Example Development and Evaluation of an MPC Controller

Workshop 1: Introduction to the BOPTEST framework for simulation-based benchmarking of advanced controllers

IBPSA Building Simulation 2021

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Workshop Sponsored By:

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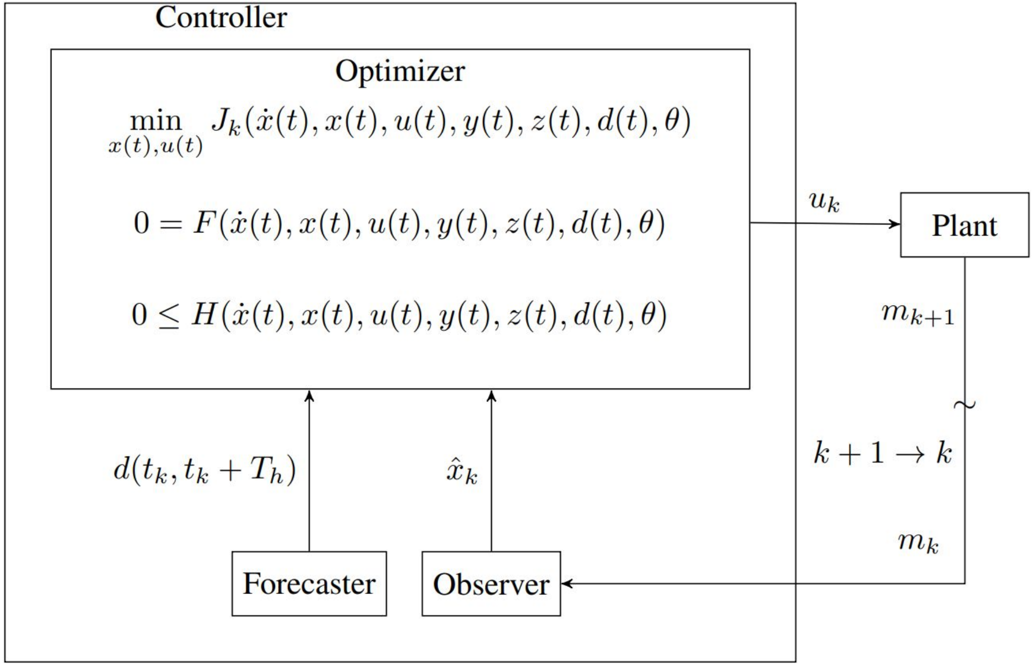
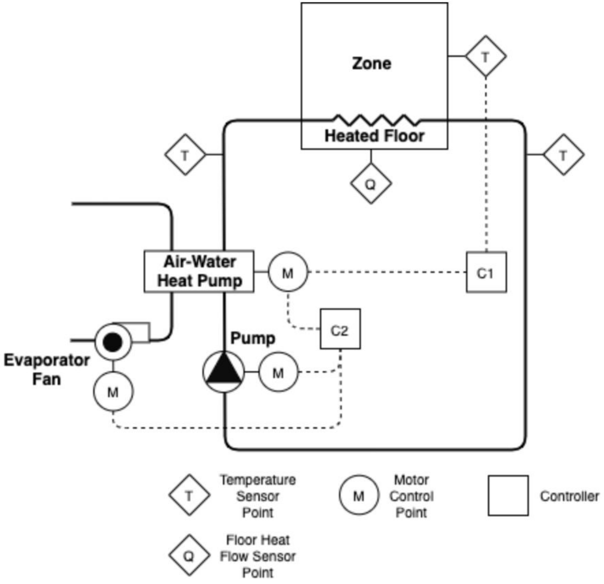
MPC working principle



