THERMAL MODEL OF A ROOM IN MATLAB SIMULINK AND SIMSCAPE

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Abstract: This paper deals with creating a thermal model of a room using Matlab Simulink and Simscape library. The model is created based on building documentation and it is evaluated against the measured temperature with good compliance. The model can be beneficially used for control algorithm verification, which is quite time consuming in real-time due to large time constants. Using the proposed model the development time can be substantially reduced.

Keywords: Room thermal model, Matlab, Simulink, Simscape

1 INTRODUCTION

Temperature control of individual rooms is getting more popular, because needed devices are much smaller and cheaper. In the past Individual Room Control (IRC) was used only for laboratories and other rooms with strict demand on temperature. Nowadays the IRC is becoming widely used in both the commercial and residential buildings. This allows energy savings using precise control and scheduled heating and cooling. The control algorithms must be designed properly to achieve a needed thermal comfort and some energy savings. Some kind of thermal model is beneficial for the algorithm development and verification, as the real experiments are time consuming, expensive and sometimes unfeasible.

In this paper we propose a dynamic thermal model of a selected room, which is based on Matlab Simulink and Simscape library [1]. The model was created based on building documentation, so the model is not dependent on any experiment or measurements.

The advantage of using Simscape library is the ability of modeling the room as a physical system based on real properties of the room (wall thickness, materials, dimensions, radiator and fancoil thermal power etc.).
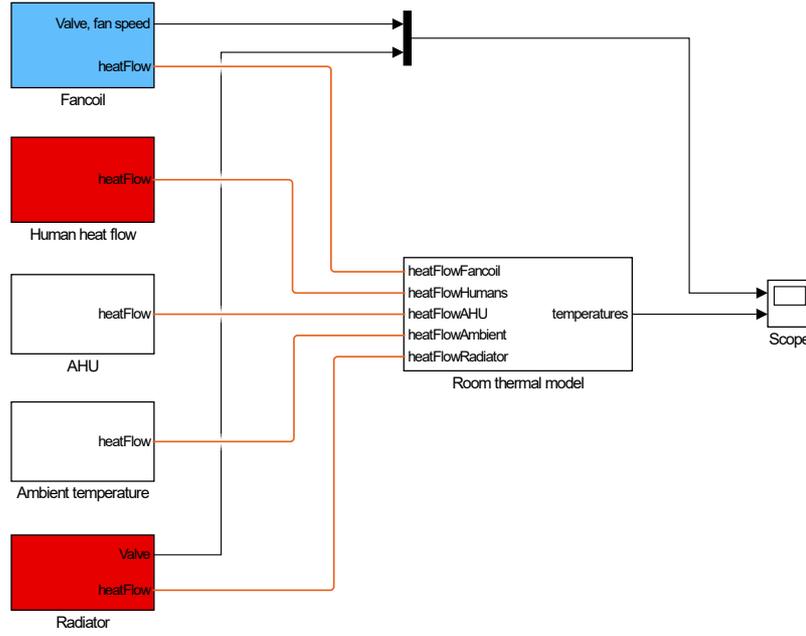
2 ROOM THERMAL MODEL

The whole model was constructed using Matlab Simulink and a library Simscape. The usage of this library is very beneficial since there are predefined blocks allowing thermal modeling. Similar approach as in [2] and [3] was used during the model construction.

The model was divided into multiple subsystems to keep it well organized. These subsystems are connected together by heat flows between them. The resultant model is shown in Fig. 1 and its parts will be described in the following text.

2.1 ROOM STRUCTURE THERMAL MODEL

The room structure model is the most important and the most complicated part of the model. The overview of room structure model can be found in Fig. 2. As can be seen in mentioned figure, the

Figure 1: Complete thermal model of a room

room model consists of room air, walls, ceiling, floor, windows and doors. The room model is also connected to other rooms by appropriate walls and also it is influenced by ambient temperature across the windows, wall and ceiling.

Each construction element (wall, ceiling, floor etc.) is composed from quite large number of layers (see Fig. 3), which correspond to composition of real element. Each layer has its heat capacity defined by the material and the mass and it is modelled using *Thermal Mass* block. Although the layers are connected together by heat flows, which are modelled using *Conductive Heat Transfer*. An example of the model of one layer is in Fig. 4.

