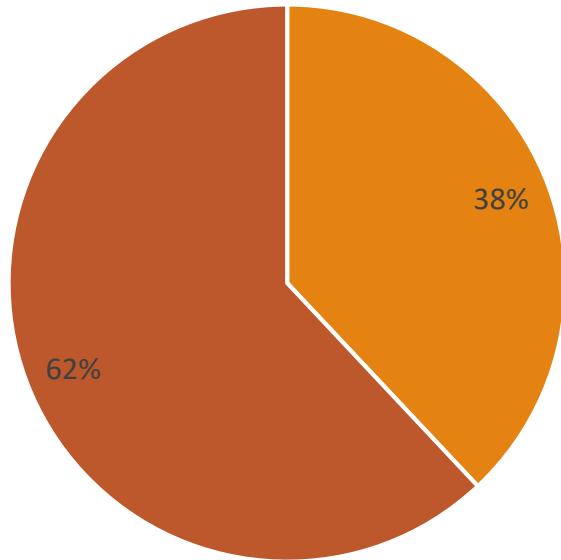# MINIMIZATION OF ELECTRICITY CONSUMPTION IN COOLING AND VENTILATION SYSTEMS

tCSC Machine Learning 2024, Split, October 2024.

Nikolina Bunijevac
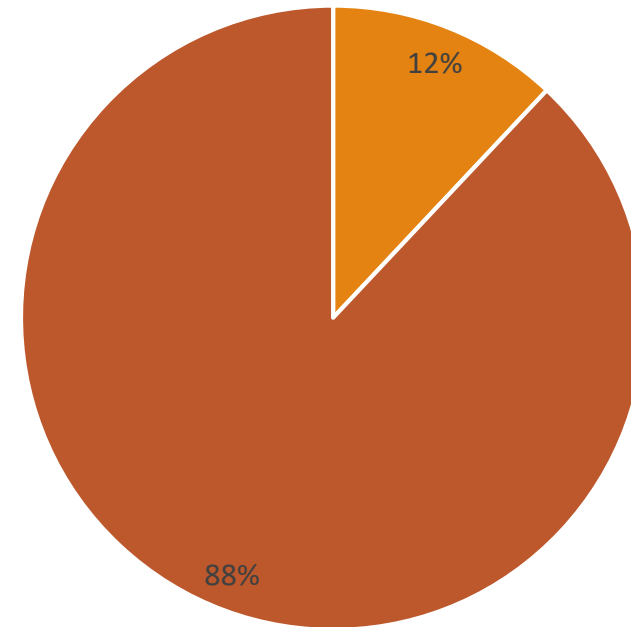EN/CV/CL

Research motivation

Residential buildings electricity consumption
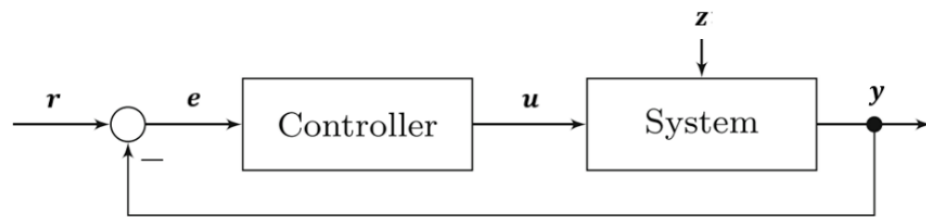
- HVAC (Heating, ventilation, and air conditioning): 38%
- other: 62%
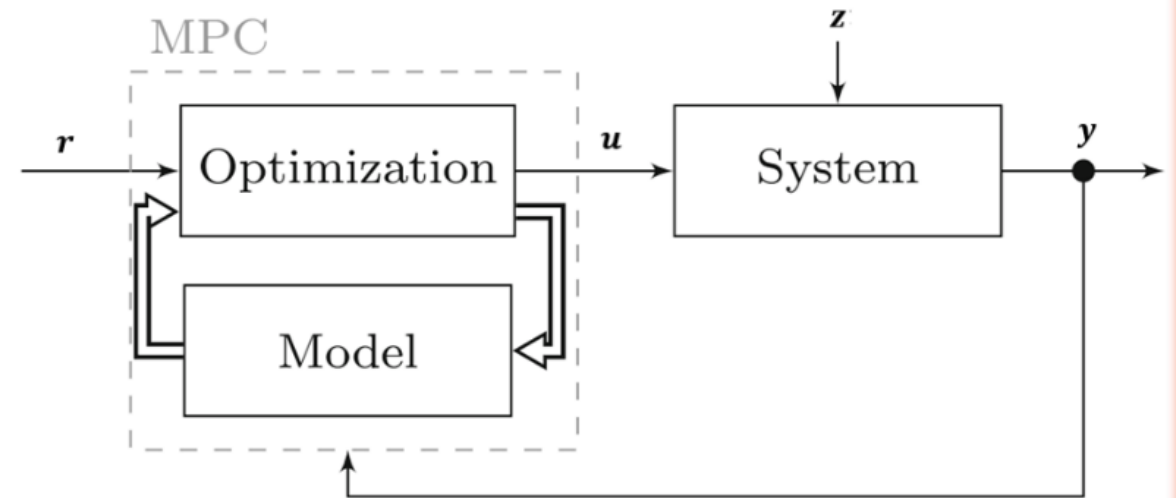
CERN/LHC electricity consumption

