Identification Of Building 27 Thermal Parameters

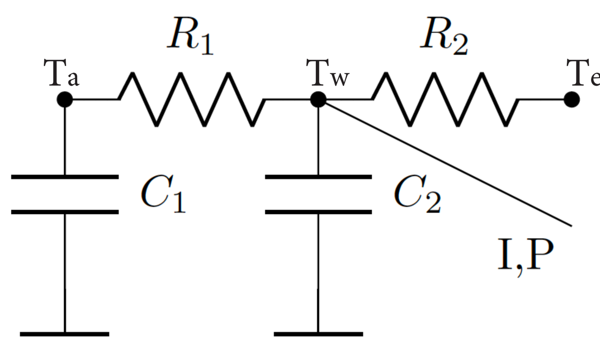
Steffany De La Torre, Emre Can Kara, Claudio Rivetta
SLAC National Acceleratior Laboratory

INTRODUCTION

Understanding the thermal parameters of buildings can help improve Heating, Ventilation and Air-Conditioning. In order to understand the parameters of buildings, first we built a model that simulates the thermal behavior of Building 27 on SLAC's campus. Then, we collected temperature data to estimate the parameters of Building 27 using this model. The motivation behind this work is to come up with a model that captures the thermal behavior accurately and using this model to improve the energy efficiency of Building 27.

METHOD

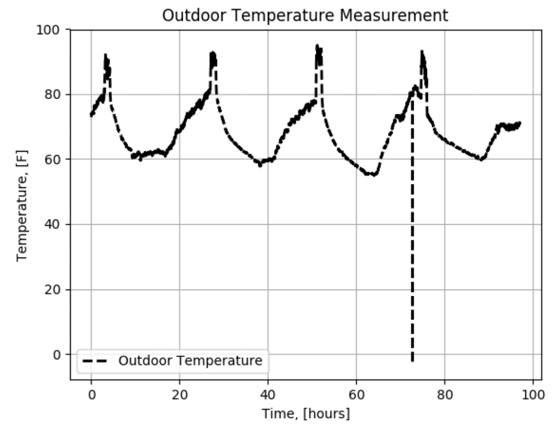
There are many different approaches to parameter estimation in buildings, one of which is using thermal networks. Thermal networks represent heat flow through a building using equivalent circuit diagrams. In its simplest form, thermal networks are built using a capacitor and a resistor, however often times this results in an over-simplified model. In this work, we used a more complex model as depicted in the next column. This model consists of three resistors and two capacitors. One can use the following heat flow equations to capture the thermal behavior of the building.

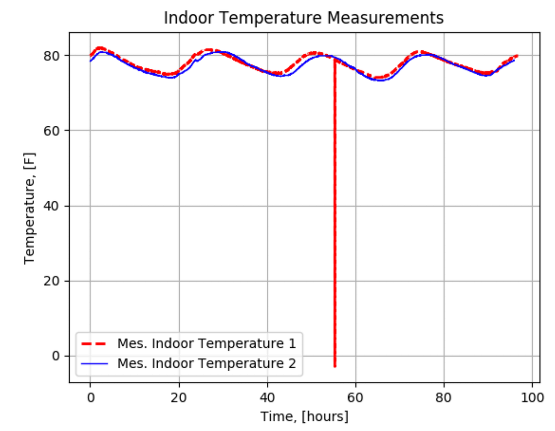


Using the model we were able to create two differential equations. In order to solve for the differential equations, all of the variables needed to be known. However, these equations can also be used to estimate thermal parameters of the building such as resistors and capacitors using measured temperature data as ground truth. For that reason, data acquisition systems with temperature sensors were built, and placed in certain locations within and outside the building to collect data of temperature. Below are plots of the collected data.

$$C_1\frac{dT_a}{dt} = P + \frac{(T_w - T_a)}{R_1} + \frac{(T_e - T_a)}{R_3}$$

$$C_2\frac{dT_w}{dt} = \frac{(T_a - T_w)}{R_1} + \frac{(T_e - T_w)}{R_2}$$





This model can be represented with the following A and B matrices in the following state space

$$A = \begin{bmatrix} -(\frac{1}{R_1 \times C_1} + \frac{1}{R_2 \times C_1}) & \frac{1}{R_1 \times C_1} \\ \frac{1}{R_2 \times C_1} & \frac{-1}{R_2 \times C_2} \end{bmatrix} \quad B = \begin{bmatrix} \frac{1}{R_1 \times C_2} & \frac{1}{C_1} & 0 \\ 0 & 0 & \frac{1}{C_2} \end{bmatrix}$$

representation. Since we were not able to measure irradiance directly, we came up with two different sinusoidal functions to serve as irradiance inputs to our model. The reasoning behind having two different irradiance inputs is to capture different times of the day where the sun directly hits a different wall of Building 27.