2.2 AIR HANDLING UNIT

A model of central air handling unit (AHU) is modelled based on amount of air supplied and exhausted to and from the room based on equations from [4]. The heat flow caused by AHU air supply can be written as

$$Q_1 = c_a \dot{m}_a T_{a1}, \tag{1}$$

where Q_1 is heat flow, c_a is the air specific heat capacity, $\dot{m}_a$ is air mass flow rate and T_{a1} is temperature of the supplied air. The heat flow due to the air exhaust can be described by

$$Q_2 = c_a \dot{m}_a T_{a2}, \tag{2}$$

where Q_2 is heat flow, T_2 is the temperature of exhausted air and we assume that specific heat capacity and mass flow rate are the same for air supply and exhaust. The resulting heat flow caused by AHU can be after combining 1 and 2 written as
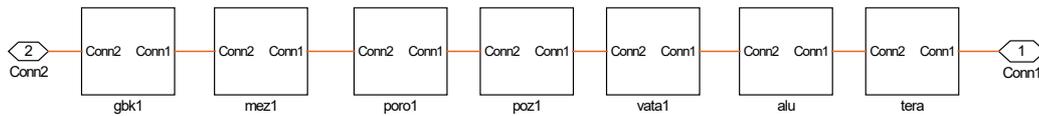
$$Q_{AHU} = c_a \dot{m}_a (T_{a1} - T_{a2}). \tag{3}$$

2.3 HUMAN HEAT DISSIPATION

Human heat dissipation is modelled as a heat source, which is connected to the room air. We assume that each human dissipates approximately 87 W according to [5]. We consider only basal metabolism
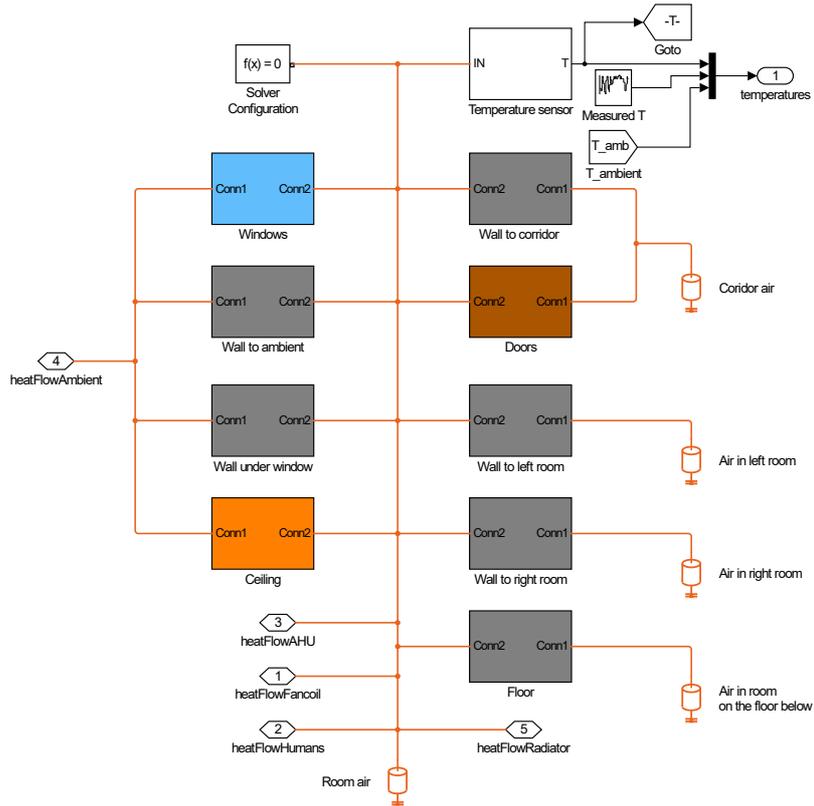
Figure 2: Room structure thermal model

Figure 3: Example of room wall

as we do not expect hard working people in this room (which is office type). To allow comparison of model and measured data, we set up a occupancy scheduler, which contains a number of people present in the room during periods of time.

2.4 RADIATOR THERMAL MODEL

For simplicity we consider a radiator as a heat source. To represent a real behaviour, we incorporated a second order dynamic system. The first time constant is introduced by a radiator valve, the second one is caused by the radiator.

$$G_{rad} = \frac{1490}{(200s+1)(800s+1)} \qquad (4)$$

2.5 FANCOIL THERMAL MODEL

Fancoil thermal model is similar to the radiator model. But it is only a first order system as a valve is very fast and it can be neglected. Obviously the gain of the fancoil thermal model is different, as the
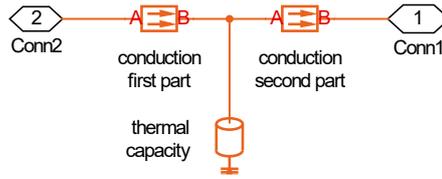
Figure 4: Example of wall layer

fancoil has different thermal power.

