METHODOLOGIES FOR DISCRETE EVENT MODELLING AND SIMULATION (SYSC 5104)

Assignment 1

Simulation of House Heating System

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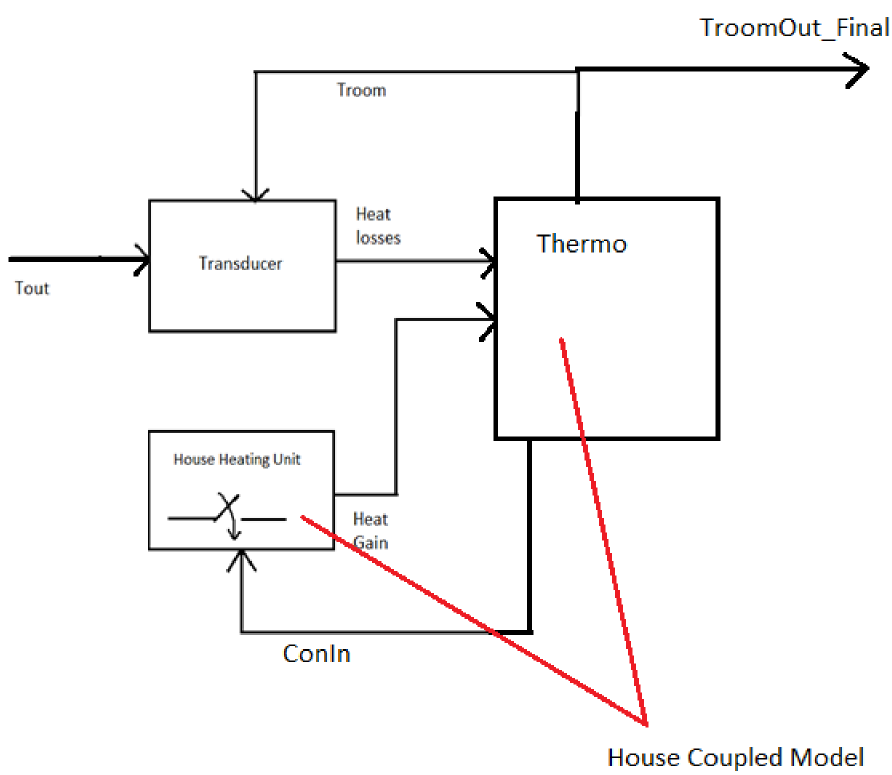
Introduction

House heating system model allows us to simulate the working of a typical house heating system in the house. In this simulation model, we will consider three atomic models namely Transducer, Thermostat and Heater. These three atomic models will then be coupled together to form the main House Heating model. The final couple model will simulate the functioning of a typical house heating system used in indoor spaces.

The house heating system consists of 3 atomic models which are:

1) Tranducer
2) Thermostat
3) House Heating Unit (Heater)

The following figure shows the block diagram of the house heating system



Transducer:

The Transducer atomic model will have two inputs which are Tout and Troom. Tout is the outdoor temperature and Troom is the current indoor temperature. Once it has values of both indoor and outdoor temperatures, it will then compute the heat loss which is difference between the two temperatures multiplied by heatloss coefficient. Once it has computed the heatloss, it will then generate the output of HeatlossOut which is current indoor temperature – heatloss.

Thermostat:

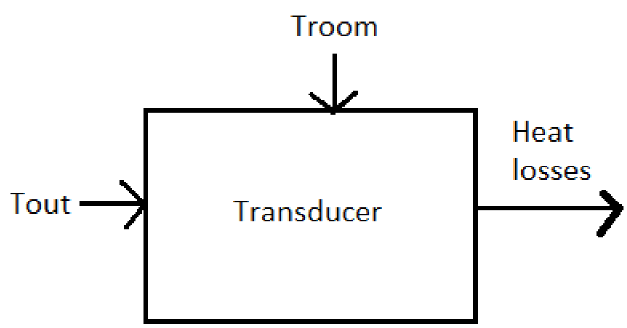
Thermostat will have two inputs and two outputs. The inputs are the HeatlossOut from Transducer and HeatGain from Heater. Once it has both the values, it will generate the new indoor temperature Troom which is summation of both the inputs which are Heatgain and HeatlossOut. Also, if this new indoor temperature generated is less than the set point, it will generate another output which is Control signal as ‘1’. If it is more than the set point, ControlSignal will be ‘0’.

