Data Efficient HVAC Control using Gaussian Process-based Reinforcement Learning

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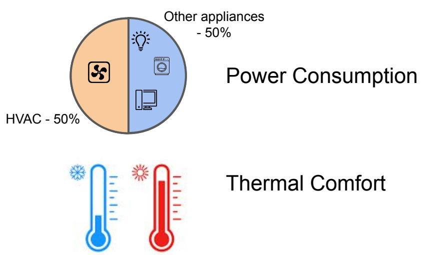
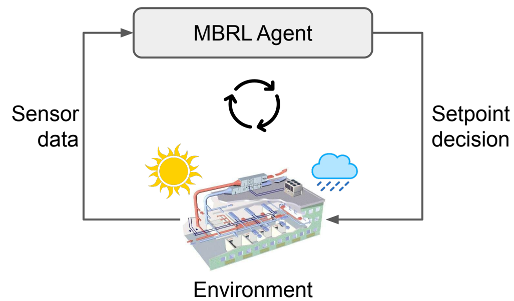
1. Building HVAC control problem

Dual-objective control with unknown dynamics



Model-based reinforcement learning solutions



2. Challenge and key solution idea

Challenge: biased data distribution; dynamics model fails to generalize with out-of-distribution inputs.

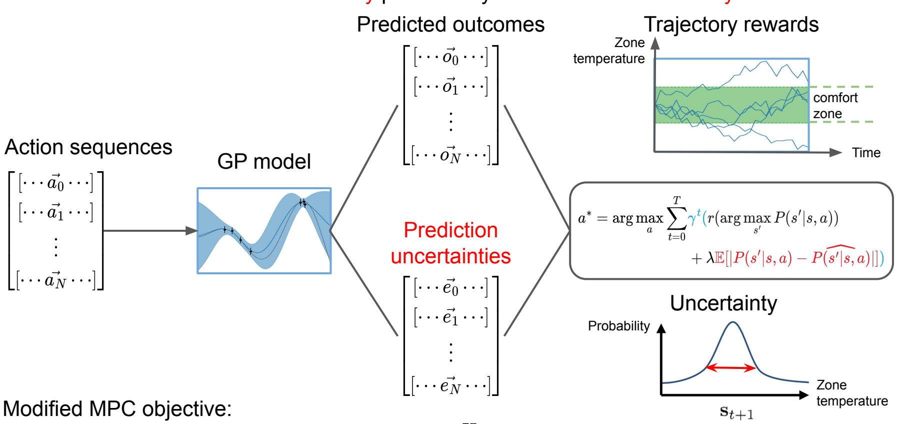
Key idea: instead of try to fit an accurate model, make the controller be aware about the uncertainty.

Solution: an **epistemic uncertainty-aware control algorithm**.

Uncertainty-aware control algorithm

Gaussian Process + Model Predictive Control

The controller considers the uncertainty provided by the Gaussian Process dynamics model.



Modified MPC objective:

$$a(\cdot)^* = \arg\max_{a(\cdot)} \sum_{t=1}^{H} \gamma^t (r(x_t) - \lambda\sigma(x_t))$$

3. Challenge with Gaussian Process Hyperparameters

GP performance depends on well-tuned kernel hyperparameters, which is not data-efficient.

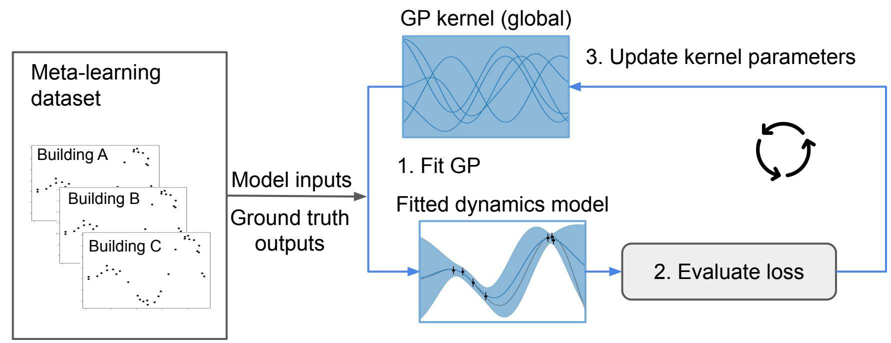
RBF kernel: $k(x, x') = \theta_{\text{scale}} \exp\left(-\frac{1}{2}(x - x')^\top \Theta^{-2}(x - x')\right)$

$\theta_{\mathcal{GP}} : \{\theta_{\text{scale}}, \Theta \in \mathbb{R}^{|\mathcal{X}|\times|\mathcal{X}|}\}, \mathcal{X} : \text{input space}$

parameter space scales quadratically with feature number.

Meta kernel learning

To automatically and effectively set kernel hyperparameters, we use meta learning to learn kernel initialization from reference building data. This significantly improves data efficiency.



4. Experiment results using EnergyPlus simulations

Training data:

MBRL-SOTA: 1200 days target bldg.

CLUE (ours): 3*300 days reference bldg. + 7 days target bldg.

	Pittsburgh	Tucson	New York	Avg.
Rule-based	.111	.333	.163	.203
MBRL-SOTA	.098	.332	.141	.190
CLUE	**.089**	**.304**	**.109**	**.167**

Table 1: Comfort violation rate results.

12.07% less comfort violation.

(kWh)	Pittsburgh	Tucson	New York	Avg.
Rule-based	1263.3	467.0	**582.9**	**772.1**
MBRL-SOTA	**1117.9**	**388.3**	838.5	781.5
CLUE	1134.1	437.5	851.8	807.8

Table 2: Energy savings results.

Similar energy savings with the previous SOTA