- Cooling and ventilation: 12%
- other: 88%

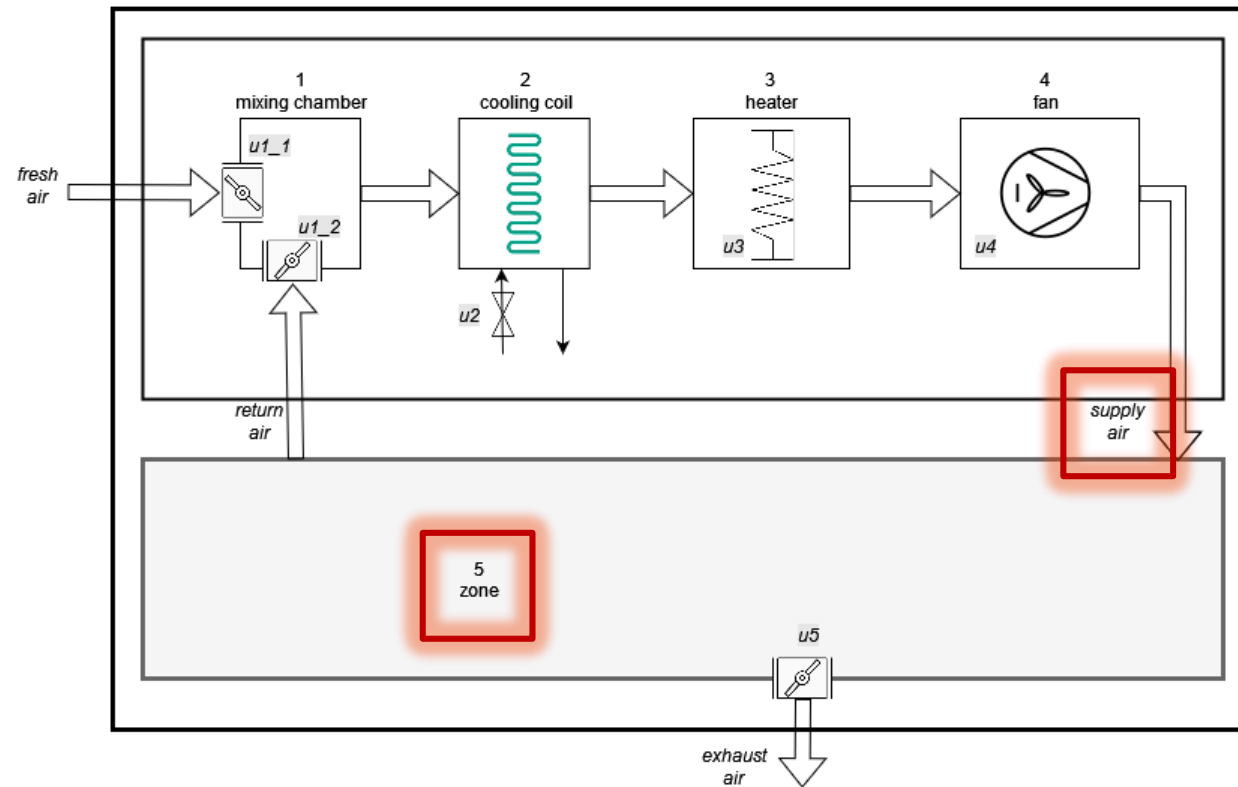# Controls optimization

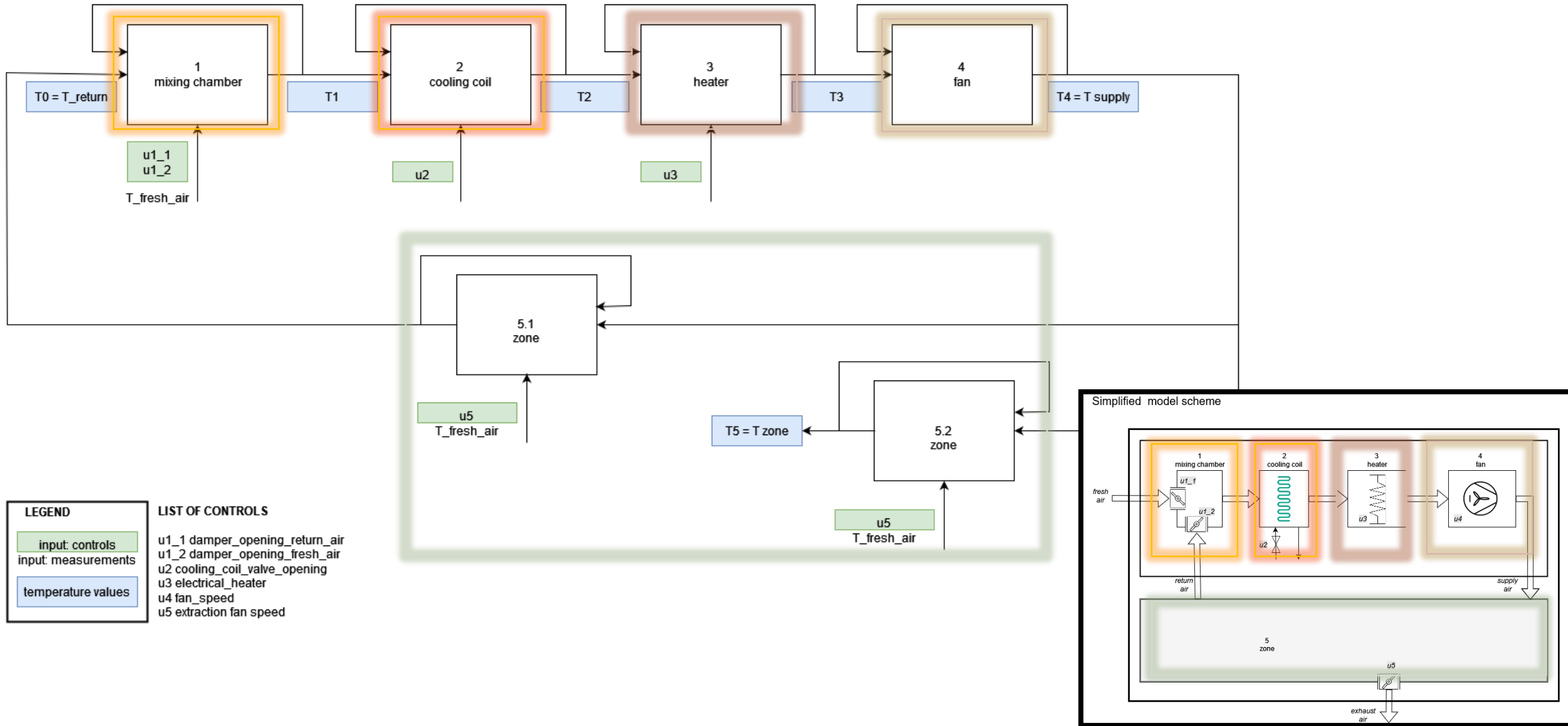CLASSICAL FEEDBACK CONTROLLER

MODEL PREDICTIVE CONTROLLER
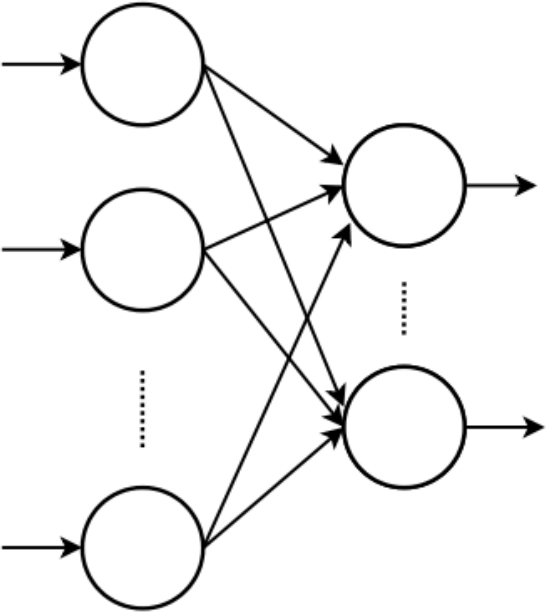
- prediction horizon

