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Estimating Building Envelope Thermal Characteristics from Single-Point-in-Time Thermal Images

Estimating Building Envelope Thermal Characteristics from Single-Point-in-Time Thermal Images

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Research Objective: Develop an At-Scale Approach for Estimating R-values for Exterior Walls and Roofs from Drive-By and Aerial Thermal Images

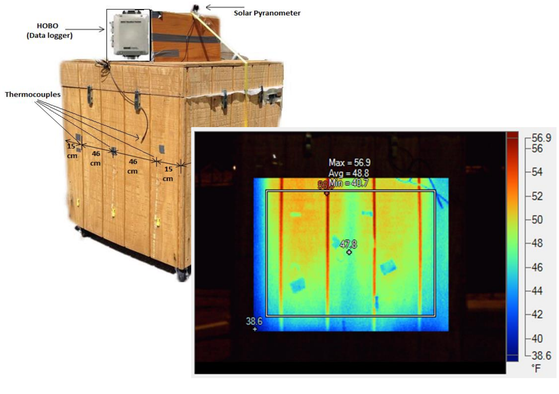
Introduction/Motivation

Traditional building energy audits are:

- Expensive.(US$0.50/sf)
- There are not enough energy auditors for US buildings (~100M)
- Qualitative, as single point in time images are strongly effected by prior weather conditions and emissivity.

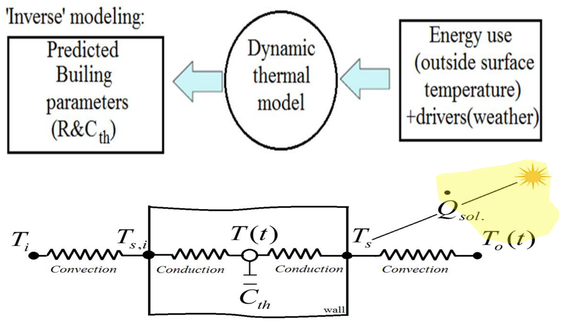
Methodology

Fly over image – University of Dayton – Dec. 27, 2014
(Acknowledgement: Woolpert LLC)



I. Physics based estimation of R-values

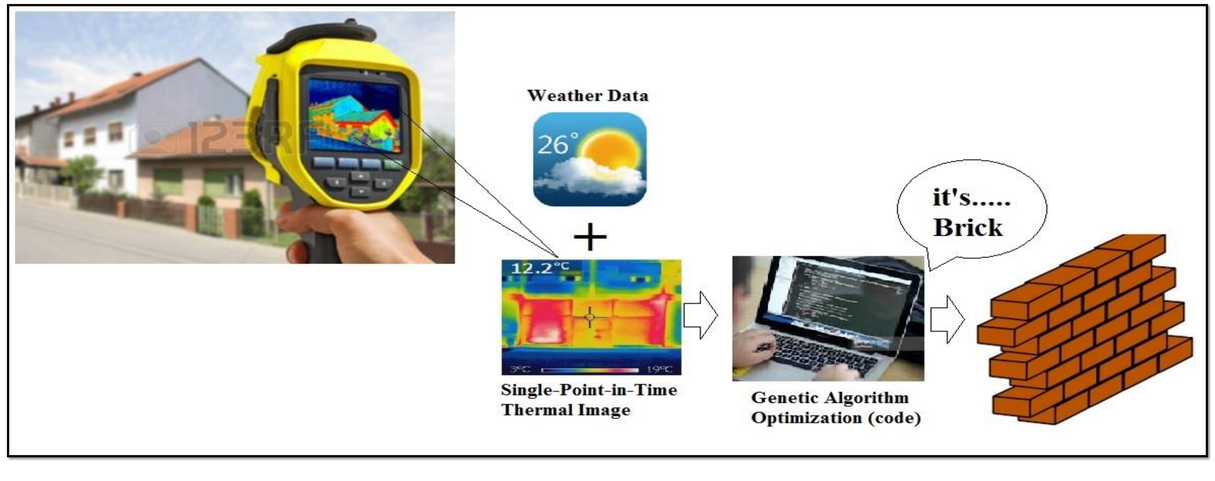
Utilize an inverse model to predict thermal resistance
and capacitance



$$mC_p\frac{dT}{dt}=\frac{T_i-T(t)}{R_{Conv,i}+\frac{R_{Cond.}}{2}}+I\alpha-\frac{T(t)-T_o(t)}{R_{Conv,o}+\frac{R_{Cond.}}{2}}$$

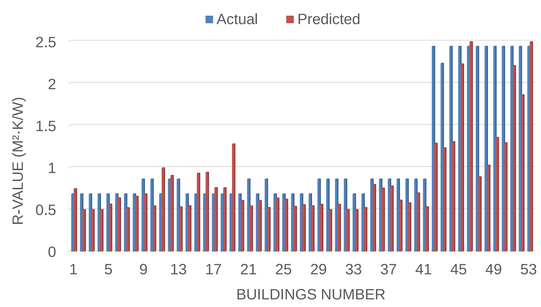
Prediction of R- and C- Values:
Dynamic **Genetic Algorithm** Inverse Model

Find R and C which minimizes:
$\left|T_{S,Measured}-T_{S,Predicted}\right|$



Physics Based Model Results (Wall)

Predicted vs actual wall R-value for UD residences

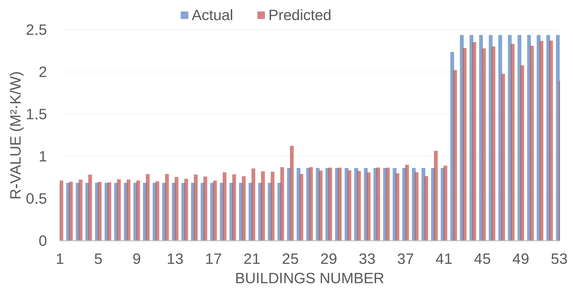


Good at predicting low, medium, and high R-value but not necessarily the magnitude of the R-value.

II . Data mining method

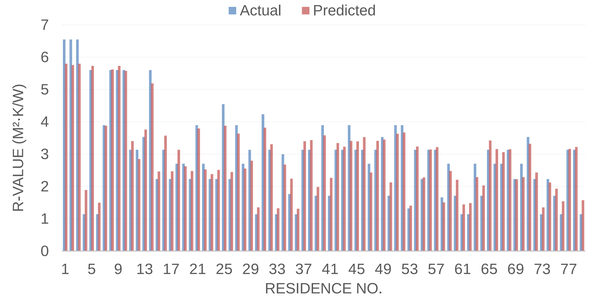
- Random Forest model is developed using the training set comprised of the residences with known R-values for 12 of the houses in the student neighborhood.
- Use model to predict R-values of all other houses from thermal image and other data.

Data Mining Model Results (Wall)



R-squared value in predicting R-value = 0.98!

Data Mining Model Results (Ceiling)



R-squared value in predicting R-value = 0.97!

CONCLUSIONS

- Demonstrated potential of approach to fairly accurately estimate a wall's R- and C-values when the wall emissivity is known or when there is a calibrated temperature measurement made on a surface
- The results indicate that accurate R-value prediction \can be obtained for a relatively small set of training houses
- This approach offers clear opportunity for conducting low cost energy audits at scale.

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