Heater:

Heater will have one input and one output. It will take input of ControlSignal and generate the output as HeatGain. If the ControlSignal is ‘1’, HeatGain will be ‘0.5’ and if the ControlSignal is ‘0’ the HeatGain will be ‘0’ as well.

Formal Specifications of Atomics and Coupled models

Transducer



Transducer =<S, X, Y, δ_{int}, δ_{ext}, λ, ta >

X = {Tout, Troom}

Y = {HeatLossOut}

S = {phase, ta, Troom, Tout}

K = 0.1 // initialize heat losses coefficient

δ_{int} (active) = preparationTime // time delay chosen as 1 sec

δ_{ext} (active) = active // temperature changes dynamically every second

If (Troom > Tout)

{

HeatLossOut = Troom – (Troom - Tout)*K ;

}

Else

{

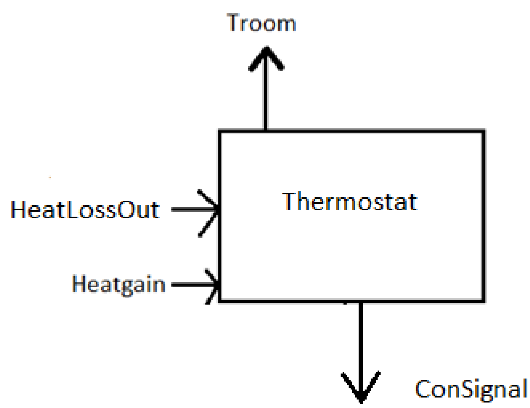
HeatLossOut = Troom;

}

ta (active) = preparationTime //time delay interval, chosen as 1 sec

λ (active) = HeatLosses //sends output data to the Thermostat i.e. HeatLossOut

Thermostat



Thermostat =<S, X, Y, δ_{int}, δ_{ext}, λ, ta >

X = {HeatlossOut, HeatGain}

Y = {Troom, ConSignal}

S = {phase, ta, HeatLossOut, Heatgain}

δ_{int} (active) = preparationTime // time delay chosen as 1 sec

δ_{ext} (active) = active // temperature changes dynamically every second

If (HeatlossOut + HeatGain > setpoint i.e 24.9)

{

Troom = HeatlossOut + HeatGain;

ConSignal = 0;

}

Else

{

Troom = HeatlossOut + HeatGain;

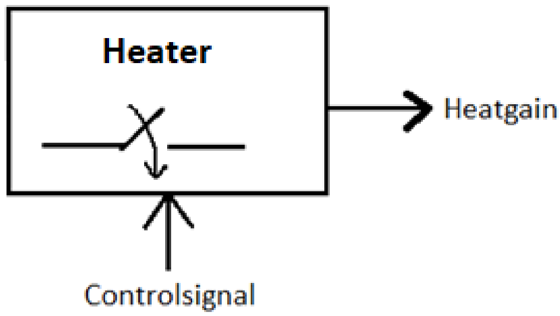
ConSignal = 1;

}

ta (active) = preparationTime //time delay interval, chosen as 1 sec

λ (active) = Controlsignal //sends output data to the Heater i.e. ConSignal

Heater



Heater =<S, X, Y, δ_{int}, δ_{ext}, λ, ta >

X = {ConSignal}

Y = {HeatGain}

S = {phase, ta, ConSignal}

δ_{int} (active) = preparationTime // time delay chosen as 1 sec

δ_{ext} (active) = active // temperature changes dynamically every second

If (Consignal == 1)

