Modeling multiple indoor climates in historic buildings due to the effect of climate change

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Intro

Problem

What is the Effect of Climate Change on Built Heritage?

Modeling

Tools

Buildings as Dynamic Complex systems

Using Tools

For the Problem

What can we simulate?

Incorporating Climate change
What is the Effect of Climate Change on Built Heritage?

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Introduction

Climate for Culture Project

- Climate change -> global challenges
- Historic buildings in different parts of Europe
- High resolution climate evolution scenarios
- Coupled with whole **building** simulation models
- Mapping most urgent risks for specific **regions**

- Scale problem: building vs. EU regions
What is the Effect of Climate Change on Built Heritage?

Buildings as Dynamic Complex systems

Modeling Tools

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Using Tools For the Problem
Buildings as Dynamic Complex Systems

What is special on complex systems?

• The whole is greater than the sum of the individual parts
Buildings as Dynamic Complex Systems

What is special on complex systems?

- **Butterfly effect**: Small parameter variations may produce large variations in the long term behavior of the system.
Importance of BuildCoSy

• Where are the dynamic complex systems at the built environment?

Everywhere and on several scales

~ km  ~ 10 m  ~ 1 m  ~ mm
Butterfly effect: Small parameter variations may produce large variations in the long term behavior of the system.
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Modeling Tools

Using Tools For the Problem
Tools HOW?  Modeling based on physics
Using state of art scientific software

Multi Buildings
'HAMBase'
MatLab

Multi Systems & Control
ODE
SimuLink

Multi Details
PDE
Comsol

Technische Universiteit Eindhoven
University of Technology
Tools
Buildings modeling physics: HAMBase
scientific software: MatLab

Simulation and validation

Anne Frank House

- Temperature
- Relative humidity
**Tools**

Detail modeling

**physics:** PDEs

**scientific software:** Comsol

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**Hunting Logde St. Hubertus**

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**3D Moisture**
Tools Systems & Control modeling physics: ODEs
scientific software: SimuLink

Building systems failure modeling

Dutch Maritime Museum
What is the Effect of Climate Change on Built Heritage?

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Intro Problem

Modeling Tools

Using Tools For the Problem
(1) Meteonorm commercial software
   • Reference year
   • Available for our models
   • Hourly based,
   • 8000 locations on earth

(2) EU Climate for Culture project data
   • 250 years: period 1850 – 2100
   • Not available yet (Max. Plank Institute Jacob et al.)
   • Hourly based,
   • Any location in Europe
Classification

building complexity

climate system complexity
Intro
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Using Tools For the Problem
New: Multi Buildings model

Table 3. Details of 11 historic buildings included in the Multi-buildings model

<table>
<thead>
<tr>
<th>Building Nr. From fig 8</th>
<th># Zones</th>
<th># Walls</th>
<th># Windows</th>
<th>Systems</th>
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<tbody>
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<td>10</td>
<td>66</td>
<td>26</td>
<td>Heating</td>
</tr>
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<td>3</td>
<td>12</td>
<td>80</td>
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<td>205</td>
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<td>51</td>
<td>19</td>
<td>Full airco</td>
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<tr>
<td>12</td>
<td>3</td>
<td>36</td>
<td>7</td>
<td>Free Floating</td>
</tr>
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</tr>
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<td>14</td>
<td>Heating</td>
</tr>
<tr>
<td>21</td>
<td>4</td>
<td>56</td>
<td>2</td>
<td>Full airco</td>
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<tr>
<td>total</td>
<td>93</td>
<td>776</td>
<td>210</td>
<td></td>
</tr>
</tbody>
</table>
Very Useful to compare building indoor climates

10 Buildings
93 indoor climates
Validated with measurements

Simulation
“AS IS” i.e
With
Heating & Internal sources

Same
10 Buildings
93 indoor climates

Simulation
“Free Floating”
Without
Heating & Internal sources
Mapping

Same building placed at several locations over Europe
Mapping

New preliminary results
Conclusion

- A preliminary method for up-scaling building spatial level models onto a continental level by the following steps:
  1. Classification of buildings;
  2. Simulation of the same type of buildings at several locations spread over Europe;
  3. Simulation of the effect of climate change using artificial local climate data sets;
  4. Visualization of the results using EU maps.
• Thank you
• Questions?