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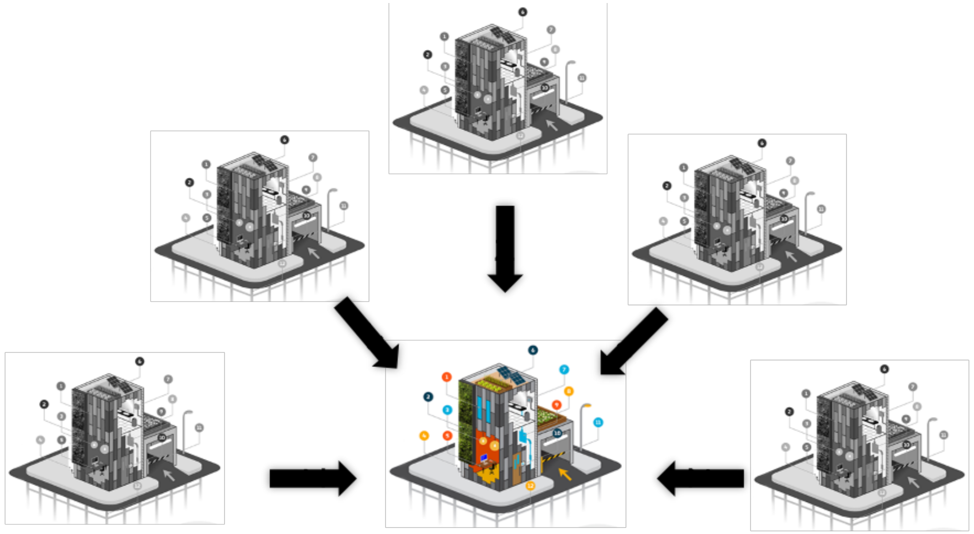
MITSUBISHI ELECTRIC RESEARCH LABORATORIES
Cambridge, Massachusetts

Meta-Learned Bayesian Optimization for Calibrating Building Simulation Models with Multi-Source Data