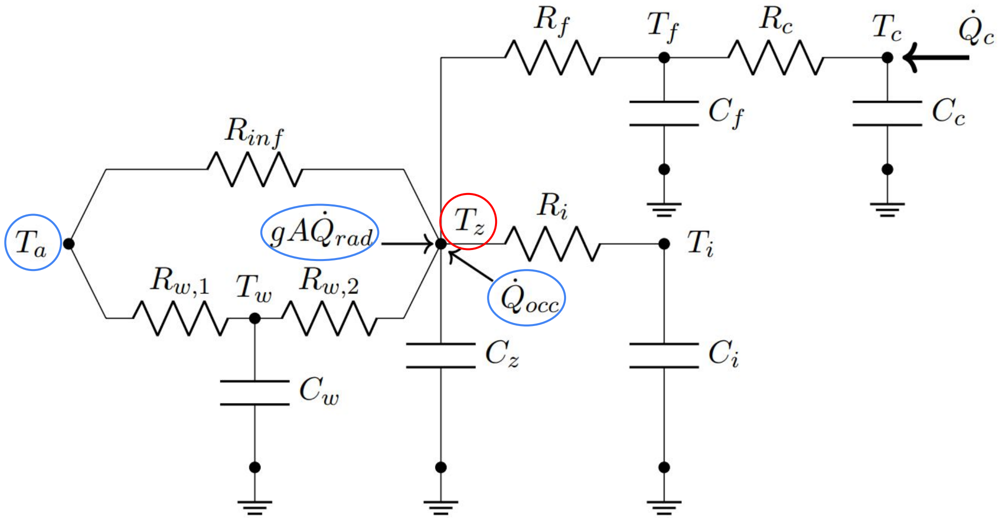
Controller
Optimizer
$\min_{x(t),u(t)} J_k(\dot{x}(t), x(t), u(t), y(t), z(t), d(t), \theta)$
$0 = F(\dot{x}(t), x(t), u(t), y(t), z(t), d(t), \theta)$
$0 \leq H(\dot{x}(t), x(t), u(t), y(t), z(t), d(t), \theta)$
u_k
Plant
m_{k+1}
$\sim$
$k + 1 \rightarrow k$
m_k
$d(t_k, t_k + T_h)$
$\hat{x}_k$
Forecaster
Observer

