MPC framework for all-air systems in non-residential buildings
Numerical and experimental study

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| Conclusions  | |
|--------------| |
High energy use in buildings
Measures taken
• Improved insulation layer
• More airtight envelope
• Better design and optimization of energy efficient HVAC systems

There is still energy waste in buildings due to inefficient operation

Smart control of HVAC systems

Reactive control (RBC) vs. predictive control (MPC)

<table>
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<tr>
<th>Time (hr)</th>
<th>Air temperature (°C)</th>
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<tr>
<td></td>
<td>Occupancy phase</td>
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Legends
- Occupancy phase
- Room temperature RBC
- Room temperature MPC
- Supply air temperature RBC
- Supply air temperature MPC
Objectives

- Proof of concept for an MPC framework in non-residential buildings with an all-air system
  - To identify suitable models for application in all-air systems
  - A robust MPC algorithm for application in all-air systems
  - To demonstrate the potential of MPC for all-air systems

MPC is a promising technique to optimize the control of the all-air system

Simple but accurate model

Conflicting targets

Integration with BAS
**MPC framework**

- Weather Forecast
- Lecture Schedule
- Occupancy
- Comfort criteria
- Prediction model
- Cost function
- Constraints
- Optimal control problem
- Predictive controller
- Ventilation system
- Measurement update
- Building and ventilation system

**Disturbances**
- Collection of forecast data

**Hourly forecast**

<table>
<thead>
<tr>
<th>Time</th>
<th>6am</th>
<th>7am</th>
<th>8am</th>
<th>9am</th>
<th>10am</th>
<th>11am</th>
<th>12pm</th>
<th>1pm</th>
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<th>3pm</th>
<th>4pm</th>
<th>5pm</th>
<th>6pm</th>
<th>7pm</th>
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<tbody>
<tr>
<td></td>
<td>2.4m/s</td>
<td>6.4m/s</td>
<td>5.7m/s</td>
<td>6.3m/s</td>
<td>6.6m/s</td>
<td>6.9m/s</td>
<td>6.2m/s</td>
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<td>Rain</td>
<td>41%</td>
<td>47%</td>
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<td>Light</td>
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</table>
• Multi-zone RC and ARX-models for CO₂ and temperature predictions

\[ \text{Min: } \sum_{k=0}^{Hp} w_1 \cdot (zCO_2)^2 + w_2 \cdot (zT)^2 + w_3 \cdot (Q_{elec})^2 + w_4 \cdot (Q_{thermal})^2 \]
• Case study: Test lecture rooms, Ghent, Belgium

• Educational building with 2 lecture rooms

• All-air system ($CO_2 + T$)

• Integration of MPC through BACnet
• Design of experiments: Feb-May 2020 and Sep-Dec 2020

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Horizon</th>
<th>Model</th>
<th>Timestep</th>
<th>Occupancy based</th>
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<tbody>
<tr>
<td></td>
<td>2 h</td>
<td>4 h</td>
<td>RC</td>
<td>ARX</td>
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<tr>
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<td>x</td>
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<td>Scenario 8</td>
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<td>x</td>
<td>x</td>
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**Demonstration of MPC**

- Expected occupancy

![Graphs showing CO2 concentration, temperature, and expected occupancy over time.](image-url)
**Introduction**

**Methodology**

**Results**

**Conclusions**

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### Energy savings MPC compared to RBC

![Bar chart comparing energy savings MPC to RBC across different scenarios.](image)

- **Thermal discomfort [Kh]**:
  - Scenario 1 (RC-MPC): 11.9
  - Scenario 4 (ARX-MPC): 11.0
  - Scenario 3 (RC-MPC): 1.31
  - Scenario 7 (RC-MPC): 1.98

- **CO2-discomfort [ppmh]**:
  - Scenario 1 (RC-MPC): 1535
  - Scenario 4 (ARX-MPC): 1460
  - Scenario 3 (RC-MPC): 706
  - Scenario 7 (RC-MPC): 502

Legend:
- Blue bars: Fan savings
- Green bars: Heating savings
• The developed all-air MPC can cope better with the intermittent use of the space compared to a RBC

• MPC strategies can control the IAQ and reduce the energy use

• Energy savings demonstrated for MPC compared to RBC: Fans 33-36%, heating coil 10-22%

Thank you for your attention!