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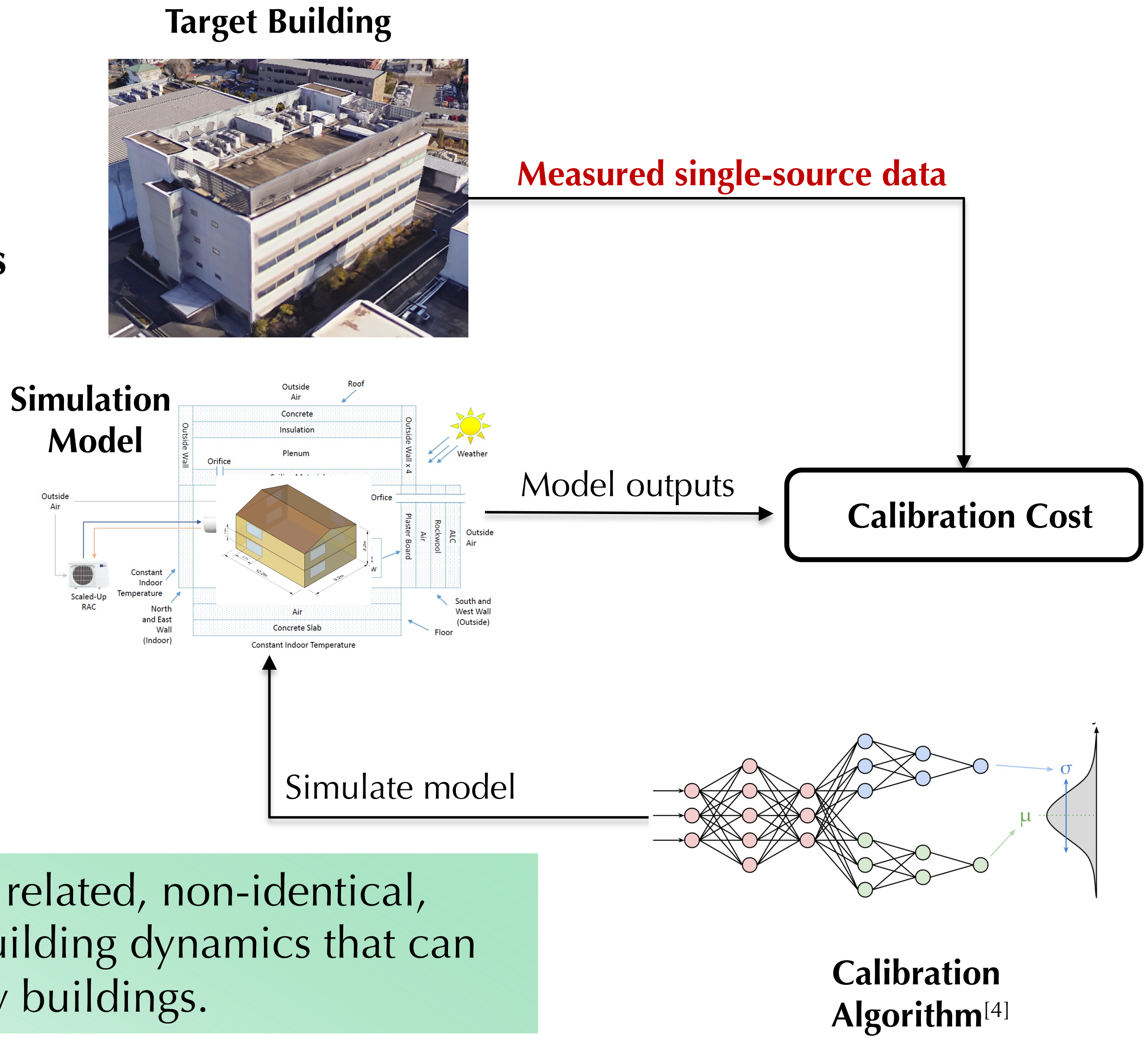
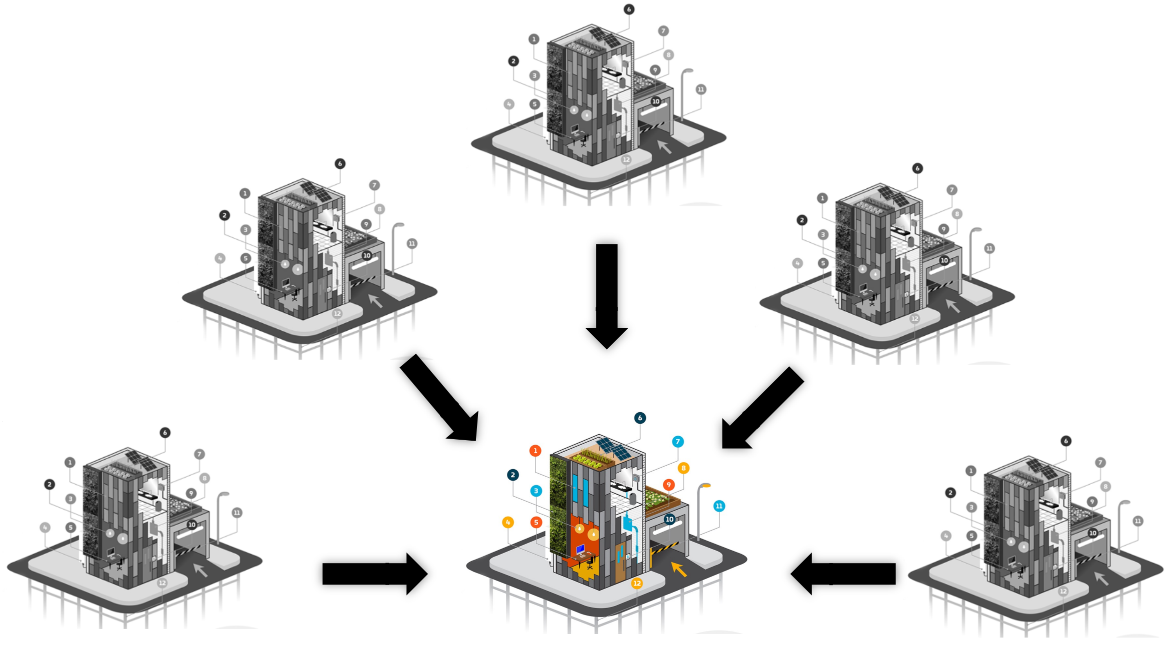
Motivation

- Buildings account for almost 40% of global greenhouse gas emissions[1] and model-based control can reduce energy[2] use up to 28% --- critical role in tackling climate change
    - **Proper calibration of building simulation models** (e.g., in digital twins) **is critical** for downstream performance optimization[3]
- Classical calibration relies only on data observed from the target building to be calibrated
    - This is usually a limited dataset
    - This wastes all the data collected during calibration of other, similar buildings

