BISCUIT: Building Intelligent System CUstomer Investment Tool

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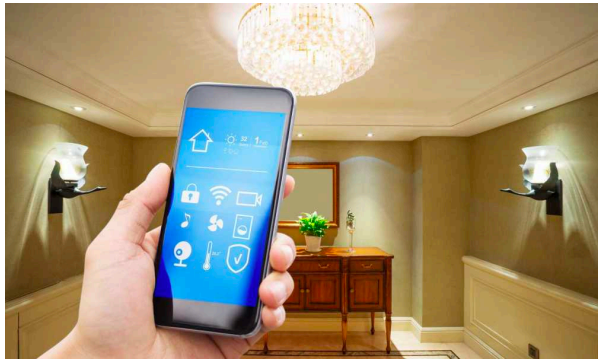
Design of smart buildings

Occupancy sensor selection problem

- Problem: which sensor to install to enable occupancy-based lighting?



	Sensor	Cost	Precision	Computation level	Lighting compatible
	environmental sensor: CO_2, temperature, etc.	Low	Low	High	Yes
	motion sensor: PIR	Medium	Medium	Low	Yes
	camera sensor	High	High	Medium	No

- What sensors are available? What are the costs?
- What are the precision? Do they require computational infrastructure?
- Are they compatible? Can they be shared by other systems (e.g. HVAC)?

Smart building design lesson #1:

In addition to costs,

we should also consider performance and functional constraints.

Heating ventilation and air conditioning (HVAC) system retrofit evaluation

- Problem: cost-benefit analysis of HVAC system retrofit plans

Candidate	Control	Computation level
Basic retrofit, no intelligent components	Basic control	Low
smart variable air volume (VAV) box	Demand-based control	Medium
smart HVAC system	Human-building interaction	High

- What is the annual cost of operation for the given building profile?
- Do they require additional computational infrastructure?

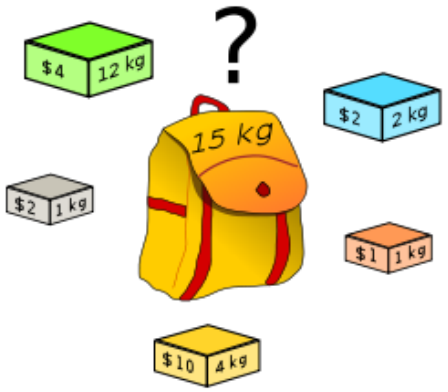
Smart building design lesson #2:

In addition to investment costs,

we should also consider available control strategies and operation cost.

“Knapsack problem” of smart buildings

- Original knapsack: which items should be chosen to maximize profits while not exceeding the weight limit?



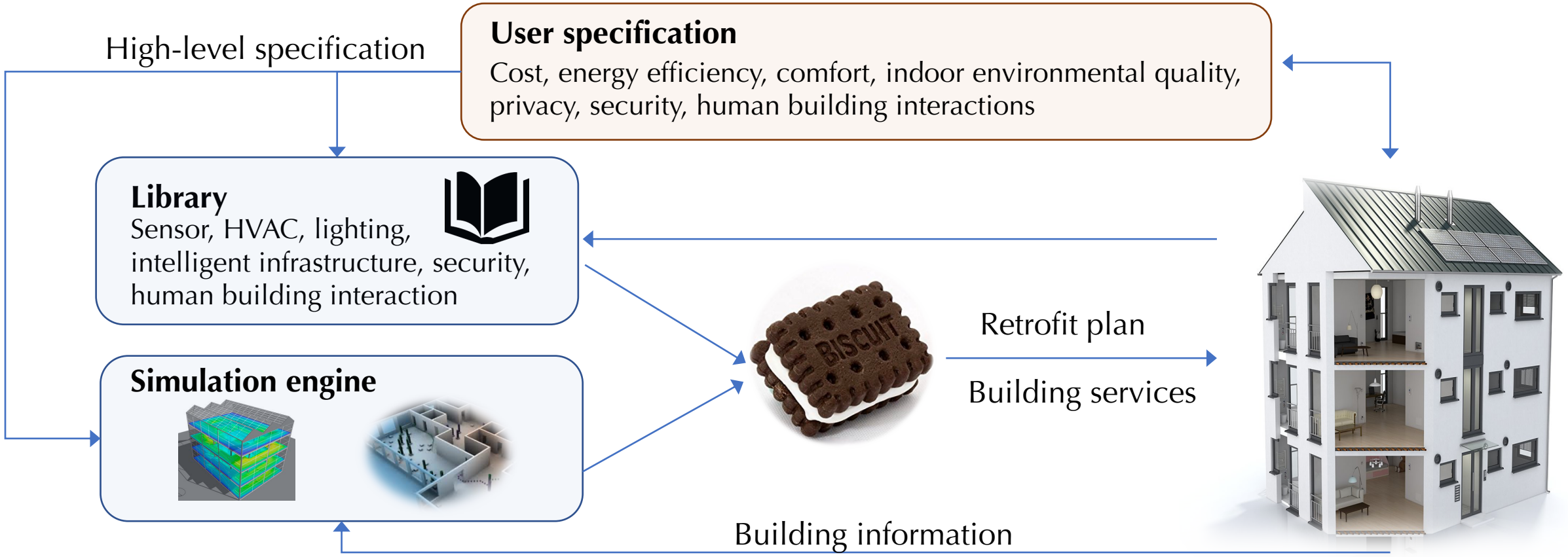
- Smart building version: which smart building technologies should be invested to maximize user satisfaction given limited budget?

