

Model Predictive Control for Buildings

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2026-04-27

Drawn on materials from:
Kevin Kircher's [Distributed Energy Resources](#) course,
[Drgoňa et al. \(2020\)](#), and [Khabbazi et al. \(2025\)](#).

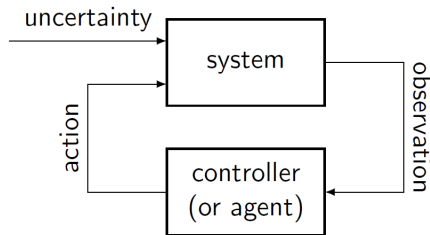
Why predictive control in sbsim?

- **reinforcement learning (RL)** control is already implemented in [sbsim](#)
- **model predictive control (MPC)** could serve as a benchmark against RL
- open the door to other predictive control strategies?
 - ◊ **data-driven predictive control (DDPC)**

$\overset{\text{Goal}}{\Rightarrow}$ give a short MPC overview and explain why predictive control may fit this project

Recourse and feedback in decision-making

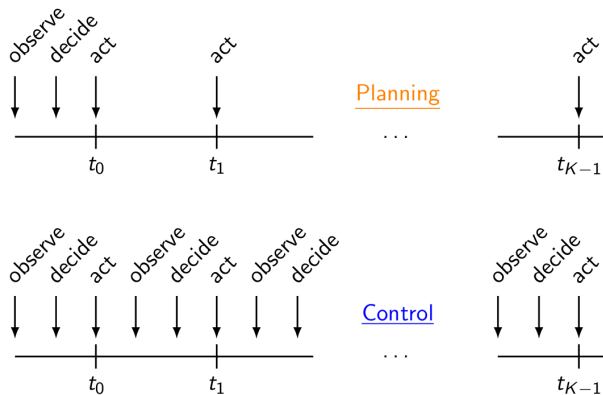
- often, new information becomes available over time
- the ability to adjust actions is called **recourse**
- repeatedly using recourse gives rise to **feedback**



- different frameworks for **sequential decision-making** under **uncertainty**
 - ◇ {feedback, stochastic, optimal, robust} control
 - ◇ multi-stage stochastic programming with recourse
 - ◇ Markov decision processes, reinforcement learning

Planning vs. control

- planning: decide once, then act
- control: observe, decide, and act repeatedly
- feedback helps handle uncertainty

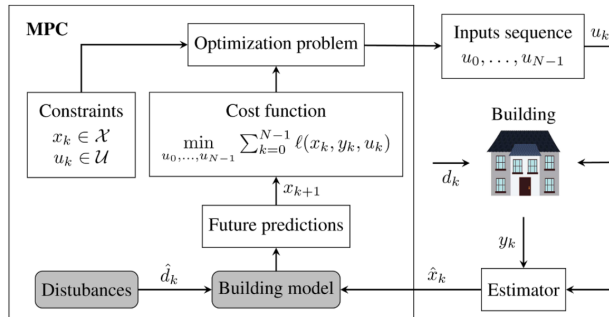


Model predictive control

- MPC is feedback control with repeated planning
- at each step:
 - ◇ observe current state
 - ◇ predict future behavior
 - ◇ solve an optimization problem
 - ◇ apply first control action
- repeat with new observations

observe → predict → optimize → act → repeat

MPC structure and key components



- x_k : states, e.g., zone temperatures
 - $\hat{x}_k$: estimated states
 - y_k : outputs, e.g., measurements
 - u_k : control inputs, e.g., HVAC actions
 - d_k : disturbances, e.g., weather, occupancy
 - $\hat{d}_k$: disturbance forecasts
 - $\mathcal{X}, \mathcal{U}$: state and input constraints
 - $\ell(\cdot)$: cost function
-
- building model predicts future behavior
 - optimizer computes input sequence $u_0, \dots, u_{N-1}$

Source: Dragoña et al. (2020), Fig. 2

MPC optimization problem

$$\begin{aligned} \min_{u_0, \dots, u_{N-1}} \quad & \sum_{k=0}^{N-1} \ell(x_k, y_k, u_k) \\ \text{s.t.} \quad & x_{k+1} = f(x_k, u_k, d_k) \\ & y_k = g(x_k, u_k, d_k) \\ & x_k \in \mathcal{X}, \quad u_k \in \mathcal{U} \end{aligned}$$

- minimize stage cost, e.g., energy use and comfort violations
- predict states and outputs using the building model
- enforce state and input constraints over the horizon

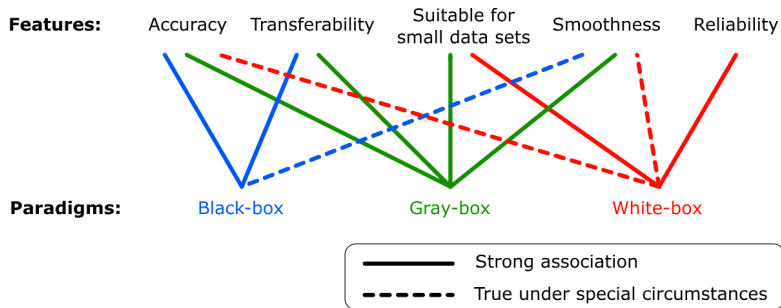
Source: adapted from Drgoňa et al. (2020), Sec. 2.1

Why MPC fits building systems

- buildings are slow systems with thermal inertia
- future loads depend on weather, occupancy, and internal gains
- comfort requirements and equipment limits create constraints
- MPC naturally combines prediction, optimization, and constraints

model + forecasts + constraints + objective $\Rightarrow$ control action

Modeling choices for MPC



- MPC requires a model of building dynamics
- white-box: physics-based (EnergyPlus, Modelica)
- black-box: data-driven (neural networks, regression)
- gray-box: physics + data (calibrated RC models)

Source: Drgoňa et al. (2020), Fig. 6; based on Afram and Janabi-Sharifi (2014) and Afroz et al. (2018)

MPC vs. RL: different approaches

	MPC	RL
decision	optimize online	learn policy
model	explicit	model-free or model-based
feedback	re-plan every step	act using learned policy
strength	constraints, interpretability	flexibility, learning

- same problem, different tools

Proposed MPC workstream in sbsim

- [sbsim](#) provides dynamics, observations, and control interfaces
- implement an MPC controller in sbsim
- define cost: energy + comfort violations
- compare against existing or future RL agents
- optional: DDPC or hybrid MPC + RL

Suggested reading and background

[Khabbazi et al. \(2025\)](#), *Lessons learned from field demonstrations of model predictive control and reinforcement learning for residential and commercial HVAC: A review*

- Sec. 2: **related literature reviews**
- Sec. 2.1: reviews of general building control
- Sec. 2.2: reviews of MPC for buildings
- Sec. 2.3: reviews of RL for buildings
- Sec. 2.4: reviews of MPC and RL field demonstrations

Thank you

Questions?

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