Multi-Objective Optimization of High Performance Residential Buildings Using A Genetic Algorithm

BCIT SCHOOL OF CONSTRUCTION AND THE ENVIRONMENT

Kelvin Y.H. Liu, MASc. Student
Supervisor: Dr. Fitsum Tariku

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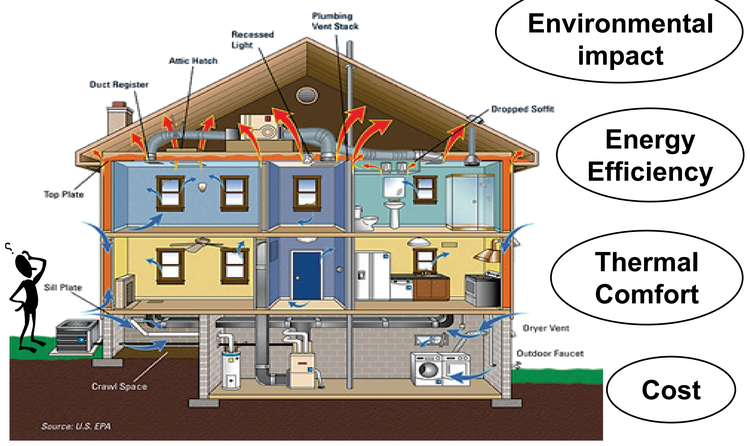
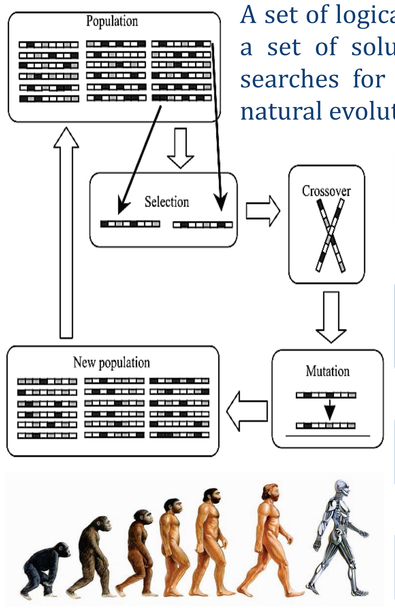
Introduction

Multi-Objective Building Optimization

Buildings are a complex system with a large design space, so finding the optimal design for a cost effective, energy efficient, and comfortable building can be extremely challenging. The traditional method of designing buildings rely heavily on designer experience and trial-and-error, but this can prove to be time and resource consuming. Multi-objective optimization takes advantage of the powerful computers we have today to search for optimal design solutions based on a pre-defined set of objectives.



What are Genetic Algorithms?



A set of logical operators that dictate how a set of solutions can be found, and it searches for it based on the concept of natural evolution found in biology.

1: Create initial random population of building designs

2: Select optimal designs for next generation

3: Select optimal designs from mixture of current and previous generation

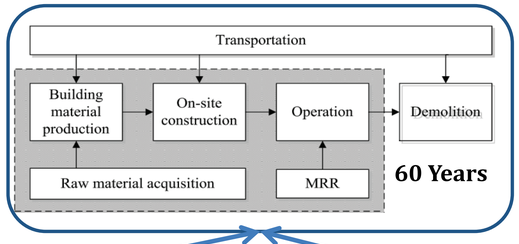
4: Repeat steps 2 and 3 until all optimal solutions discovered

Objective

To develop a building optimization framework using genetic algorithms and energy simulation that is easy for architects and engineers to use. The methodology is targeted towards single-family residential homes, but can be altered to optimize the energy efficiency, thermal comfort, cost, and environmental impact of multi-unit residential and commercial buildings as well. The primary focus will be on wood-framed construction applicable to a Canadian climate.

The Building Life Cycle

Current design practice mainly focuses on initial investment costs for buildings, but the entire life cycle of a building must be considered as well.