Challenges

- Large-scale: >100K variables
- Nonconvexity (discrete optimization)
- Human-centric designs (soft constraints)

BISCUIT: **B**uilding **I**ntelligent **S**ystem **Cu**stomer Investment **T**ools

- Idea: Library + Optimization-based design space exploration



Functional-level abstraction

- Library: sensors, HVAC, lighting, intelligent infrastructure, etc.
- Component: properties and constraints

Library	Items	Properties	Constraints
Sensors	Available sensor models	Sensing modalities (environmental parameters, sound, visual), functions (presence/occupancy/indoor position/identity detection), cost	User specifications (privacy, IEQ, etc.); compatibility with intelligent HVAC/lighting/infrastructure
HVAC	Intelligent/ traditional systems	Vendor, investment cost, maintenance cost, rate power, efficiency, lifespan, supported control strategies	User specifications (intelligence upgrade, safety), requirement on the existence of compatible sensors and intelligent infrastructures
Lighting	Intelligent/ traditional systems	Vendor, investment cost, maintenance cost, rate power, efficiency, lifespan, supported control strategies	
Security	Available systems	Vendor, investment cost, subscription cost, lifespan	
HBI	Available systems	Maintenance cost, lifespan, control strategies, efficiency	
Infrastructure	Available packages	Vendor, cost, maintenance cost, lifespan	User specifications

Formulation of intelligent building design

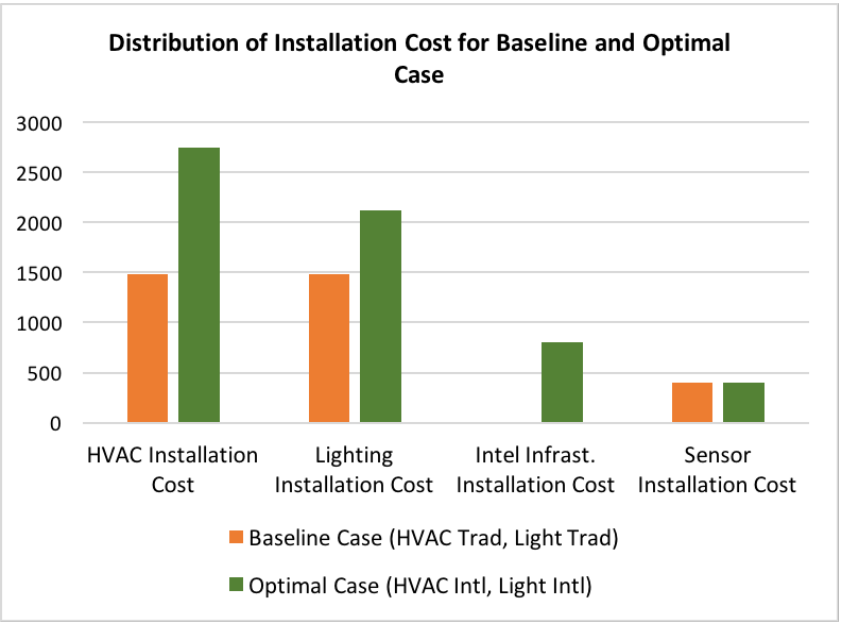
min **investment cost** + **annual operation cost**