{

HeatGain = 0.5;

}

Else

{

HeatGain = 0;

}

ta (active) = preparationTime //time delay interval, chosen as 1 sec

λ (active) = HeatGain //sends output data to the Thermostat i.e. Heatgain

Coupled Model Formal Specifications

House:

The House Coupled model will consist of Thermostat and Heater

X = { HeatLossOut };

Y = {Troom};

D = {Thermostat, Heater};

I (Thermostat) = {Heater, self};

I (Heater) = self;

Z(Thermostat) = Heater;

Z(Thermostat) = self;

Z(Heater) = self;

Select: ({Thermostat, Heater}) = Thermostat;

HouseTop:

HouseTop coupled model will consist of 'Transducer' and 'House' models.

X = {Tout };

Y = {TroomOut};

D = {Transducer, House};

I (Transducer) = {House, self};

I (House) = self;

Z(Transducer) = House;

Z(Transducer) = self;

Z(House) = self;

Select: ({Transducer, House}) = Transducer;

Test Cases and Execution analysis

Heater

The ‘Heater’ atomic model receives ‘Control Signal’ from ‘Thermostat’ and gives output as Heat gain.

Test Case 1:

The case 1 is taken as when the Input Control Signal is provided as ‘1’. The desired output for this test case should be ‘0.5’ as heater generates value 0.5 when input control signal is 1.

Test Case 2:

In this case, we will provide the input as ‘0’ and the desired output is also ‘0’ since the control signal is ‘0’, no heat is generated.

Simulation Results:

Input File

```
00:00:01 0
00:00:02 1
00:00:03 0
00:00:04 1
00:00:05 1
```

Output File

```
00:00:01:000
State for model input_reader_Con is next time: 00:00:01:000
State for model heater1 is index: 0
00:00:02:000
State for model input_reader_Con is next time: 00:00:01:000
State for model heater1 is index: 0.5
00:00:03:000
State for model input_reader_Con is next time: 00:00:01:000
State for model heater1 is index: 0
00:00:04:000
State for model input_reader_Con is next time: 00:00:01:000
State for model heater1 is index: 0.5
00:00:05:000
State for model input_reader_Con is next time: inf
State for model heater1 is index: 0.5
```

The output at time 2 second is the Test Case 1 and the output at time 3 seconds is the Test Case 2.

It can be seen that at time 2 seconds the model generated 0.5 and at time 3 seconds the model generated 0 which corresponds to the input control signal values 1 and 0 respectively.

Thermostat

The ‘Thermo’ atomic model takes two inputs which are ‘HGIn’ and ‘HeatLossIn’ and generates two outputs which are ‘Control Signal’ and ‘Troom’.

The Troom output is the sum of both ‘HeatLossIn’ and ‘HGIn’.

The ‘Control Signal’ output is set to ‘1’ if the Troom generated is lower than the set point which is kept 24.9. And if the Troom generated is higher than the set point, it is set to ‘0’.

Test Case 1:

In this case, the ‘Heatgain’ input is kept at 0.5 and the ‘HeatloosIn’ is kept as 23.9. Hence the desired outputs are:

Troom = 23.9 + 0.5 = 24.4

Control signal = 1 (because 24.4 < 24.9)

Test Case 2:

In this case, The ‘Heatgain’ is kept 0 and the ‘HeatlooIn’ is kept as 22.48.

