The University of Texas at Austin
Civil, Architectural and Environmental Engineering
Cockrell School of Engineering

INTELLIGENT ENVIRONMENTS LABORATORY

Occupant-Centric Grid-Interactive Buildings

8. Occupant Centric Building Design and Operation

CE 397

Spring 2024

Prof Dr Zoltan Nagy

Tentative Course Outline / Schedule

Week	Class	Topic	Guest Lecture
1	01/17	Introduction / Overview / Python	
2	01/24	Machine Learning I	
3	01/31	Machine Learning II	
4	02/07	Machine Learning III	Justin Hill (Southern)
5	02/14	Occupant Behavior Modeling	
6	02/21	Occupant Behavior Modeling	Tanya Barham (CEL)
7	02/28	Occupant Behavior Modeling	Jessica Granderson (LBNL)
8	03/06	Occupant Behavior Modeling	Hussain Kazmi (KU Leuven)
9	03/13	Spring Break	
10	03/20	Advanced Control & Calibration	Ankush Chakrabarty (MERL)
11	04/27	Calibration	Donghun Kim (LBNL)
12	04/03	Introduction to CityLearn	
13	04/10	Project Work	Siva Sankaranarayanan (EPRI)
14	04/17	Project work	
15	04/24	Project work	

Plan for today

- Short recap
- Advanced Simulation methods for OCC

- continue on HW 4
- intro to HW5

Advanced occupant modeling

one or more of the following possible and desirable traits

- \- **Stochastic:** A randomness to consider the reality that occupants' individual decisions are often diverse, unpredictable, and inconsistent
- \- **Dynamic**: The recognition that conditions (e.g., air temperature) alter the way occupants behave and locate themselves within a space.
- \- **Data-Driven**: The trait that occupant models are generated based on measurements.
- \- **Agent-Based**: The acknowledgement that occupants interact with buildings and/or each other through a series of decisions that are likely a result of one or more conditions

Stochastic models

- stochastic = probabilistic
- make use of stochastic processes to reproduce occupancy and a variety of behaviors
- results in probabilistic distribution of predicted results
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Model type	Typical purpose	Application
Binomial model	Data analysis (e.g., to understand which factors influence occupants to execute an action) and stochastic modeling (e.g. to simulate a human operations in building performance simulation software)	A model for predicting binary outcomes (e.g., yes/no, awake/asleep, open/closed, opening action/closing action)
Markov Chains	Stochastic modeling with time dependencies (e.g., to model an event that is more likely to happen at particular time of day, or particular day of week)	A model for predicting outcomes with *n* states, where *n* can be an integer and represent, for example, specific locations in a building, occupant presence (e.g., present and awake, present and asleep, absent), or position of a window (open, half opened, closed), e.g., at different time of the day

binomial model

- Well established
- Analyze/model binary variables (on/off, yes/no, up/down)
- Often called *logistic regression*
- example: state of a window (open/close), state change of a window (from closed to open)

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p(x). expresses the probability function for a certain event to happen

$$p = \frac{1}{1 + e^{-(\propto + \beta x)}}$$

$$ln\left(\frac{p}{1-p}\right) = \propto + \beta x$$

example window state change depending on an explanatory variable x (ex temperature)

$$ln\left(\frac{p}{1-p}\right) = \propto + \beta_0 x_0 + \beta_1 x_1 + \cdots + \beta_n x_n$$

occupants in simulation-aided design

- How to integrate occupant models into simulation design process?

occupants in simulation-aided design

Two-key questions to decide:

1. Do the occupant models respond to the iterative changes of building design or not? That is, are the occupant models static or dynamic in relation to changes in building design?

2. Are the occupant models themselves subjected to iterative changes in the design process or not? That is, are the occupant-related assumptions among the fixed or variable parameters the designers deal with?

occupants in simulation-aided design

Static Occupant Behavior Model as fixed design parameters - simplest form, widely adopted - static assumptions for different spaces (maximum/ schedules of occupancy, equipment use)	

occupants in simulation-aided design

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- simplest form, widely adopted - static assumptions for different spaces (maximum/ schedules of occupancy, equipment use)	- study implications of different occupancy patterns - example: control max number of occupants

occupants in simulation-aided design

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Dynamic Occupant Behavior Models as fixed design parameters - two-way relationship between design performance and occupant behavior (stochastic or deterministic)	

occupants in simulation-aided design

Static Occupant Behavior Model as fixed design parameters - simplest form, widely adopted - static assumptions for different spaces (maximum/ schedules of occupancy, equipment use)	**Static Occupant Behavior Models as design variables** - study implications of different occupancy patterns - example: control max number of occupants
Dynamic Occupant Behavior Models as fixed design parameters - two-way relationship between design performance and occupant behavior (stochastic or deterministic)	**Dynamic Occupant Behavior Models as design variables** - dynamic/data-driven occupant behavior models

Your turn: Performance based design of a window

In a performance-based design of a window, the designer/modeler aims to find the optimum size of the window that minimizes the energy demand of an office space in a typical year.

