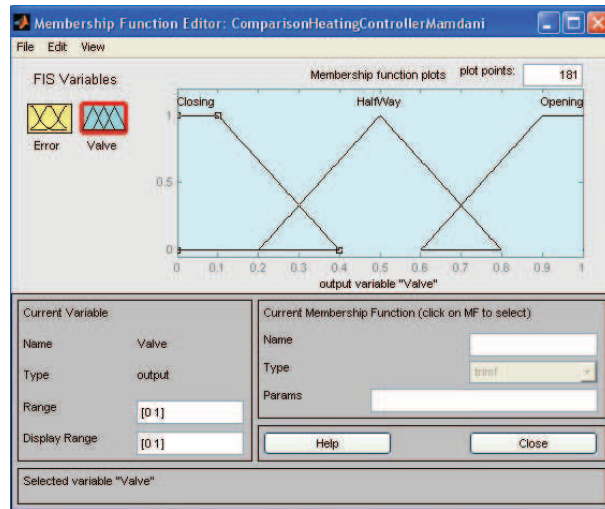
***If*** ( $T$  is high) ***Then***  $u = 0$

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

***If*** ( $T$  is high) ***And*** ( $dT/dt$  is negative) ***Then***  $u = 0.5 \cdot \text{input}$

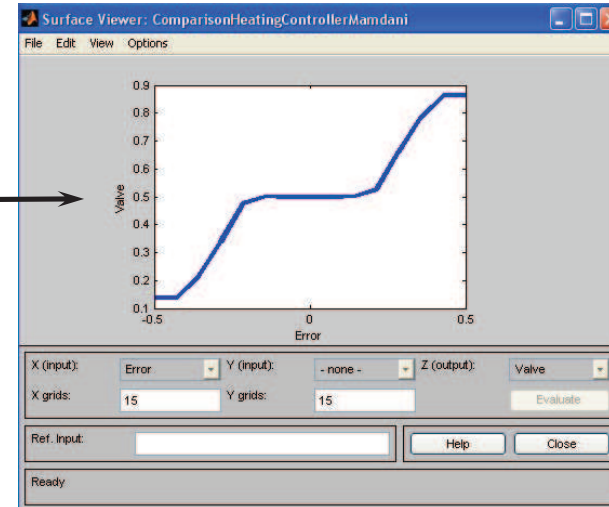
i.e. Sugeno inference can output to some mathematical function of the fuzzy input(s)

# 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

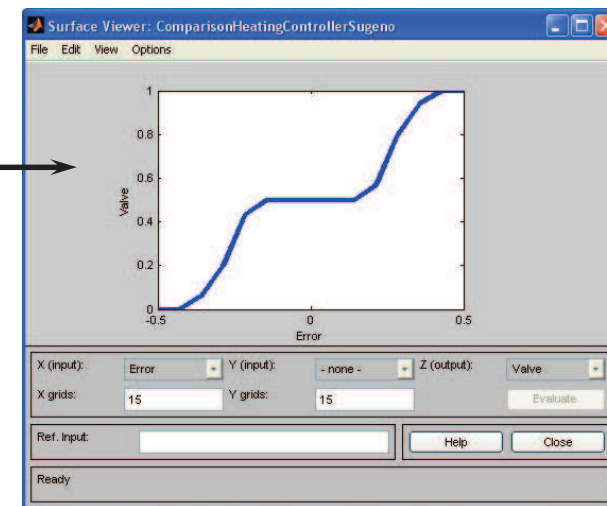


Sugeno case:

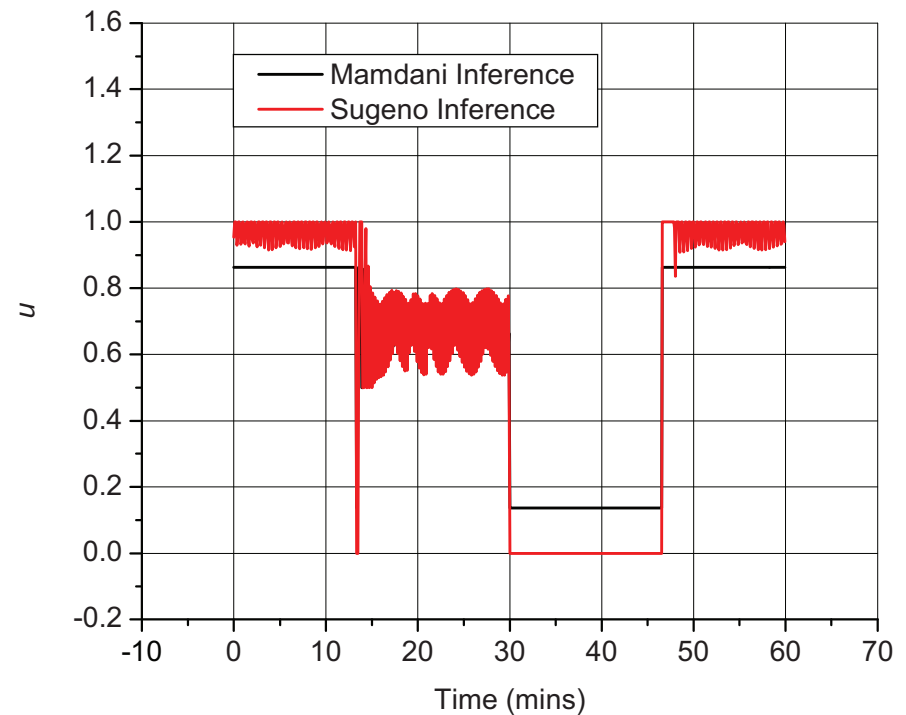
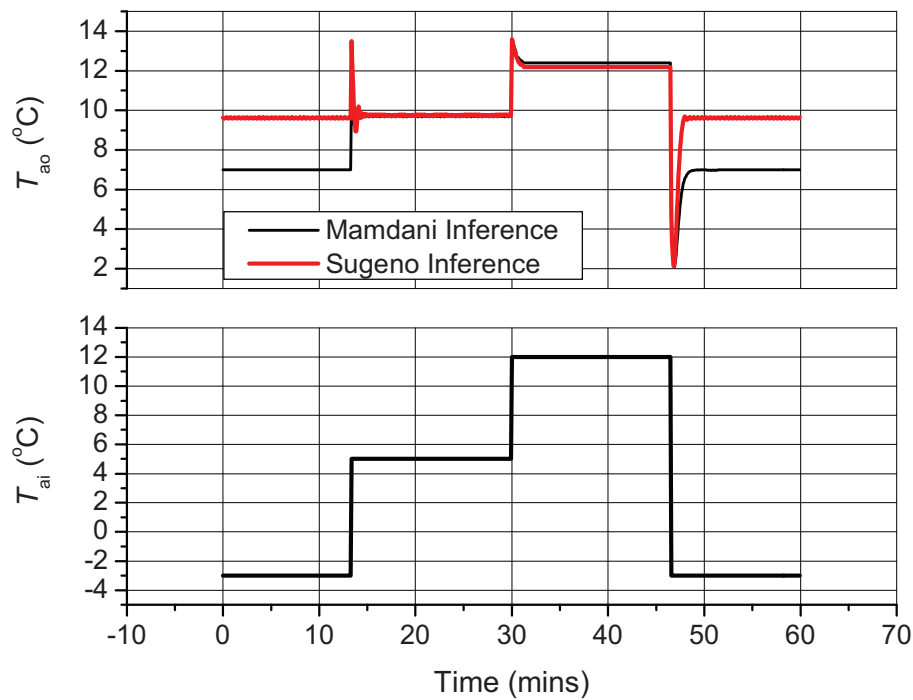
If ( $T$  is low) Then: Valve = 1