System identification

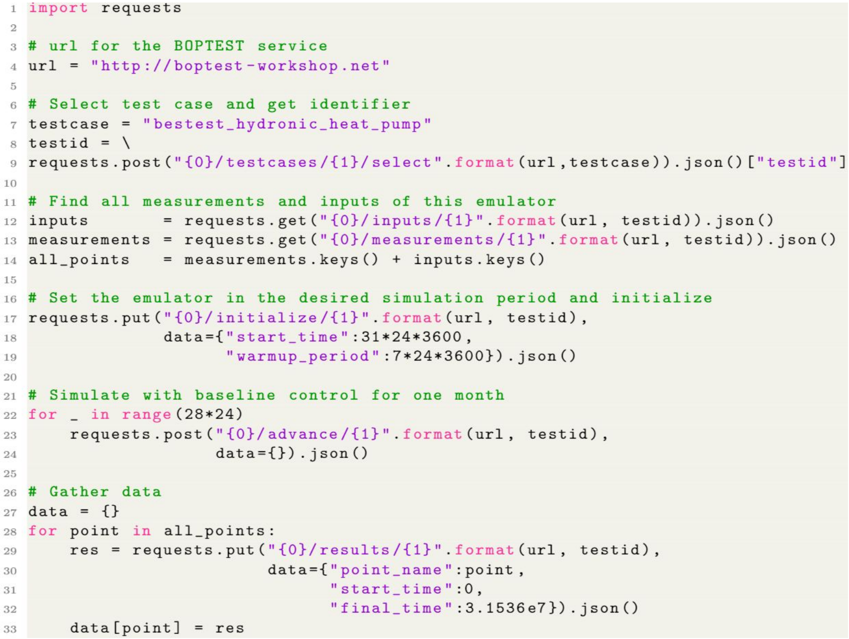


=

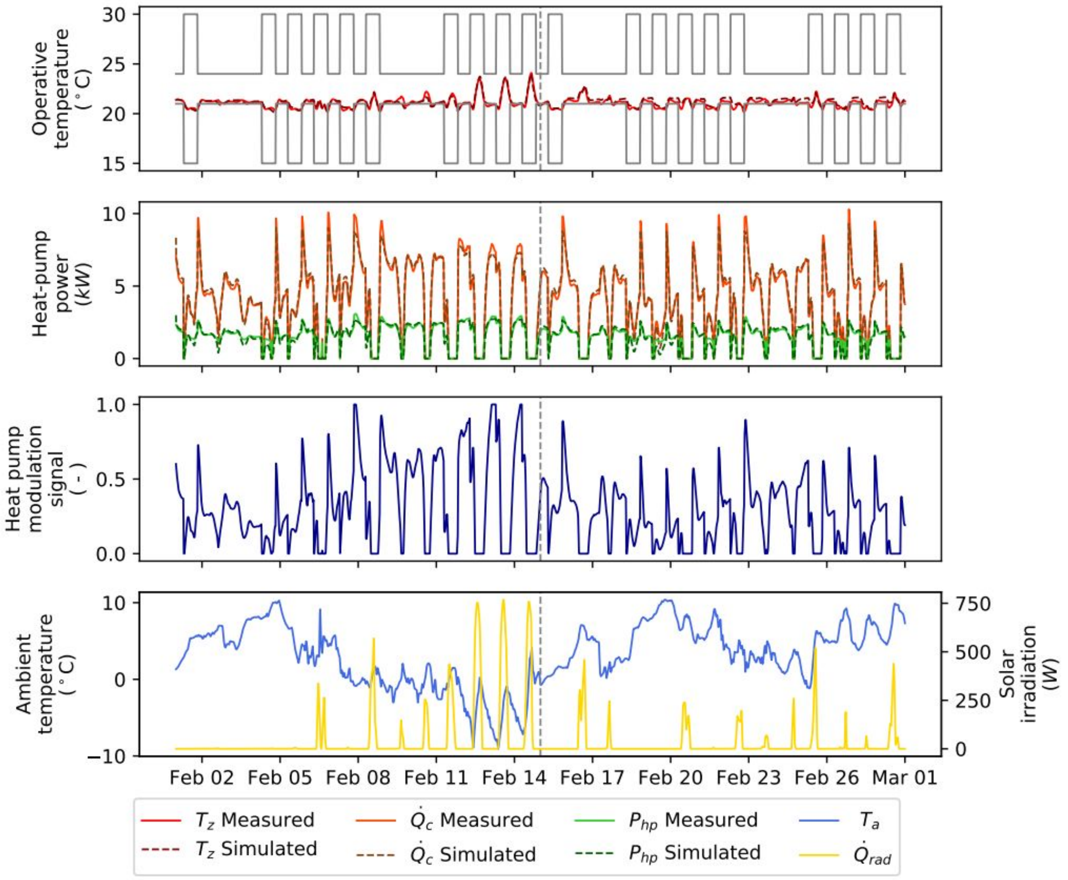
$$\dot{Q}_c = (a_c + b_c(T_c - T_{c,n}) + c_c(T_a - T_{a,n}))k_c u_{hp}$$
$$\dot{Q}_e = (a_e + b_e(T_c - T_{c,n}) + c_e(T_a - T_{a,n}))k_e u_{hp}$$
$$P_{hp} = \dot{Q}_c - \dot{Q}_e$$
$$COP = \frac{\dot{Q}_c}{P_{hp}},$$