How is the problem set up in each of the four cases? What are the key differences?

Static Occupant Behavior Model as fixed design parameters	Static Occupant Behavior Models as design variables
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4 common simulated aided design methods at different design stages:

1. Uncertainty and Risk Assessment.

2. Sensitivity Analysis.

3. Parametric Design.

4. Optimization.

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4. Optimization. “the process of finding the best [design] alternative”

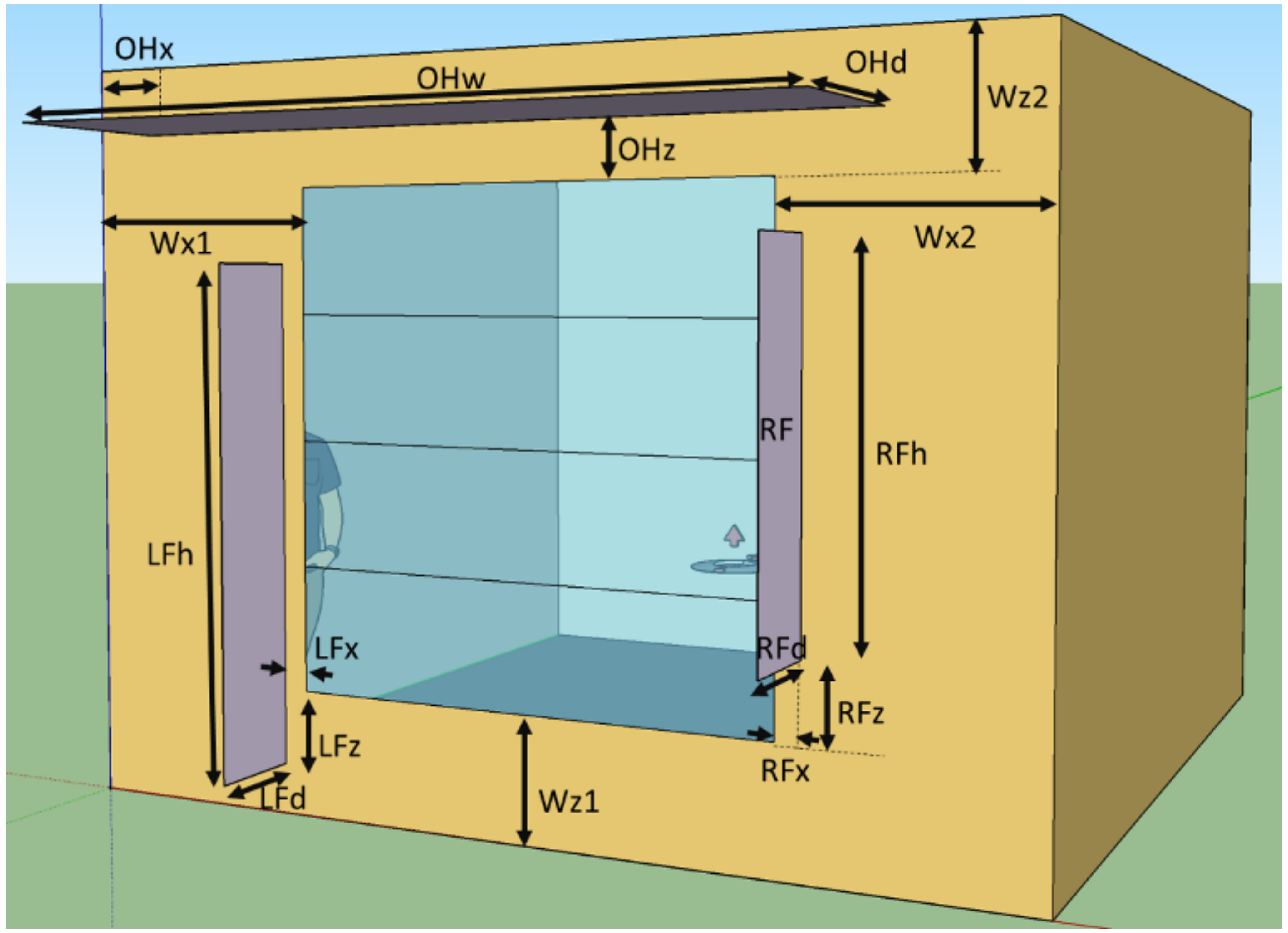
A prototypical testbed for simulation aided design