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

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



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

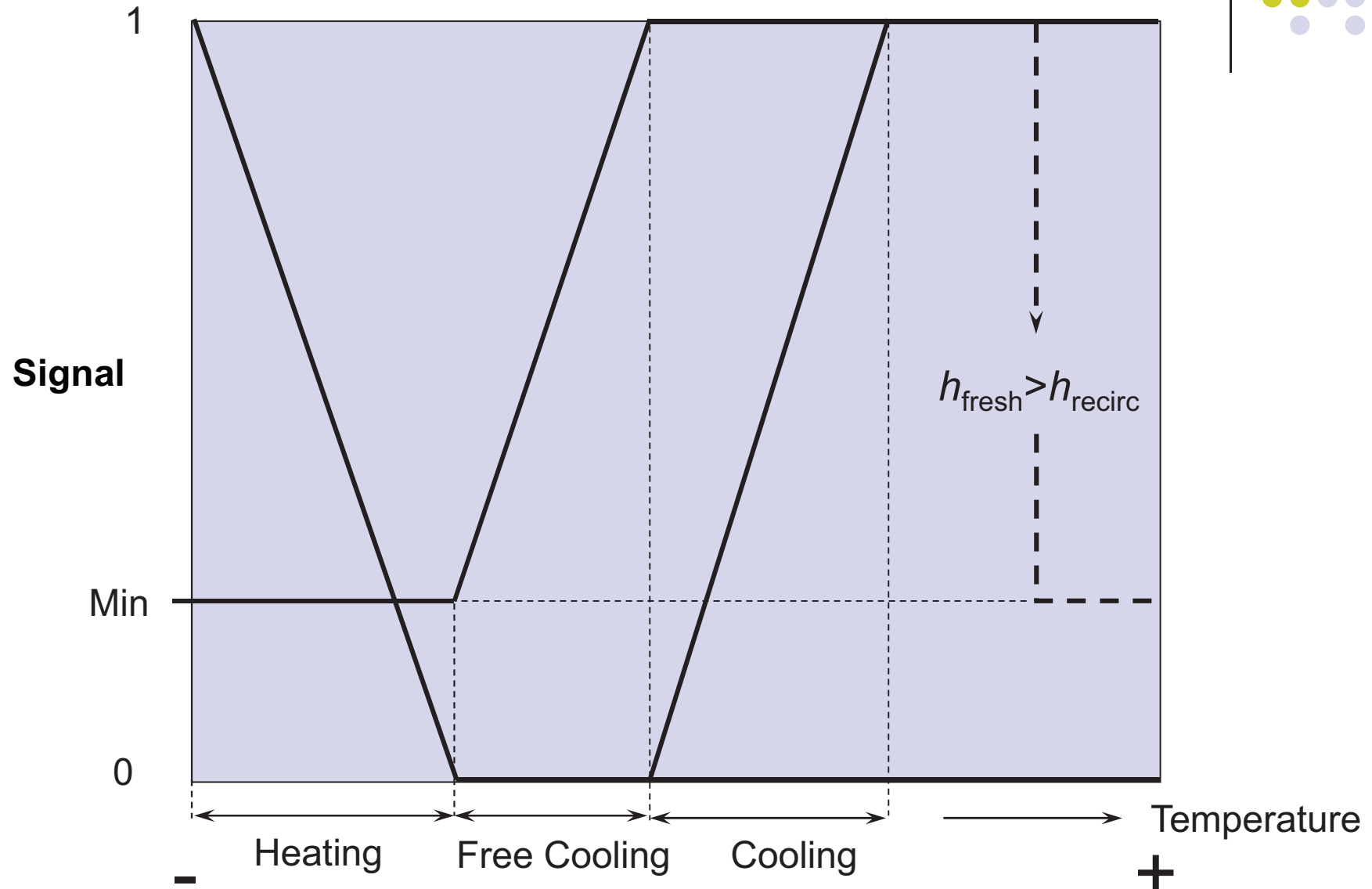


Outlet temperature set point: 10°C

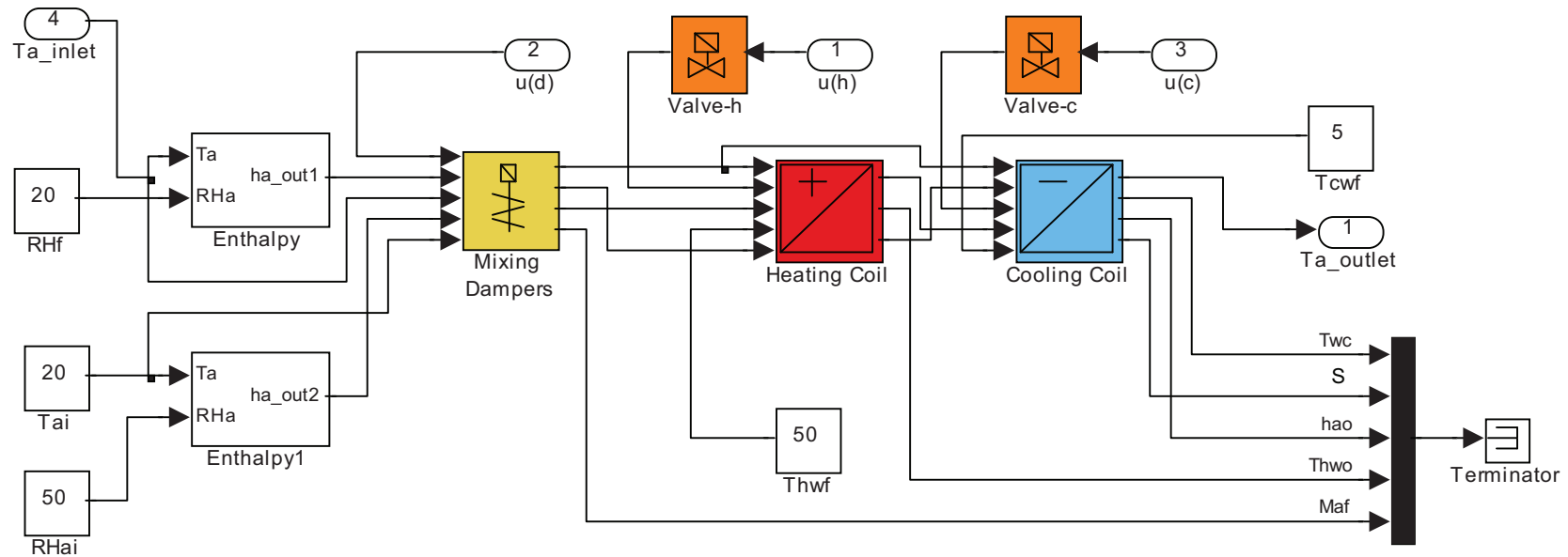
$T_{ao}$  = air outlet temperature       $T_{ai}$  = air inlet temperature