System identification



```python
import requests

# url for the BOPTEST service
url = "http://boptest-workshop.net"

# Select test case and get identifier
testcase = "bestest_hydronic_heat_pump"
testid = \
requests.post("{0}/testcases/{1}/select".format(url,testcase)).json()["testid"]

# Find all measurements and inputs of this emulator
inputs       = requests.get("{0}/inputs/{1}".format(url, testid)).json()
measurements = requests.get("{0}/measurements/{1}".format(url, testid)).json()
all_points   = measurements.keys() + inputs.keys()

# Set the emulator in the desired simulation period and initialize
requests.put("{0}/initialize/{1}".format(url, testid),
             data={"start_time":31*24*3600,
                   "warmup_period":7*24*3600}).json()

# Simulate with baseline control for one month
for _ in range(28*24)
    requests.post("{0}/advance/{1}".format(url, testid),
                  data={}).json()

# Gather data
data = {}
for point in all_points:
    res = requests.put("{0}/results/{1}".format(url, testid),
                       data={"point_name":point,
                             "start_time":0,
                             "final_time":3.1536e7}).json()
    data[point] = res
```

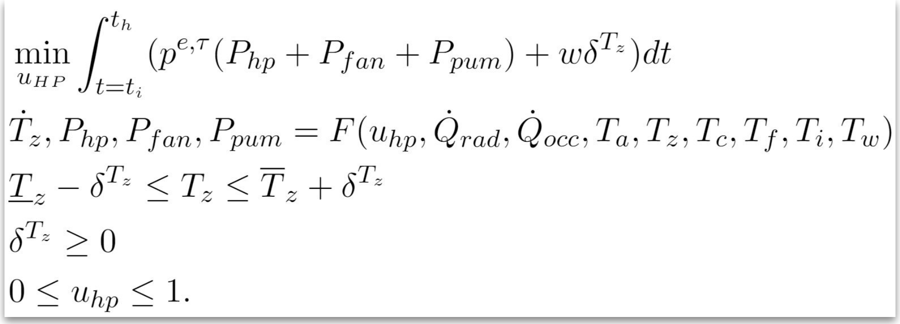


The **Grey-Box Toolbox**[1] is used to prototype the model and train its parameters

1 - R. D. Coninck, F. Magnusson, J. Akesson, and L. Helsen, "*Toolbox for development and validation of grey-box building models for forecasting and control*"Journal of Building Performance Simulation, vol. 9, no. 3, pp. 288–303, 2016. [Online]. Available:https://doi.org/10.1080/19401493.2015.1046933

MPC description

- Controlled variable: zone operative temperature
- Control variable: modulation signal for HP compressor frequency
- BOPTEST deterministic forecast
- Prediction horizon: 12, **24**, 48 hours
- Control step: 15, **30**, 60 minutes
- Direct collocation with JModelica
- Unscented Kalman filter



$$\min_{u_{HP}} \int_{t=t_i}^{t_h} (p^{e,\tau}(P_{hp} + P_{fan} + P_{pum}) + w\delta^{T_z})dt$$

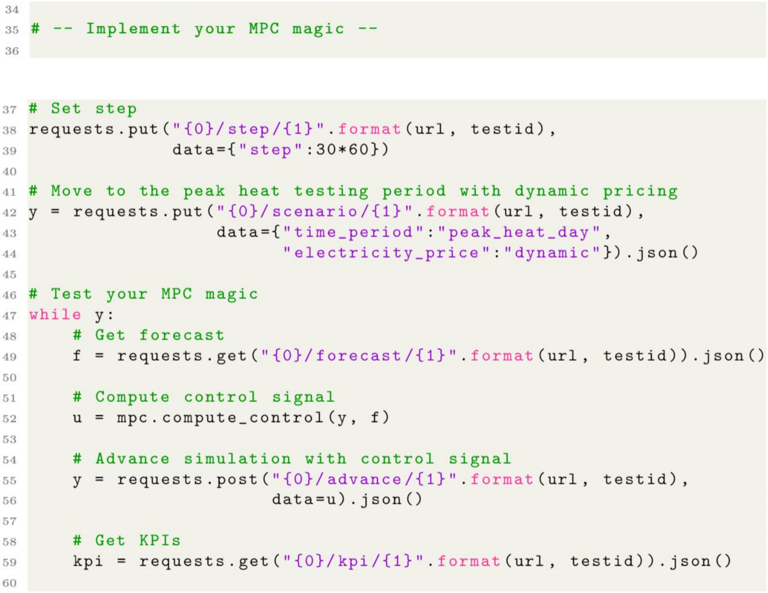
$$\dot{T}_z, P_{hp}, P_{fan}, P_{pum} = F(u_{hp}, \dot{Q}_{rad}, \dot{Q}_{occ}, T_a, T_z, T_c, T_f, T_i, T_w)$$