- A series of examples to demonstrate simulation-aided design

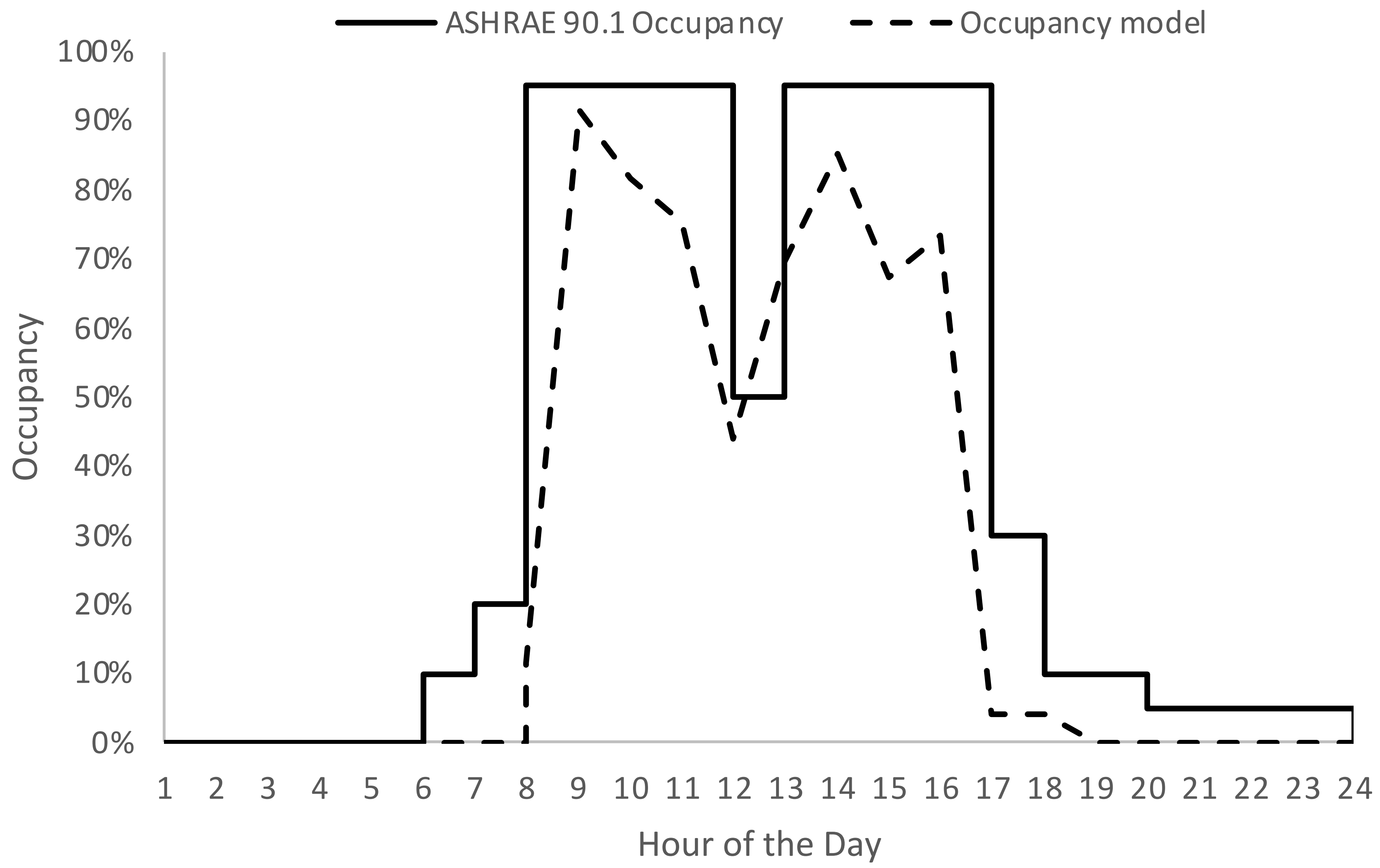
- shoebox office (W × L × H = 4.0 × 4.0 × 3.0 m)
- 3x2m window on South side