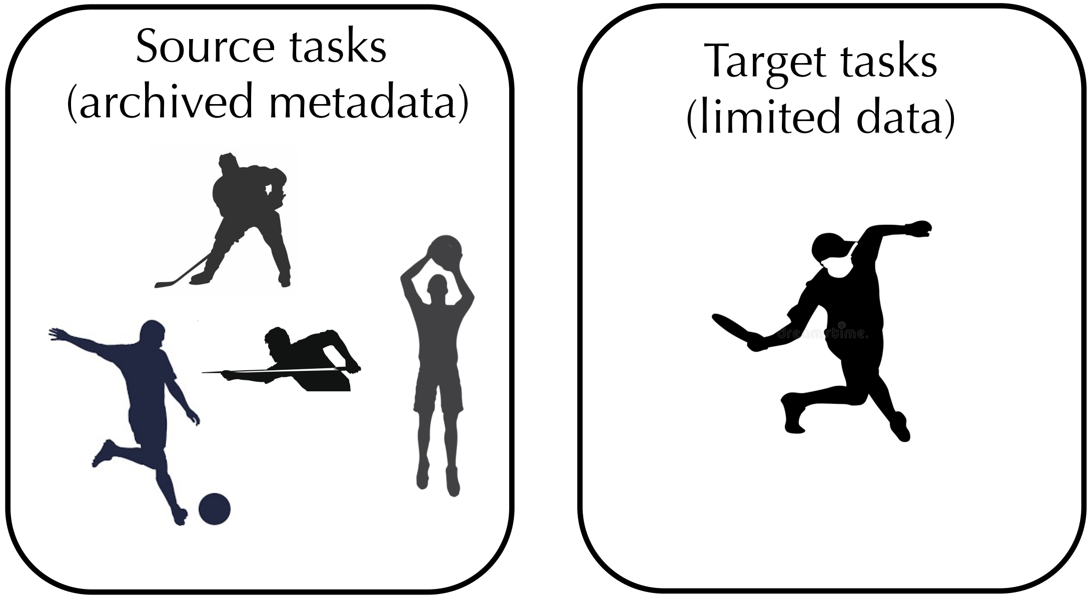


We demonstrate that data obtained during calibration of related, non-identical, buildings often contain useful information about general building dynamics that can significantly accelerate the calibration of new buildings.

[1] UN Environment, 2020
[2] Drgona et al., Annual Reviews in Control, 2020
[3] S. Zhan and A. Chong, Renewable and Sustainable Energy Reviews, 2021
[4] A. Chakrabarty et al., ICML CCAI 2021



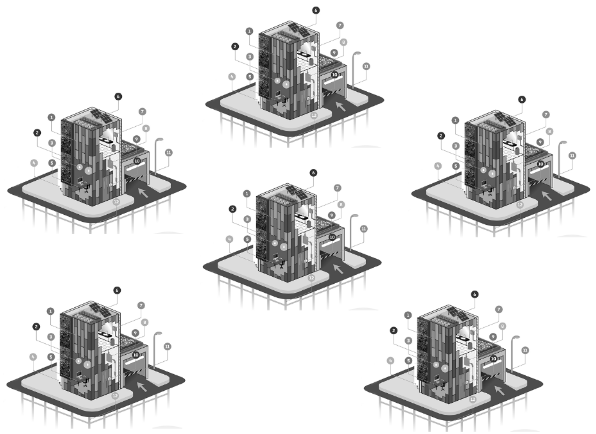
Problem: How to assimilate data from (related but not identical) source calibration tasks and exploit it to accelerate a target calibration task?