The desired outputs are:

Troom = 22.48 + 0 = 22.48

Control signal = 1 (because 22.48 <24.9)

Test Case 3:

The ‘Heatgain’ is kept 0.5 and the ‘HeatlossIn’ is kept at 24.84

The desired outputs are:

Troom = 24.84 + 0.5 = 25.34

Control Signal = 0 (because 25.34 > 24.9)

Simulation Results

Input file

HeatloosIn

00:00:01	23.9
00:00:02	22.48
00:00:03	24.84
00:00:04	22.35
00:00:05	20.94

HeatGainIn

00:00:01	0.5
00:00:02	0
00:00:03	0.5
00:00:04	0
00:00:05	0.5

Output file

```
00:00:01:000
State for model input_reader_HGIn is next time: 00:00:01:000
State for model input_reader_HLIn is next time: 00:00:01:000
State for model thermo1 is Troom: 24.4 & ControlSignal 1
00:00:02:000
State for model input_reader_HGIn is next time: 00:00:01:000
State for model input_reader_HLIn is next time: 00:00:01:000
State for model thermo1 is Troom: 22.48 & ControlSignal 1
00:00:03:000
State for model input_reader_HGIn is next time: 00:00:01:000
State for model input_reader_HLIn is next time: 00:00:01:000
State for model thermo1 is Troom: 25.34 & ControlSignal 0
00:00:04:000
State for model input_reader_HGIn is next time: 00:00:01:000
State for model input_reader_HLIn is next time: 00:00:01:000
State for model thermo1 is Troom: 22.35 & ControlSignal 1
00:00:05:000
State for model input_reader_HGIn is next time: inf
State for model input_reader_HLIn is next time: inf
State for model thermo1 is Troom: 21.44 & ControlSignal 1
```

The output at seconds 1,2 and 3 corresponds to the input cases 1,2 and 3 respectively. It can be noted from the output file that the values of Troom and ControlSignals are generated as desired.

Transducer

Transducer takes two inputs namely ‘Tout’ and ‘Troom’ and generates one output which is ‘Heatloss’

The ouput Heatloss is computed as:

If the value of Troom is more than the Tout.

Heatloss = Troom – (Troom – Tout)*0.1

If the value of Troom is less than Tout, the value of Heatloss is equal to Troom.

Test Case 1

In this case, the ‘Tout’ is kept at 23 and ‘Troom’ is kept at 25. Hence, the desired output of Heatloss should be 25 – (25-23)*0.1 = 24.8 (because here Tout < Troom)

Test Case 2

In this case, the ‘Tout’ is kept at 25 and ‘Troom’ is kept at 21. Hence, the desired output of Heatloss should be 21 (because here Tout > Troom)

Simulation Results

Input Files

Tout

```
00:00:01 23
00:00:02 25
00:00:03 21.8
00:00:00 20.2
00:00:00 21
```

Troom

```
00:00:01 25
00:00:02 21
00:00:03 23.84
00:00:04 22.64
00:00:05 21.11
```

Output File

```
00:00:01:000
State for model input_reader_Tout is next time: 00:00:01:000
State for model input_reader_Troom is next time: 00:00:01:000
State for model transduc1 is heatlossout 24.8
00:00:02:000
State for model input_reader_Tout is next time: 00:00:01:000
State for model input_reader_Troom is next time: 00:00:01:000
State for model transduc1 is heatlossout 21
00:00:03:000
State for model input_reader_Tout is next time: inf
State for model input_reader_Troom is next time: 00:00:01:000
State for model transduc1 is heatlossout 23.636
00:00:04:000
State for model input_reader_Tout is next time: inf
State for model input_reader_Troom is next time: 00:00:01:000
State for model transduc1 is heatlossout 22.556
00:00:05:000
State for model input_reader_Tout is next time: inf
State for model input_reader_Troom is next time: inf
State for model transduc1 is heatlossout 21.11
```

The output at time 1 and 2 seconds corresponds to the Test Cases 1 and 2 respectively. It can be verified that the output generated by Transducer is as desired

Top Model

Top model consists of the three atomics model combined and hence in this test, we will simulate and execute different test cases in order to check if all the three atomics models are working as desired or not when coupled together.

Test Case 1:

In this case we will check the output of the atomic model 'Transducer' and see if it is generating the correct output or not.