- location: Ottawa, Ca,
- simulated in EnergyPlus V8.8,
- using Canadian typical weather file

- typical settings



Ex: demand controlled ventilation (DCV)

- DCV = provide ventilation according to the number of people in the room
- Comparison of deterministic (fixed) vs stochastic occupancy and its effect on ventilation
- 

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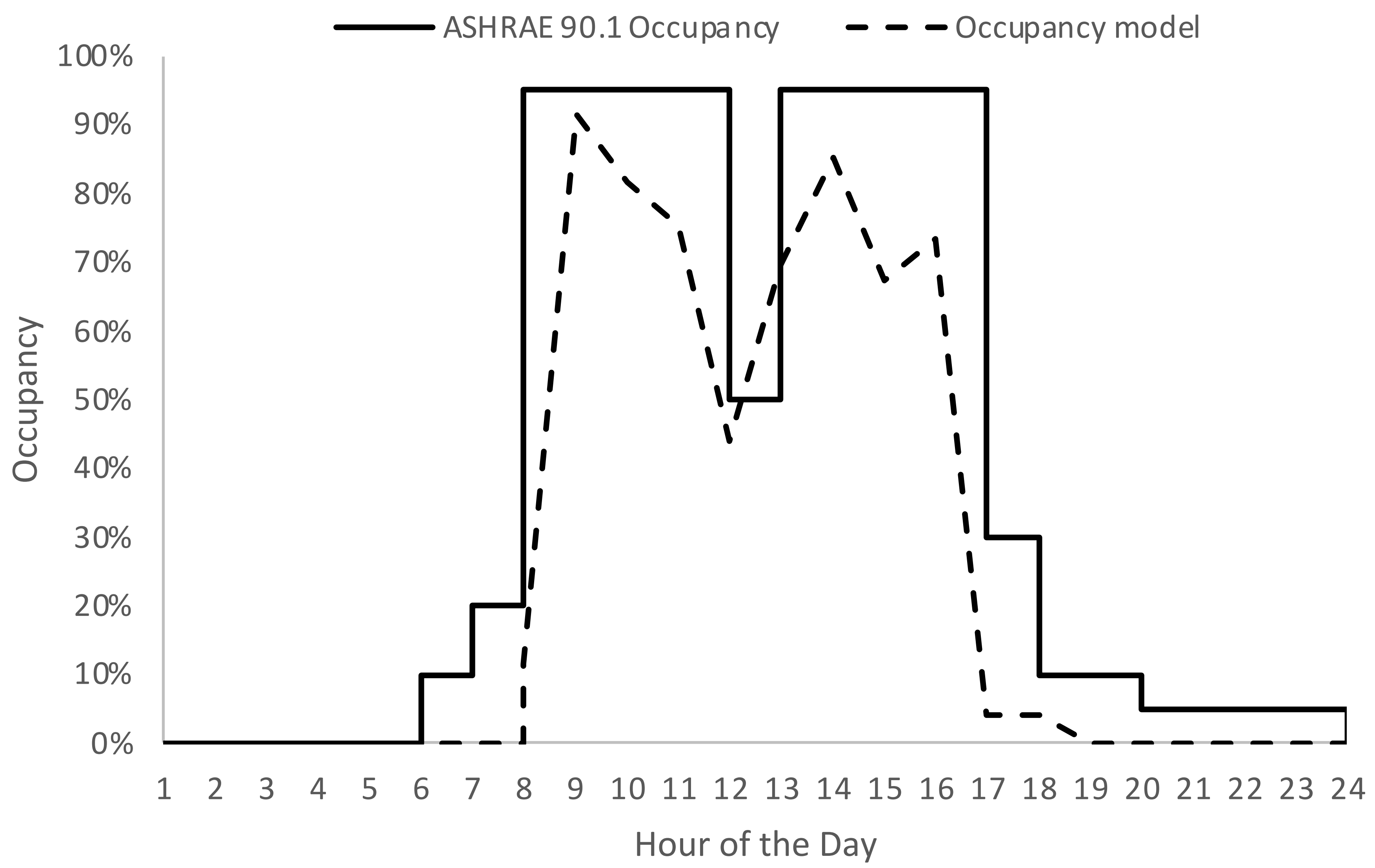
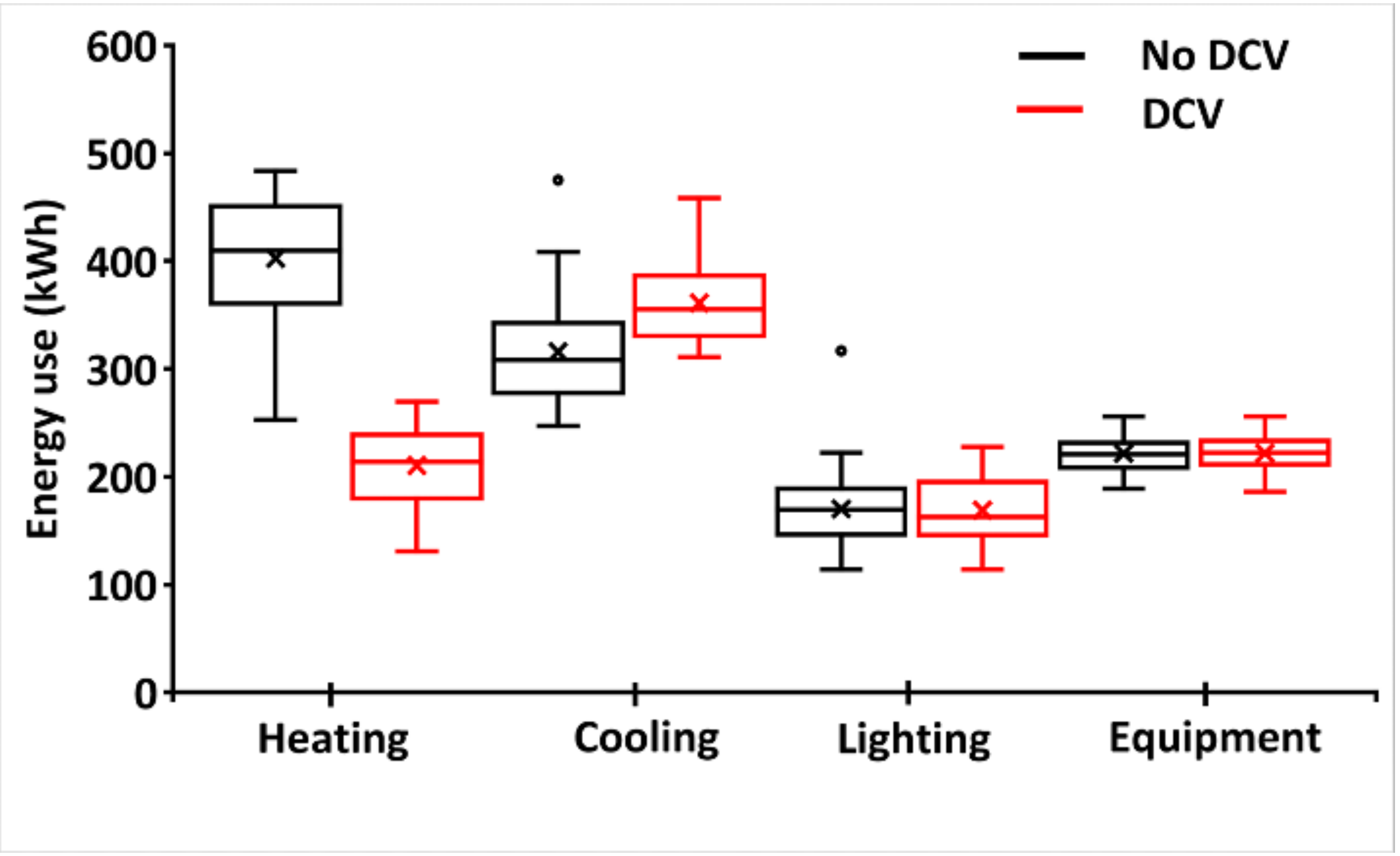
- 