Potential solution: Meta-learning for few-shot building calibration

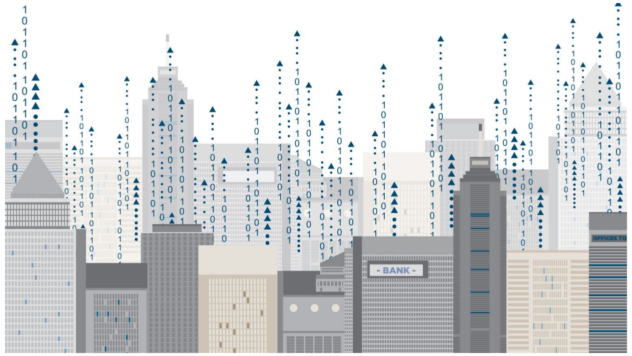
Meta Learning for Building Calibration

Previous calibration runs:
source tasks



Meta-training data storage

Source task data forms
meta-training set



Meta-train

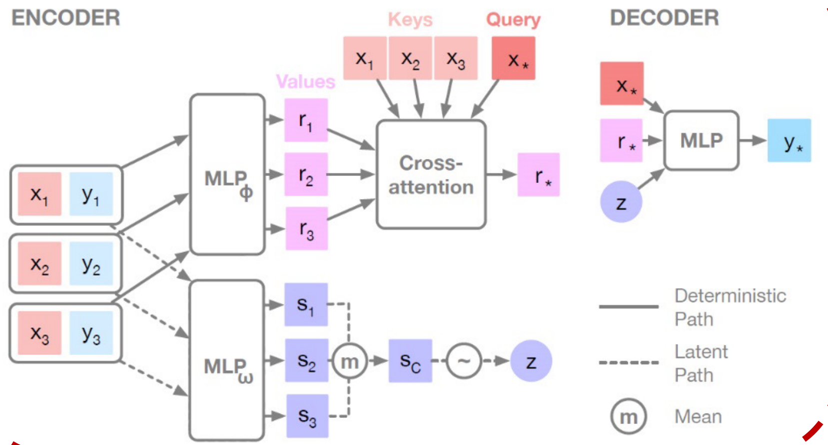
Attentive Neural Process (ANP)

- Learn from meta-data and predict target objective by observing a few context points
- Incorporate uncertainty brought by different tasks in the latent path
- Scalable to massive datasets

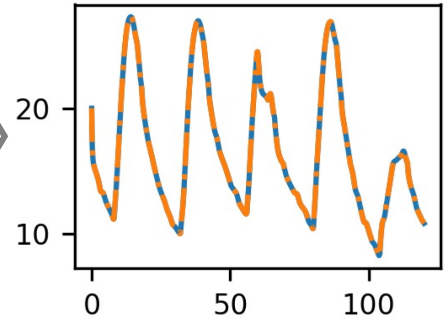
Previously unseen building data and model: **target tasks**

Uncalibrated simulation model

Limited target dataset for BO



Inference via meta + target data



Calibrated simulation model

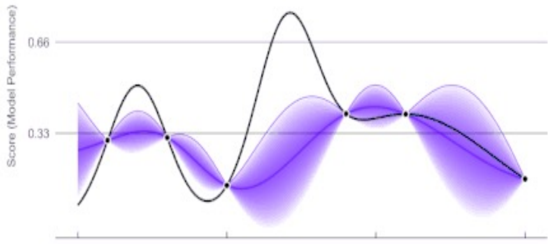
Experimental Setup

Construct a library with 60 similar (but not identical) houses across the US

Generate meta-training data via Bayesian Optimization with Gaussian Processes (GP-BO)

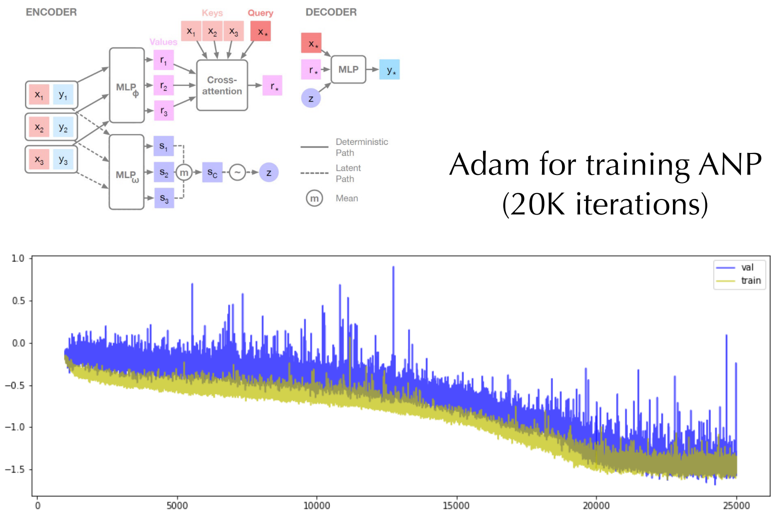
Target: 3-day room temperature and relative humidity

Parameters: external roof solar emissivity, effective infiltration leakage area, window thermal conductivity