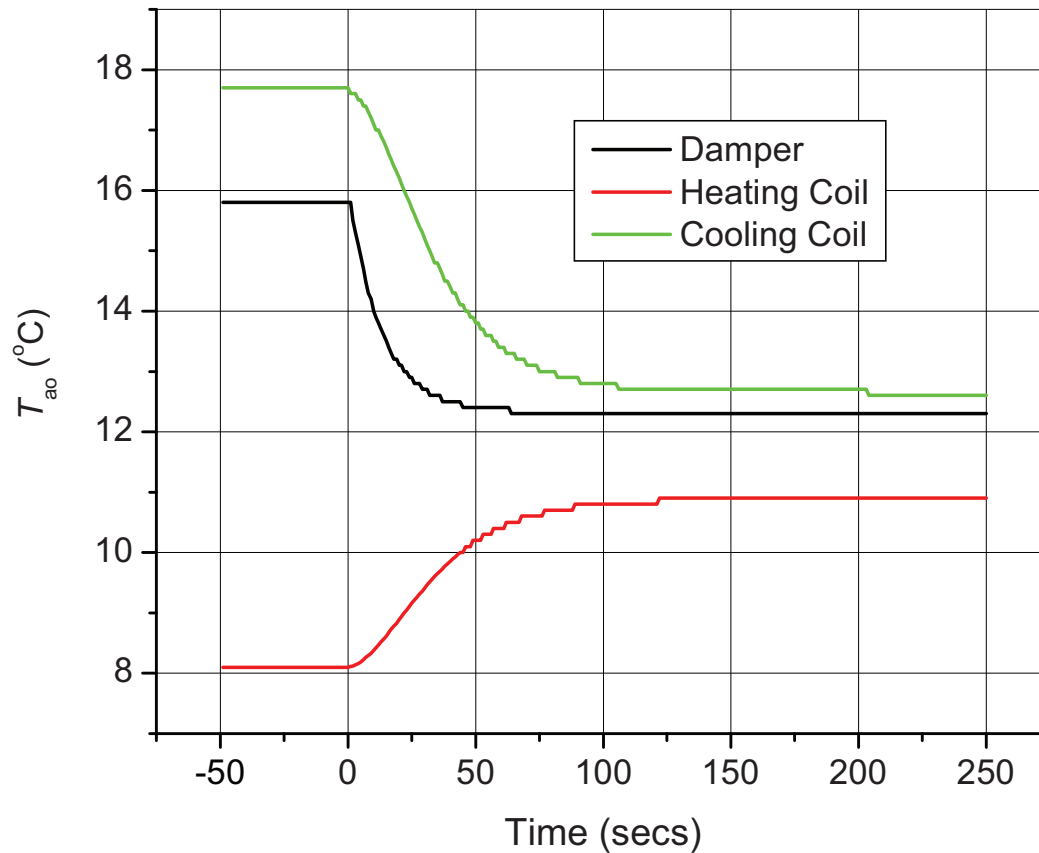
# *The Problem: Sequencing Temperature Control of AHP*



# Vehicle – Simulink Air Handler Model



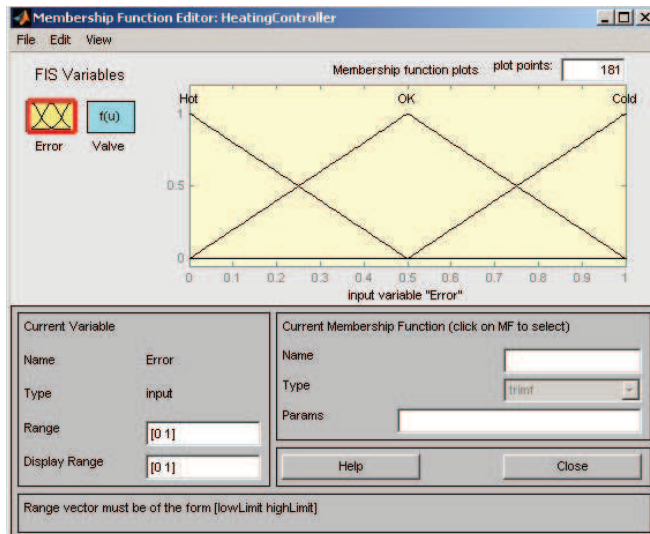
# ***PID Control: Ziegler-Nichols Tuning Parameters Fitted to Open Loop Step Response “Tests”***



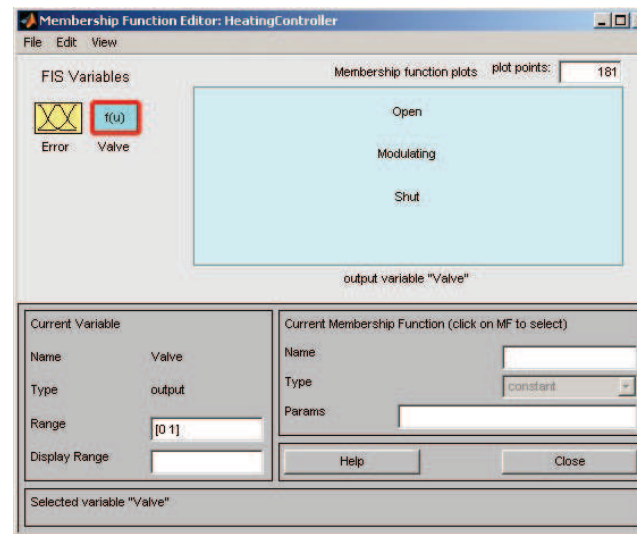
PID tuning parameters:

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

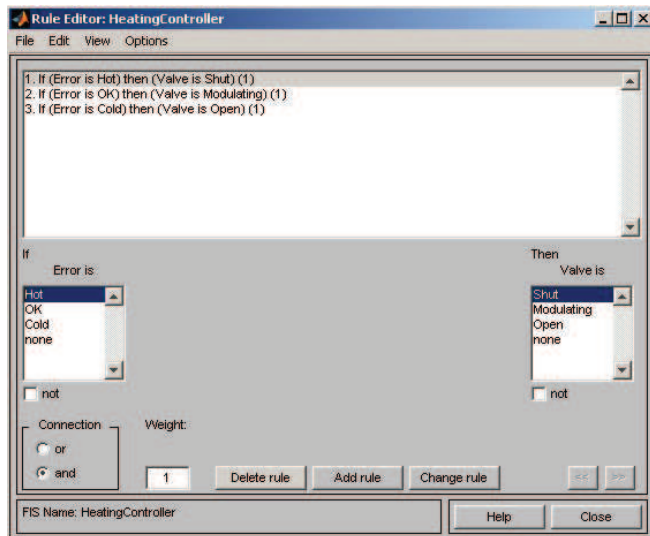
# Fuzzy Heating Controller



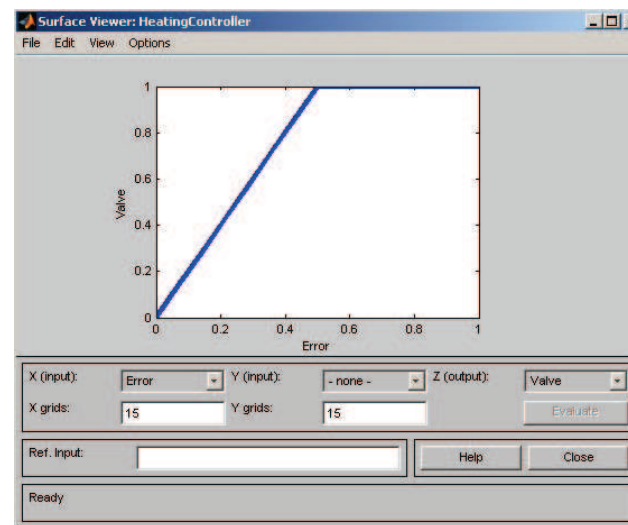
1. Input MFs



2. Output MFs

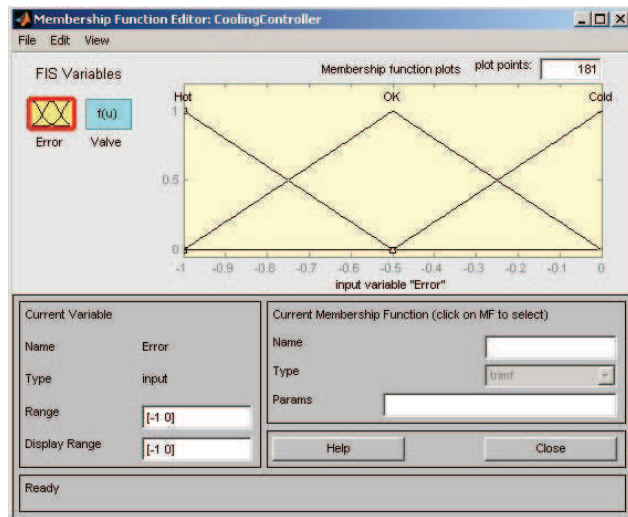


3. Rules

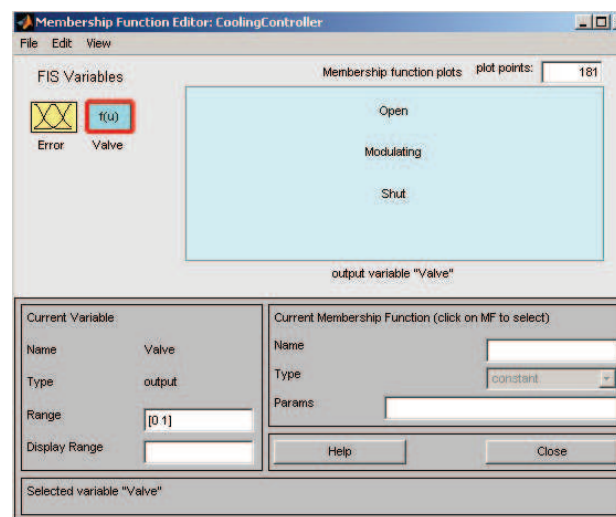


4. Surface

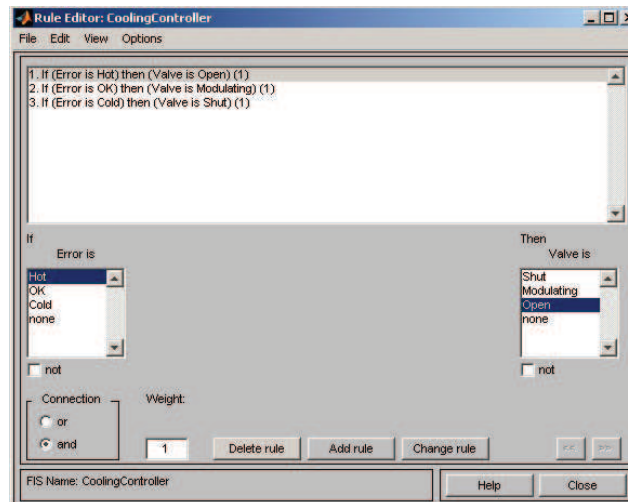