Ex: Shading Design optimization

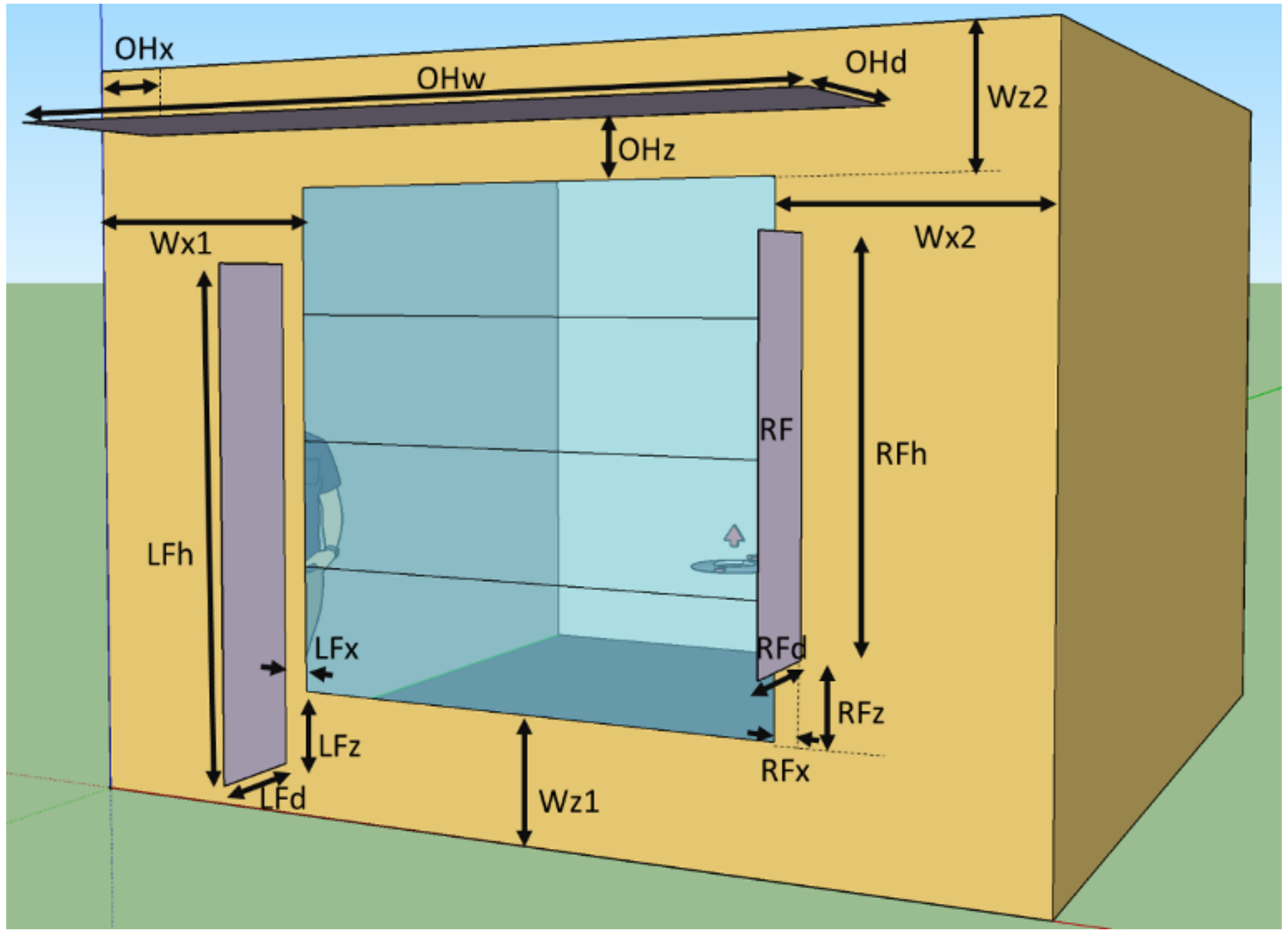
optimize fixed shading size to reduce frequency of glare

- stochastic occupancy, lighting and shading models (light and shade are operated manually)