System: Air Handling Unit

Simplified model scheme

System diagram

T0 = T_return

1
mixing chamber

T1

2
cooling coil

T2

3
heater

T3

4
fan

T4 = T supply

u1_1
u1_2
T_fresh_air

u2

u3

5.1
zone

u5
T_fresh_air

T5 = T zone

5.2
zone

u5
T_fresh_air

LEGEND

input: controls

input: measurements

temperature values

LIST OF CONTROLS

u1_1 damper_opening_return_air
u1_2 damper_opening_fresh_air
u2 cooling_coil_valve_opening
u3 electrical_heater
u4 fan_speed
u5 extraction fan speed

Simplified model scheme

fresh air

1
mixing chamber

u1_1

u1_2

2
cooling coil

u2

3
heater

u3

4
fan

u4

return air

5
zone

u5

supply air

exhaust air
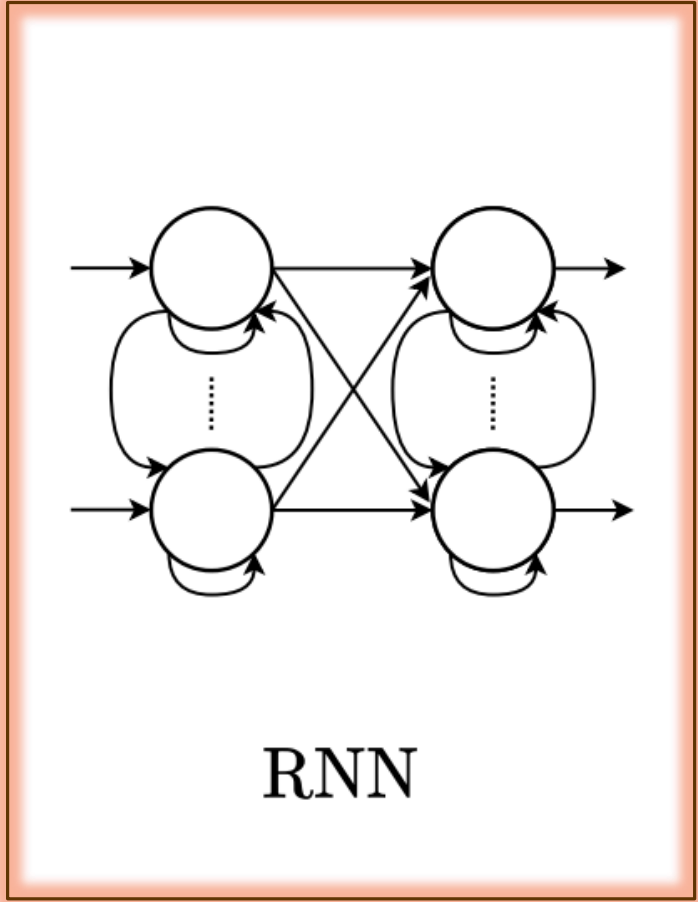
Modelling: methodology

FFNN   RNN

Optimization

- optimization variables: u1, u2, u3

- constraints:
  ◦ control constraints
  ◦ variable constraints

$$0 < u^k[t] < 100, \text{ k in } \{1,2,3\}, \forall t$$

$$u^2[t] * u^3[t] = 0, \forall t \, .$$

$$T_{SUPPLY_{MIN}} = 15°C < T_{SUPPLY} < T_{SUPPLY_{MAX}} = 30°C,$$

$$T_{ZONE_{MIN}} = 21°C < T_{ZONE} < T_{ZONE_{MAX}} = 24°C.$$

- optimization function: estimation of electricity consumption for the prediction horizon of 2h:

- **genetic algorithm**

$$J = \sum_{t \text{ in prediction horizon}} J[t]$$

Results: Advanced vs classical controls

- comparison in virtual environment:
  - existing controls (PID) vs advanced controls (MPC)