# Fuzzy Cooling Controller



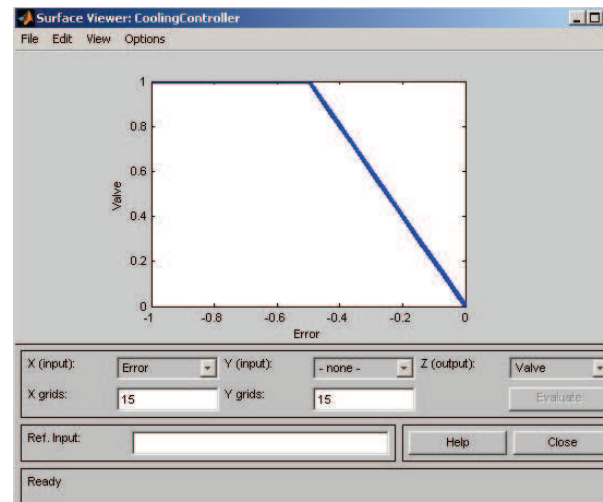
1. Input MFs



2. Output MFs

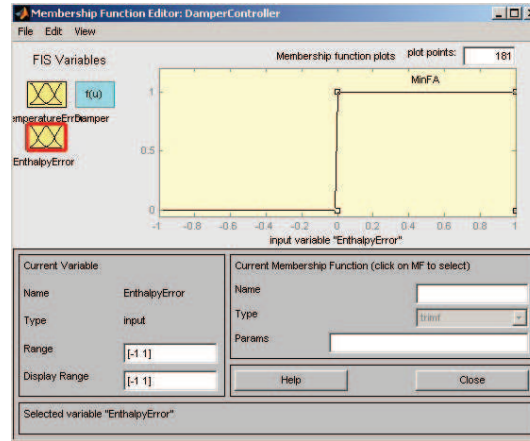
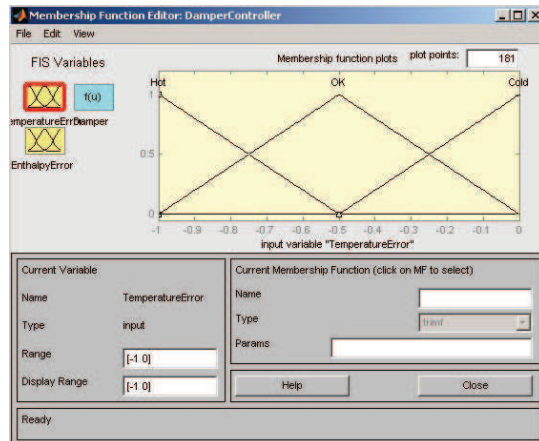


3. Rules

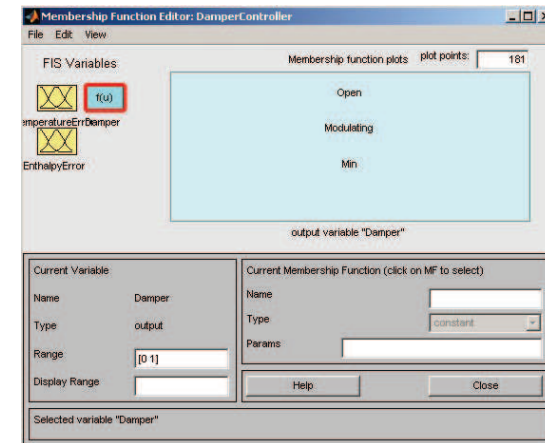


4. Surface

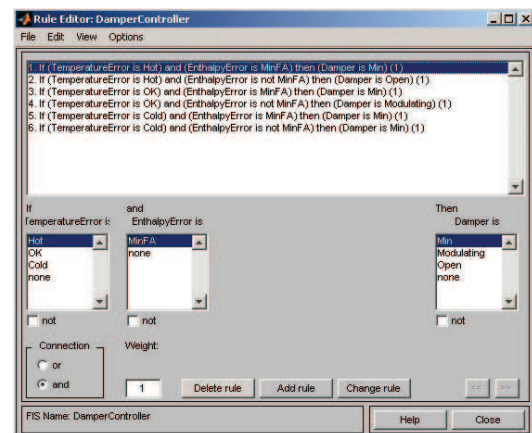
# Fuzzy Damper Controller



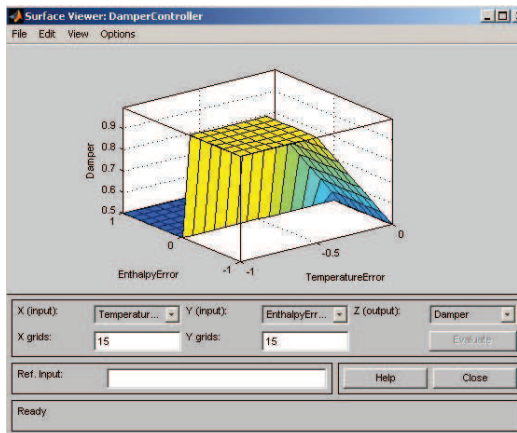
## 1. Input MFs (2 inputs)