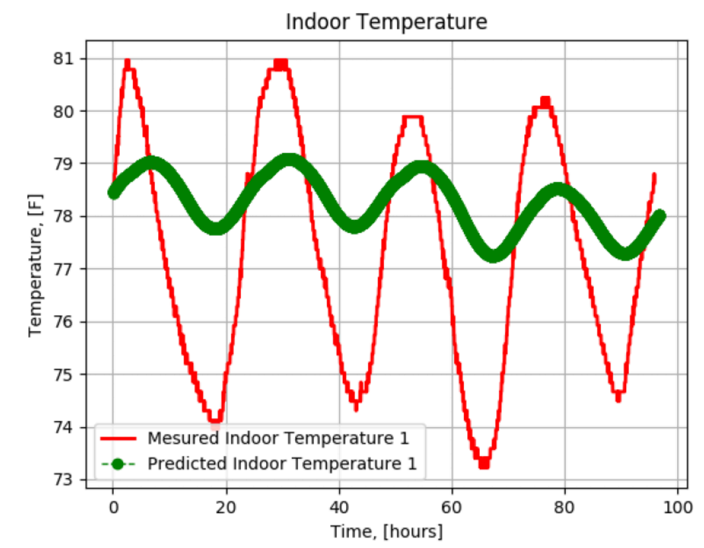
Below are the nalized sinusoidal functions that are used as inputs, we only use the positive values of these functions.

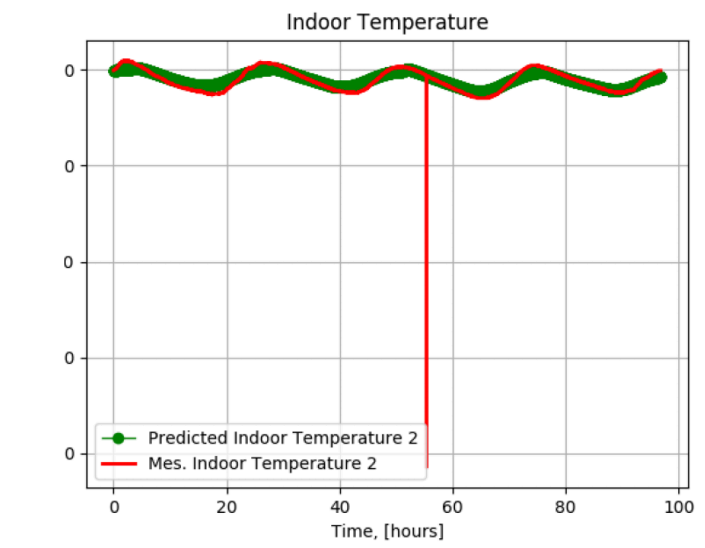
$$Tirr1 = 2 + 27 \times sin(\frac{8 \times pi \times (1:1:N)}{N+1} + \frac{0.85 \times pi}{2})$$

$$Tirr2 = 5 + 20 \times sin(\frac{8 \times pi \times (1:1:N)}{N+1} + \frac{0.5 \times pi}{2})$$

We created a Julia code to run the thermal model given different R and C values to observe the thermal behavior of the system. We then compare the indoor temperatures measured at two different points with the estimates that come out of this model.

RESULTS





The previous figures include the two indoor temperatures that were estimated using the thermal network model described earlier.

For temperature 1, we believe that the capacitance 1 is under estimated and the resistance between the wall and the ambient is over estimated. Additional data and analysis can help us fine-tune these parameters. For temperature 2, the proposed thermal network model does a better job, and we believe that the corresponding R and C estimates are close to their real-values.

CONCLUSIONS

In order to improve Heating, Ventilation and Air-Conditioning in buildings, we need models that can represent the thermal behavior accurately. In this work we have provided a simple thermal network model to capture the temperature dynamics of a lab building at SLAC National Accelerator Laboratory. For future research more experiments need to be completed to fine-tune the thermal parameters. It would be very helpful to include more sensors that cover more area in the building such as different walls or windows. Experiments can also include trials where the air-conditioner or heater are activated. There can also be further research in which we measure the irradiance to have a more appropriate model and method to estimate it.

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