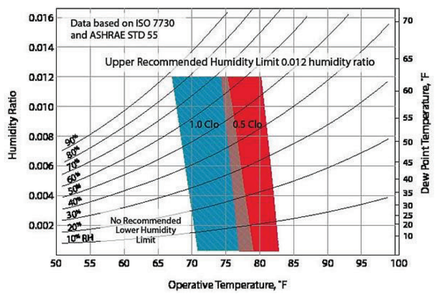
- Material Costs
- Construction Costs
- HVAC System Costs
- Energy Utility Costs
- Material Replacement Costs

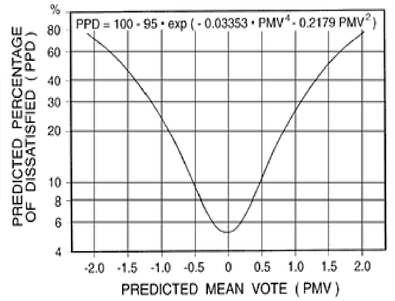
- Material Global Warming Potential
- Construction Phase GWP
- HVAC System GWP
- Energy Consumption GWP
- Material Replacement GWP

When the entire building life cycle is considered during early phase design, significant cost and environmental impact can be reduced, while ensuring energy efficiency and overall build quality.

Occupant Thermal Comfort

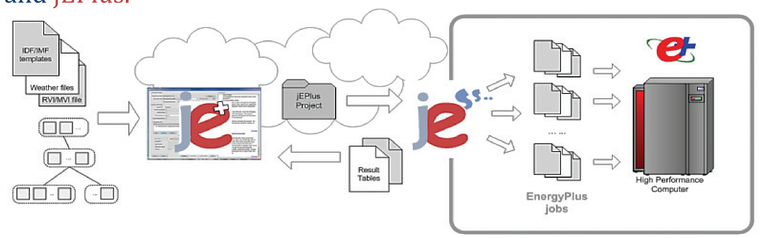
Ultimately, buildings are designed for people, so occupant thermal comfort is a crucial design objective that must be considered. Studies show that people perform their daily tasks better when the thermal comfort in a building is optimal. The primary method of determining occupant thermal comfort is based on the ASHRAE Standard 55 and the Fanger PMV model.





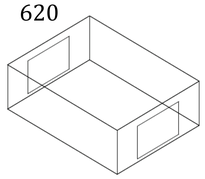
Methodology

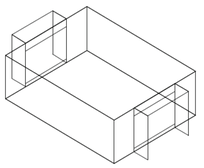
The methodology is developed using a combination of free open-sourced software tools available to the public; mainly EnergyPlus and jEPlus.



Validation & Case Studies

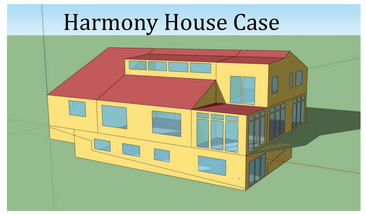
BESTEST Case 620



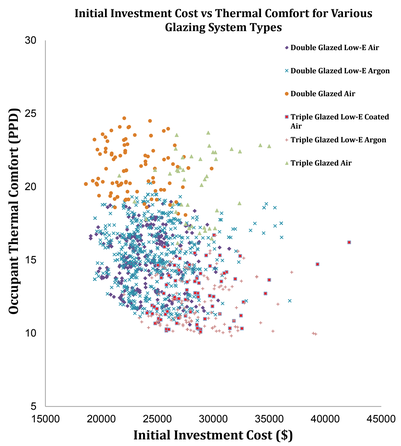


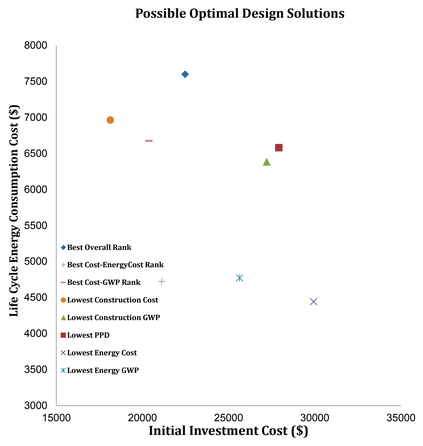
BESTEST Case 630

Harmony House Case



Expected Results





What's Next?

- Further develop an accurate and comprehensive database of material properties, life cycle costs, and life cycle environmental impact factors that is suitable for any location and climate
- Integrate framework into popular BIM and design software such as Revit or SketchUp
- Use this approach in everyday design by customizing the objectives, variables, and criterion weights to suit the designer and/or clients requirements
- Develop a solutions analysis tool that can further help designers choose from a more concise set of optimal solutions