## 2. Output MFs

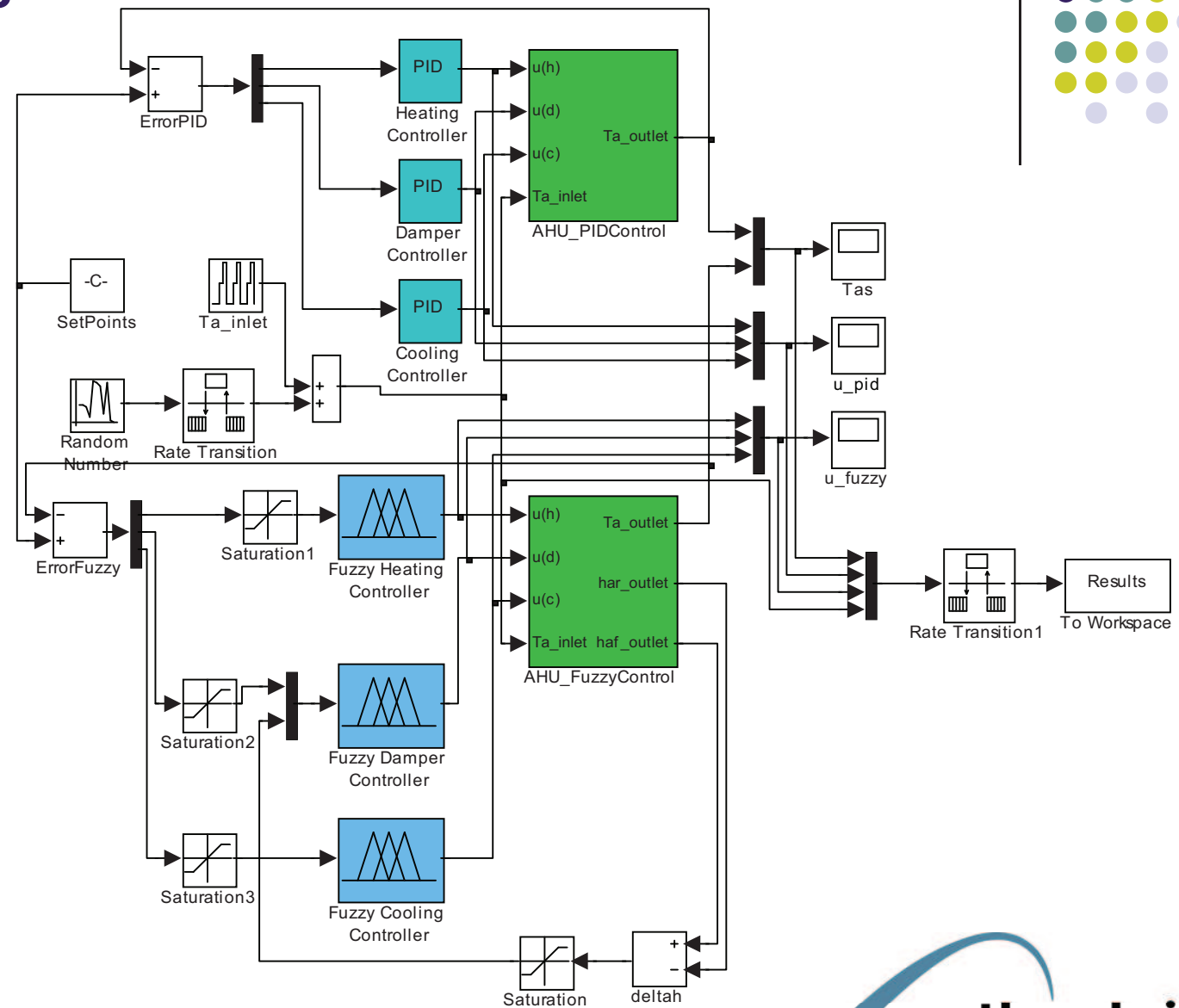


## 3. Rules

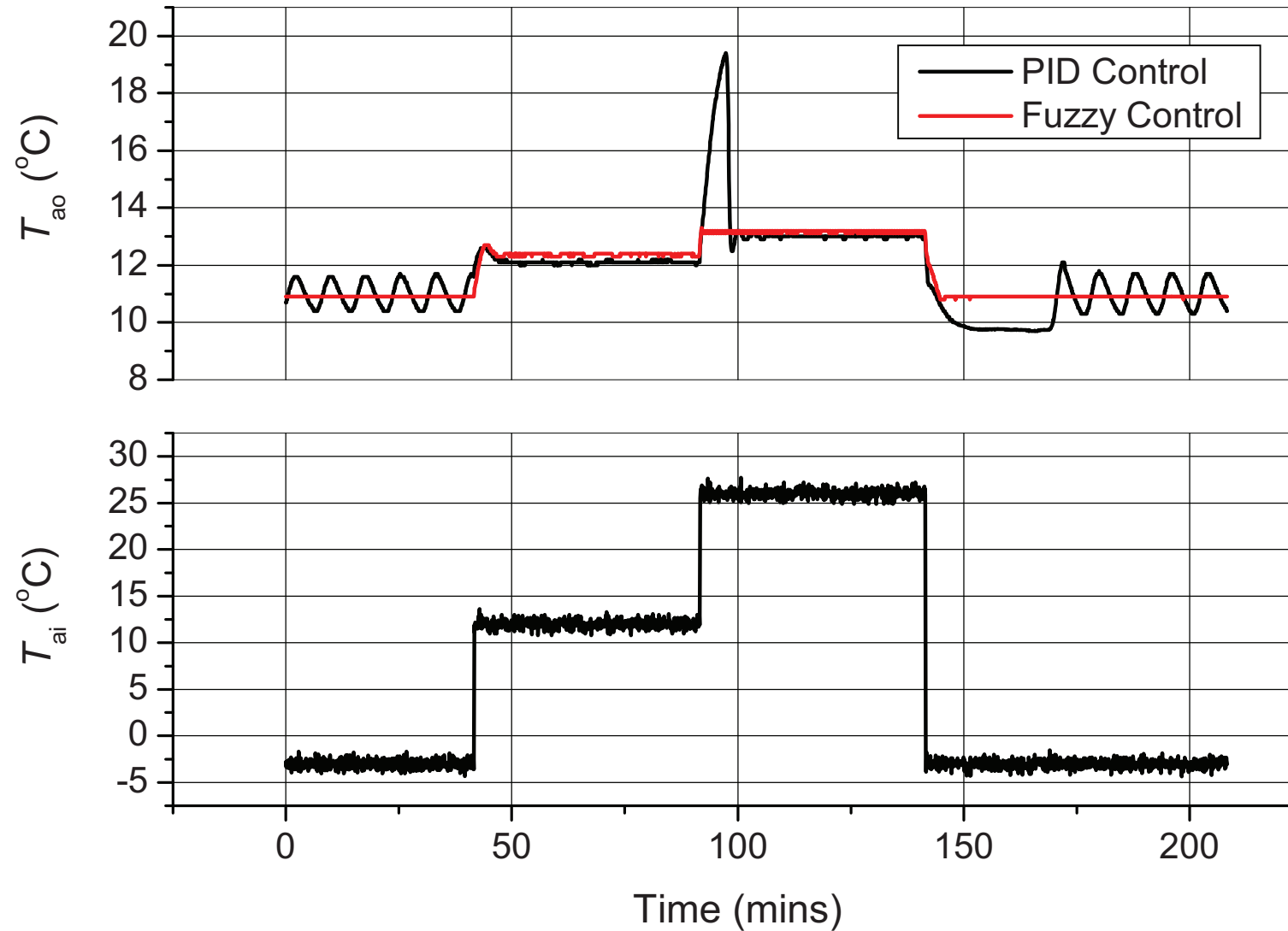


## 4. Surface

# Simulink Model Adapted for