$$\underline{T}_z - \delta^{T_z} \leq T_z \leq \overline{T}_z + \delta^{T_z}$$

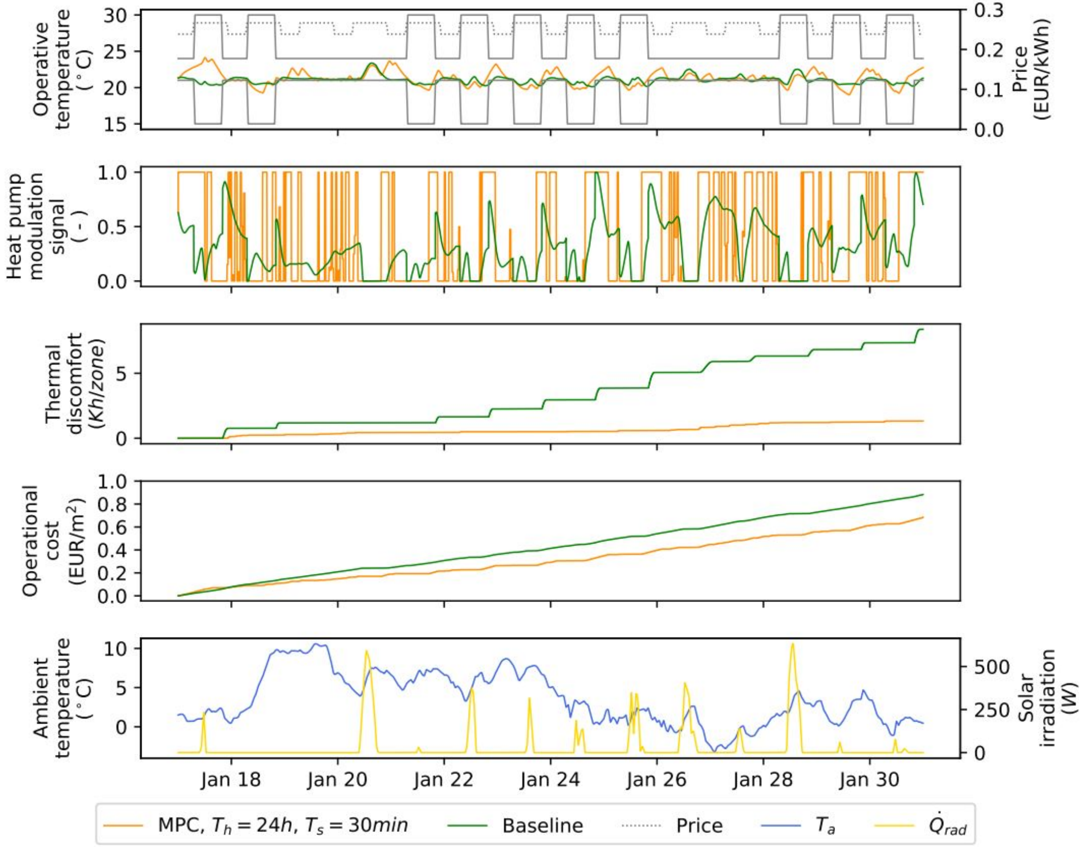
$$\delta^{T_z} \geq 0$$

$$0 \leq u_{hp} \leq 1.$$

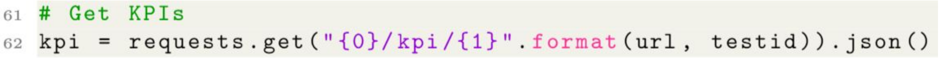
MPC results



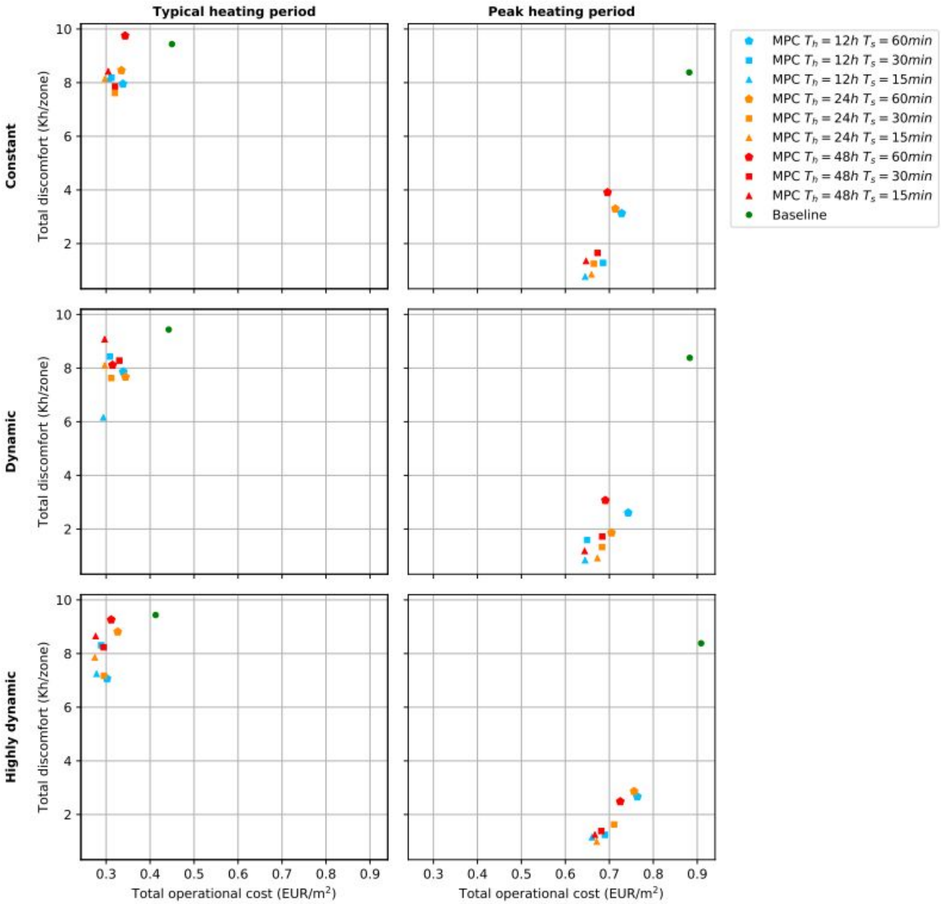
```python
# -- Implement your MPC magic --


# Set step
requests.put("{0}/step/{1}".format(url, testid),
             data={"step":30*60})

# Move to the peak heat testing period with dynamic pricing
y = requests.put("{0}/scenario/{1}".format(url, testid),
                 data={"time_period":"peak_heat_day",
                       "electricity_price":"dynamic"}).json()

# Test your MPC magic
while y:
    # Get forecast
    f = requests.get("{0}/forecast/{1}".format(url, testid)).json()

    # Compute control signal
    u = mpc.compute_control(y, f)

    # Advance simulation with control signal
    y = requests.post("{0}/advance/{1}".format(url, testid),
                      data=u).json()

    # Get KPIs
    kpi = requests.get("{0}/kpi/{1}".format(url, testid)).json()
```



MPC results



```python
# Get KPIs
kpi = requests.get("{0}/kpi/{1}".format(url, testid)).json()
```



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Thank you!

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