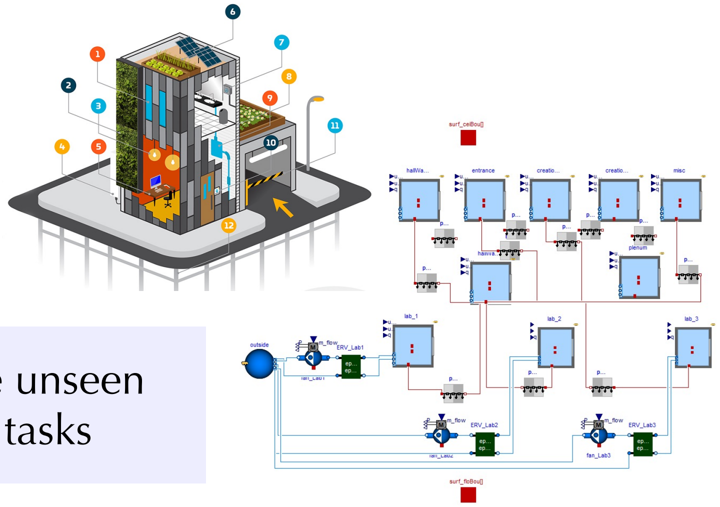


Meta-training set: parameter and calibration cost function values for 48 buildings, 3 parameters, 150 data points/building

Train the Attentive Neural Process



Adam for training ANP (20K iterations)



Calibrate unseen target tasks

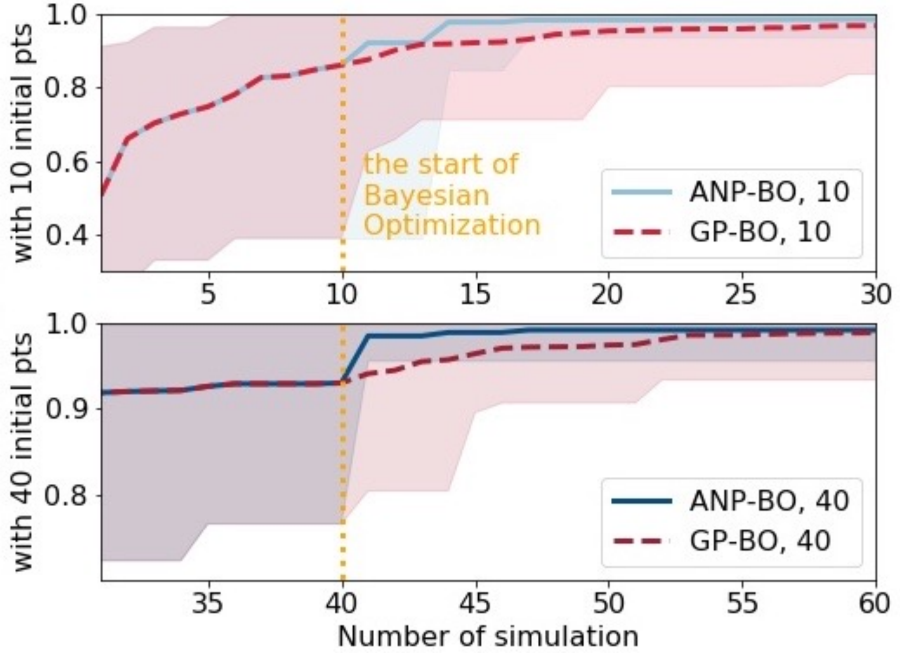
Few-shot initialization → ANP-BO → faster convergence rate