$$G_{FC} = \frac{4700}{300s + 1} \tag{5}$$

3 SIMULATIONS

The model was evaluated against the measured data in several simulations. We were able to get historical temperatures, valves settings, heating water temperature, ambient temperature and AHU supply air temperature from a database, which is been used for data logging. Furthermore we added occupancy estimation to complete the inputs of the model. In Fig. 5 there is a comparison of measured and modeled temperature during winter (heating with the radiator). The time span is one day and a setpoint of temperature was 23 °C. It can be seen that there are small deviations of modelled temperature from the measured temperature, but the overall compliance is very good.
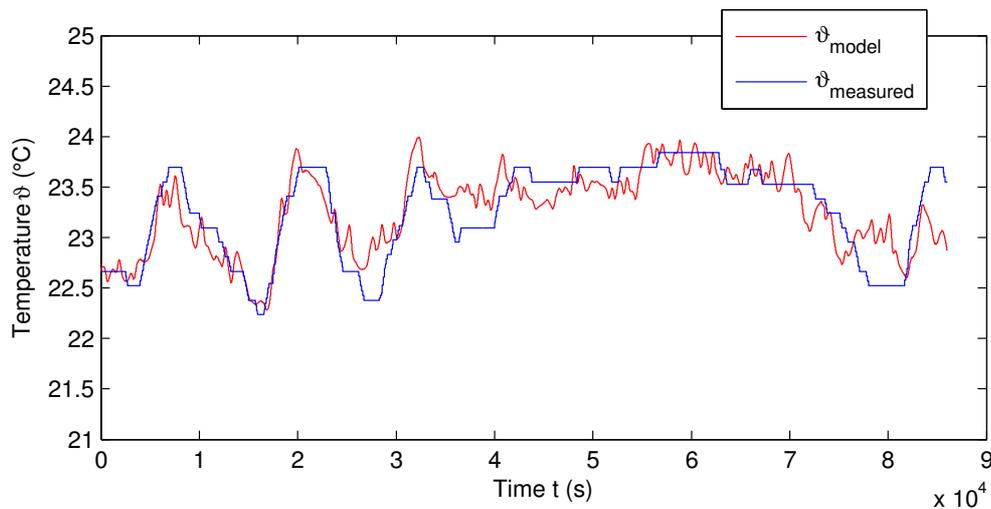
Figure 5: Comparison of Simscape model and measured temperature during heating

The second example is from hot summer, when it is needed to cool the room using fancoil due to heat gains from ambient and the human dissipation inside the room. The resulting modelled temperature in Fig. 6 is quite well matching the measured temperature. The temperature setpoint was also 23 °C. It can be seen that during some time intervals the modelled temperature is lower than the measured, it can be caused by room equipment heat losses (like computers and other machines) or solar heat transfer, none of these influences are included in the model.
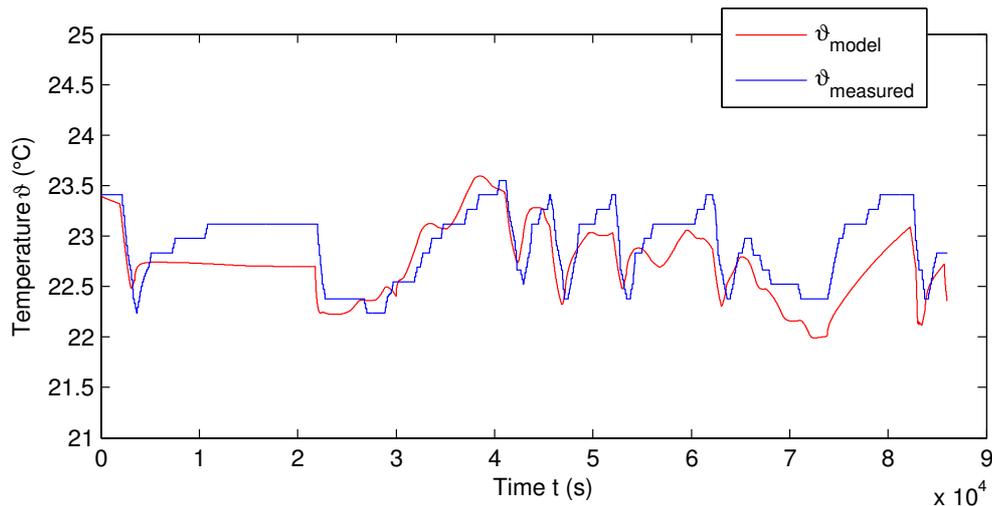
Figure 6: Comparison of Simscape model and measured temperature during cooling

4 CONCLUSION

In this paper we investigated an approach to creating a dynamic thermal model of the room, which was created using Matlab Simulink and especially Simscape library. This model was constructed based on building documentation and the process of construction can be easily repeated for another room (if the documentation is available). After comparison of modelled and measured temperature the model can be regarded as a good replacement of real room for evaluation of control algorithms. And the usage of the model can considerably shorten a time needed for algorithms development as the simulation is much more faster compared to the real experiments.

ACKNOWLEDGEMENT

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