- each model is ran 50 times to obtain daily mean and standard deviation

- focus on lighting energy

- optimization using genetic algorithm in MATLAB calling energyPlus



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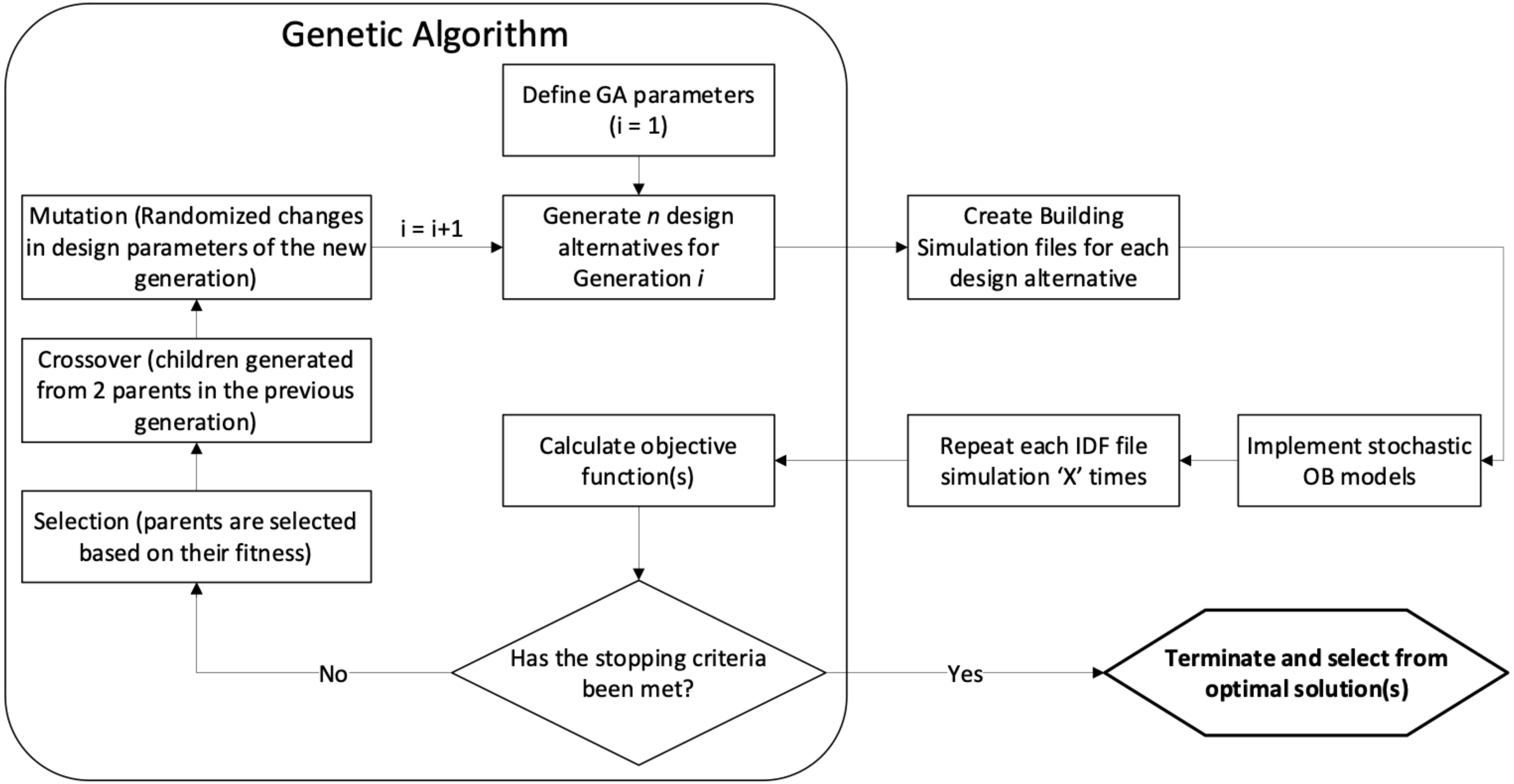