- tested on 10 datasets (running time: 2h)
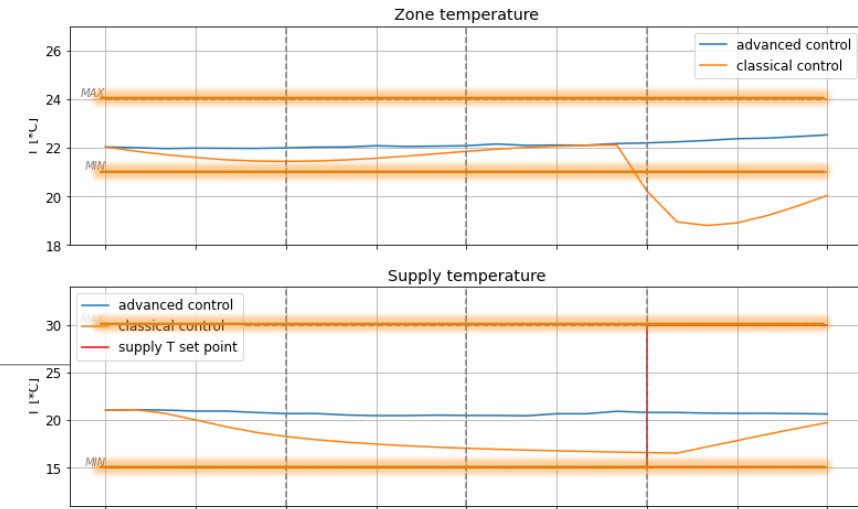
- results:

Average electricity consumption is 5.96kWh with MPC, compared to 35.5kWh with standard controls, with average relative improvement of around 77%.

Zone temperature / Supply temperature
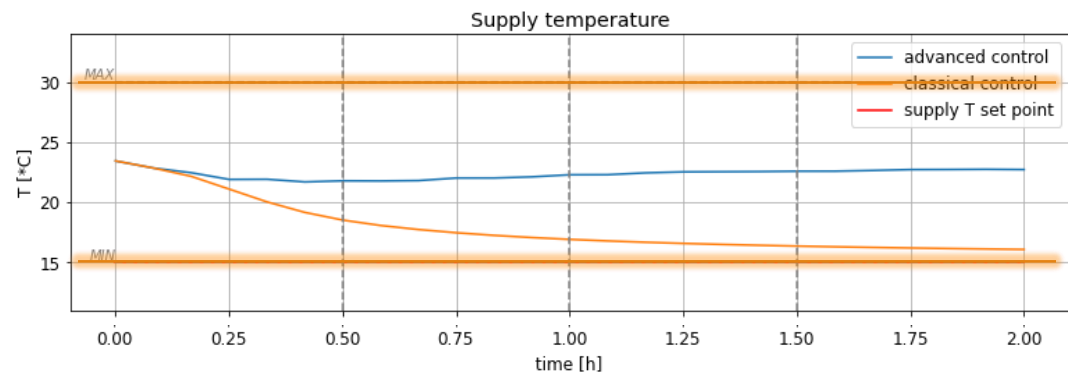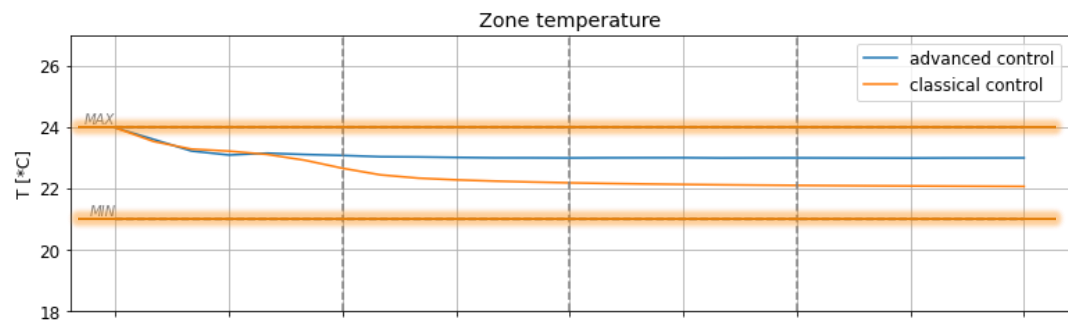
- temperatures within limits