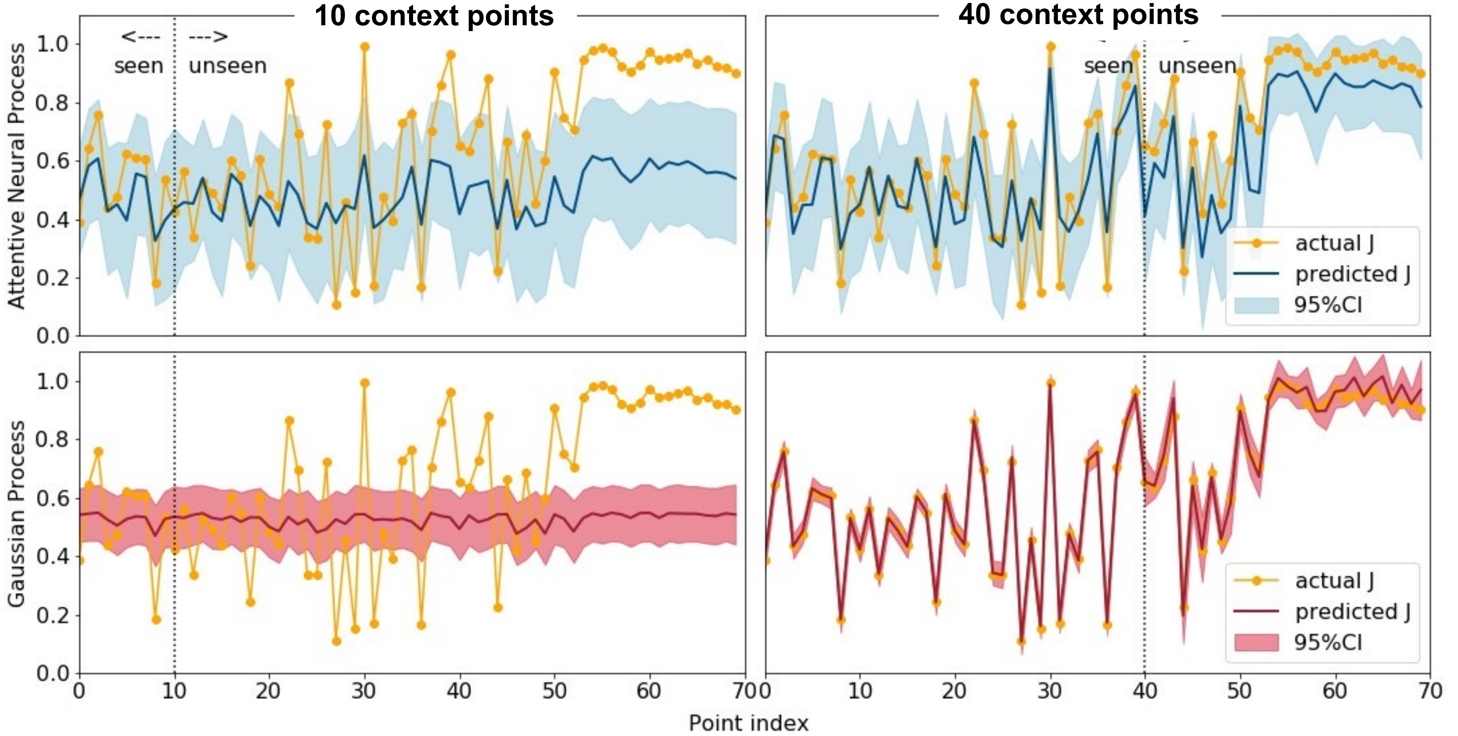
Few-shot initialization → GP-BO → slower convergence rate

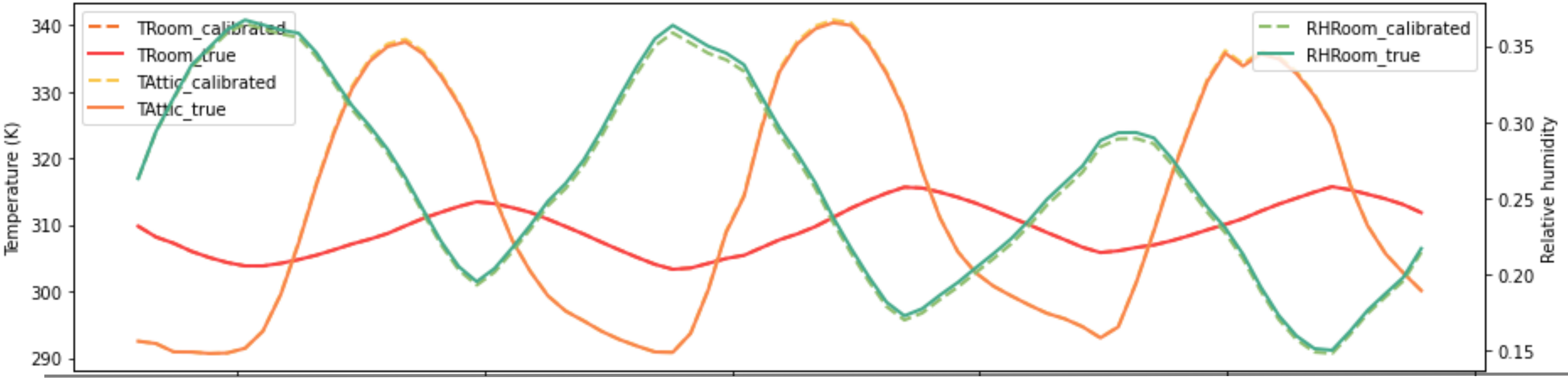
Comparative study

Effectiveness of Meta-ANP-BO

Convergence to optimum is **3x faster**







Meta-learned model is **more representative of the true calibration cost**

Final calibrated model exhibits **excellent predictive performance**

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