Test Case 2:

This case will check the proper functioning of the 'Heater' atomic model.

Test Case 3:

Finally, we will check whether the 'Thermostat' atomic model is generating the desired output or not.

Simulation Results

Top Model Input file

```
00:00:01 24
00:00:02 24
00:00:03 24
00:00:04 24
00:00:05 25
```

Output File

```
00:00:01:000
[cadmium::basic_models::pdevs::iestream_input_defs<float>::out: {24}] generated by model input_reader
[Transduc_defs::HeatlossOut: {24.9}] generated by model transduc1
[Thermo_defs::TroomOut: {24.9}, Thermo_defs::ConOut: {0}, Thermo_defs::TroomOut_final: {24.9}] generated by model thermo1
[Heater_defs::HGOut: {0}] generated by model heater1
00:00:02:000
[cadmium::basic_models::pdevs::iestream_input_defs<float>::out: {24}] generated by model input_reader
[Transduc_defs::HeatlossOut: {24.81}] generated by model transduc1
[Thermo_defs::TroomOut: {24.9}, Thermo_defs::ConOut: {1}, Thermo_defs::TroomOut_final: {24.9}] generated by model thermo1
[Heater_defs::HGOut: {0}] generated by model heater1
00:00:03:000
[cadmium::basic_models::pdevs::iestream_input_defs<float>::out: {24}] generated by model input_reader
[Transduc_defs::HeatlossOut: {24.81}] generated by model transduc1
[Thermo_defs::TroomOut: {24.81}, Thermo_defs::ConOut: {1}, Thermo_defs::TroomOut_final: {24.81}] generated by model thermo1
[Heater_defs::HGOut: {0.5}] generated by model heater1
00:00:04:000
[cadmium::basic_models::pdevs::iestream_input_defs<float>::out: {24}] generated by model input_reader
[Transduc_defs::HeatlossOut: {24.729}] generated by model transduc1
[Thermo_defs::TroomOut: {25.31}, Thermo_defs::ConOut: {0}, Thermo_defs::TroomOut_final: {25.31}] generated by model thermo1
[Heater_defs::HGOut: {0.5}] generated by model heater1
```

Analysis of output of Top model

Here, the outputs at time 1, 2 and 4 seconds are the output for test cases 1, 2 and 3 respectively.

Test Case 1:

At time 1 second, the Tout is kept at 24 and Troom initially is kept at 25. Hence, as Tout is less than Troom, the output of the Transduc atomic model which is HeatloosOut should be 25 – (25-24)*0.1 = 24.9.

It can be seen that the HeatlossOut at time 1 second is exactly 24.9. This shows that the Transduc atomic model is working as desired.

Test Case 2:

At time 2 seconds, the heater is feed with the control signal ‘1’. Hence, at the next time advance step, the output of the Heatgain (HGOut) should be equal to 0.5.

It can be seen that at time 3 seconds, the output of the Heater atomic model changes to 0.5 from 0 which shows that it is performing satisfactorily.

Test Case 3:

At time 4 seconds, we will now check the functioning of the Thermostat atomic model. At time 4 seconds, the Troom is 24.81 and Heatgain(HGOut) is 0.5, hence the desired output of Thermostat atomic model should be Troom = 24.81 + 0.5 = 25.31. Also, as the value of Troom is more than the setpoint which is 24.9, it should also change the ControlSignal Value from 1 to 0. It can be seen that the output of Thermostat model is Troom = 25.31 and ConOut = 0 which is correct.

Conclusion

We tested all the three atomic models individually providing different inputs to check proper functionality in all the different test cases. We found out from the simulation results that indeed all the three atomic models generated output as desired indicating proper functionality of the atomic models. Once we ensured proper functionality of all the atomic models, we then coupled all the three atomic models and check the functioning of all the atomic models when coupled together. After performing different test cases, we concluded that all the atomic models did perform as desired when coupled together and hence the top coupled model simulates a typical house heating system accurately.