- advance controls: damper management

- PID: more active components

Results

- constraints violated

- unusual system response

- unusual PID response

Zone temperature

Supply temperature

Conclusion

- promising results, but too optimistic (savings 77% comparing to 20% in literature)

- improvements:
- ◦ improving model:
  - ◦ dataset, architecture, training
- ◦ improving optimization algorithm:
  - ◦ faster execution → faster test comparison
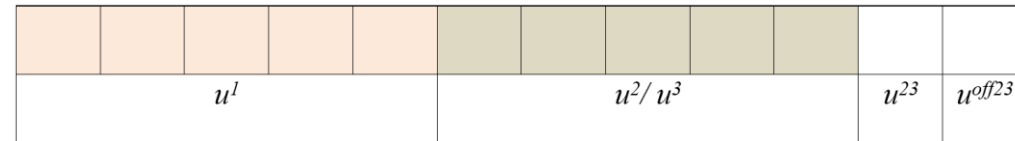- ◦ tunning PID for fair comparison
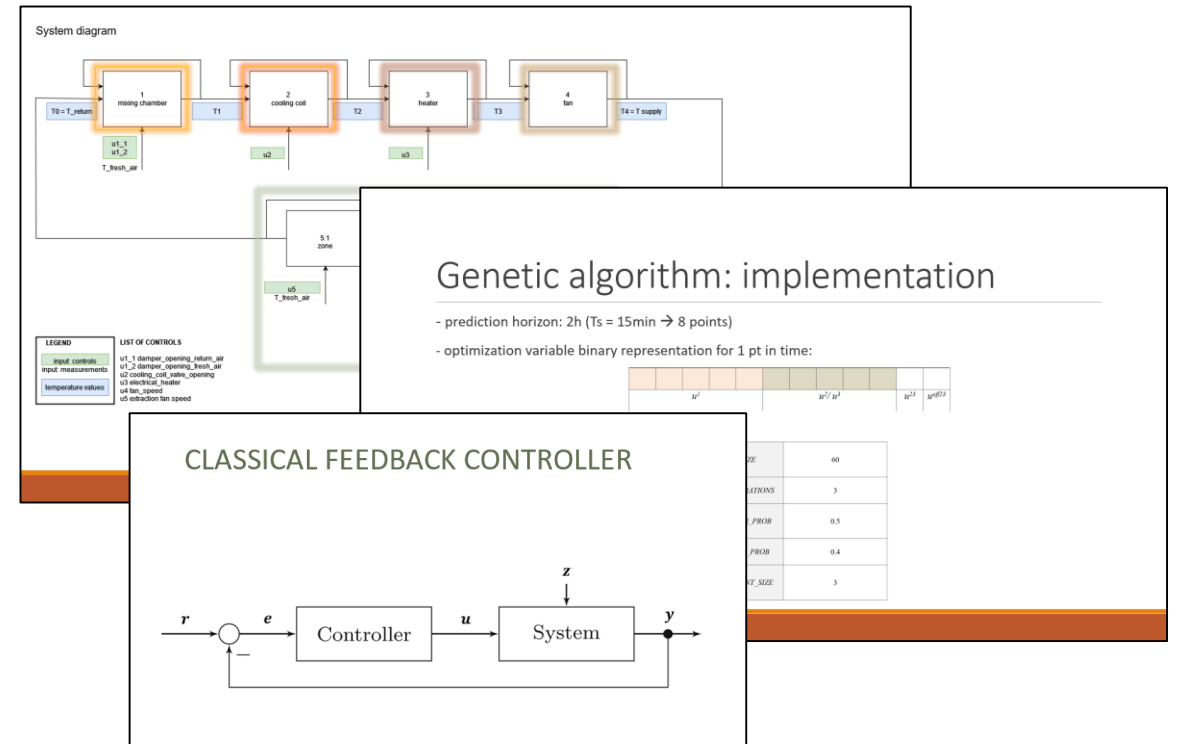
Discussion

Genetic algorithm: implementation

- prediction horizon: 2h (Ts = 15min → 8 points)

- optimization variable binary representation for 1 pt in time:

										u^{23}	u^{off23}
		u^1					u^2/u^3				

- bits in total: 8*12 = 96 bits/optimization

- parameters:

POP_SIZE	60
NUM_GENERATIONS	3
CROSSOVER_PROB	0.5
MUTATION_PROB	0.4
TOURNAMENT_SIZE	3