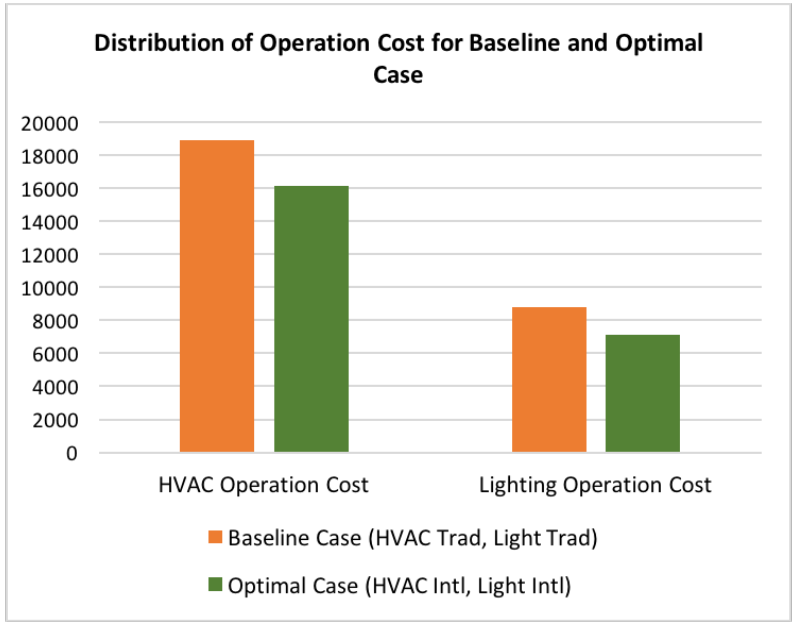
s.t. **(1)** user specifications
(2) technology constraints
(3) operation constraints

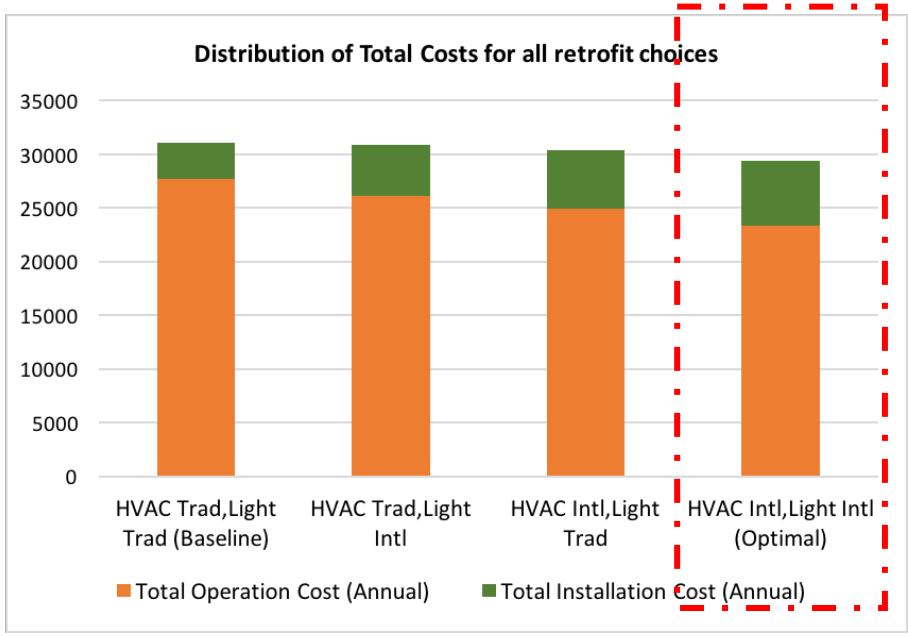
- Mixed integer linear program
- Optimization over both integer and continuous variables:
  - Investment decision (binary)
  - System control strategy (binary)
  - Operational variables (continuous)

Case study: medium-sized commercial building renovation

- Setup: a medium-sized building (40 rooms, 100 occupants) in California, USA
- RSMeans cost manual and market prices

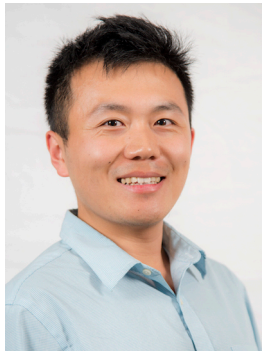


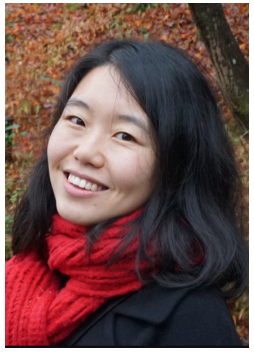


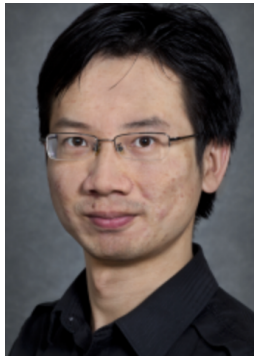


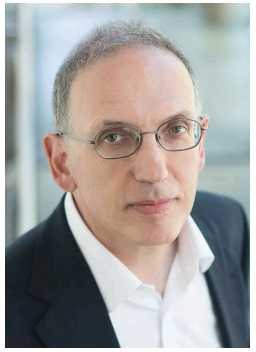
Acknowledgement

- Collaborators


Ming Jin


Ruoxi Jia


Wei Feng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