Controller Comparisons



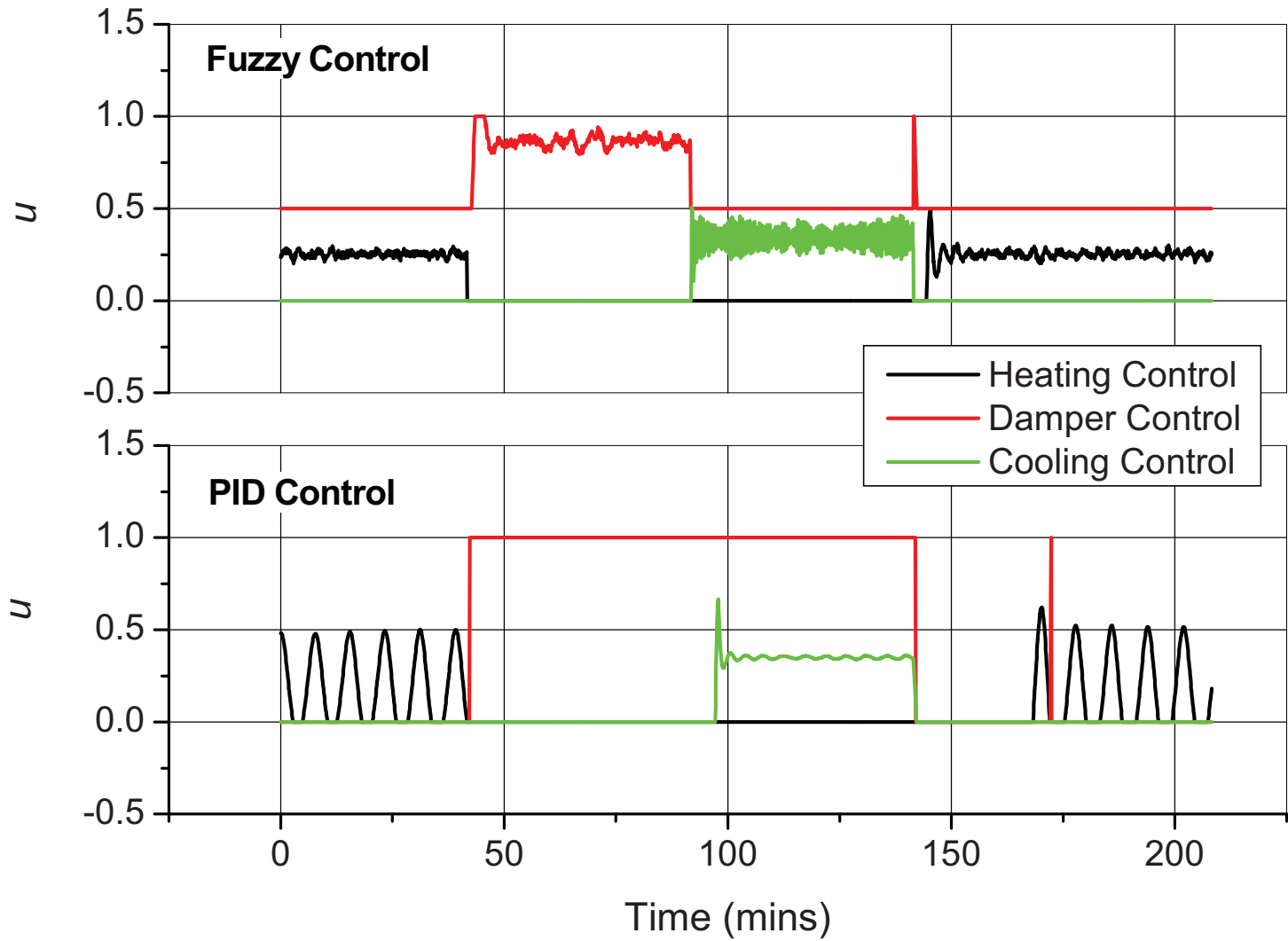
## Comparative Results: Controlled Variable



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)