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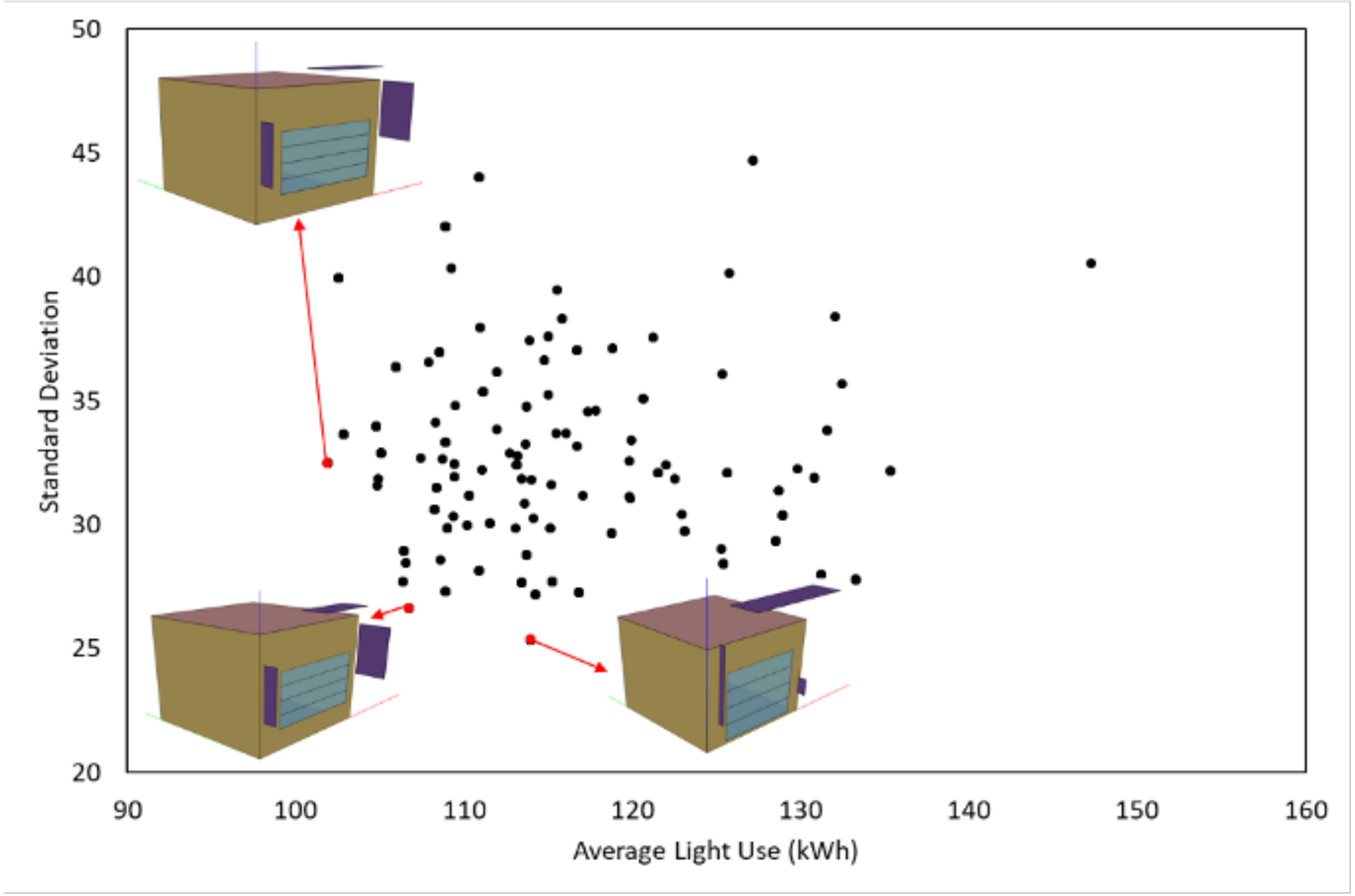

Break

Activity

Read paper

Modeling occupancy in single person offices

by Danny Wang & others

Energy and Buildings (37) 2005, p. 121-126

Questions to answer:
- what kind of occupancy sensing technology do they use?
- how is the data organized (range, resolution)?
- what kind of analysis is performed?

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Energy and Buildings 37 (2005) 121–126

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Modeling occupancy in single person offices

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Homework 4

Use Wang05 paper to generate occupancy schedules:

1. Using the distribution parameters estimated in the paper for occupancy length, generate 1000 samples, and plot the probability distribution/histogram. Compare to Figures 3 and 6 in the paper.
2. Using the distribution parameters estimated in the paper for vacancy length, generate 1000 samples, and plot the probability distribution/histogram. Compare to Figures 4 and 7 in the paper.
3. Simulate ONE day of occupancy following the variables in Section 3.2
4. Simulate a year (365 days), generate average daily schedule and compare to Figure 10
5. Convert the occupancy schedule from 4 from minute resolution to hourly resolution.

Homework 4 Hints

First, of all remember that there are many possible solutions/ approaches.

1. the overall goal is to create an array with 0's (vacant/absent) and 1's (occupied).
2. each entry of the array will be either a 0 or a 1. So you can initialize an array with the length that you need to either 0 or 1, and then update the entries. One of the two makes more sense, think about it :)
3. think about the length of the array. What is the smallest time unit you want to represent? In the initial tips I mentioned to use one minute resolution.
4. now that you have an array of a certain length, you have to fill it with either 0's or 1's. you can treat the index of the array as the minute for which you decide whether or not there is occupancy

Homework 4 Hints

5. there are many strategies. they will probably include some sort of loop (either for loop or while loop). remember that the length of absence and presence are a) generated in minutes and b) are consecutive, so each presence period is followed by an absence period. You may have to make some assumptions.

6. you can generate the arrival/departure and lunch break times. you know that there is no occupancy before arrival, after departure, and during lunch, so all those entries have to be 0.

7. the arrival/departure/lunch times that you generate will be floating point (502.3min), but you need integers to use them as index in the array, so you need to cast the type into the correct format (if you're using this approach).

Homework 5

- Use HW4 and generate 100 occupancy profiles, save it as csv
- Run energy+ simulation for each profile and observe impact of occupancy on total energy use and cooling/ heating loads