Linking climate with building energy performance through surrogate models.

OpenMod workshop, 4th of December 2020

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Motivation

Scalable modelling processes are essential for scaling our impact on sustainable building design
Fast Machine Learning
Building Energy Simulation
Surrogate Models
The International Bestseller

Thinking, Fast and Slow

Daniel Kahneman
Winner of the Nobel Prize
The example of the chess player

Find next move in seconds
Building performance design
Fast and Slow

Find building energy performance in seconds
Building performance design
Fast and Slow

Machine learning model - “Surrogate” as System 1

Physics-based model as System 2

Find building energy performance in seconds
Surrogate modelling

Building description file (.idf)
Annual hourly climate (.epw)

Simulation outputs (e.g. heating demand)

Building simulation software

Surrogate model (feed-forward neural net)

Estimates

Training/validation labels

WWR, SHGC, AEC

<table>
<thead>
<tr>
<th>WWR</th>
<th>SHGC</th>
<th>AEC [kWh]</th>
</tr>
</thead>
<tbody>
<tr>
<td>.50</td>
<td>.4</td>
<td>1500</td>
</tr>
<tr>
<td>.65</td>
<td>.5</td>
<td>2000</td>
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</tbody>
</table>

Surrogate modelling

Use of climate data
Generalization of surrogate models: Weather file as surrogate model input

Building description file (.idf)

Annual hourly climate (.epw)

Building simulation software

Simulation outputs (e.g. heating demand)

Surrogate model (feed-forward neural net)

Training/validation labels

Estimates

The climate file

~150’000 values

The convolutional neural network (CNN)

ResNet for TMY feature learning

### Performance on Canadian Climates

<table>
<thead>
<tr>
<th>Feature set</th>
<th>$R^2$</th>
<th>nMBE %</th>
<th>MAPE %</th>
<th>RMSPE %</th>
<th>$R^2$</th>
<th>nMBE %</th>
<th>MAPE %</th>
<th>RMSPE %</th>
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<tbody>
<tr>
<td>No Weather Data</td>
<td>0.3223</td>
<td>0.84</td>
<td>43.37</td>
<td>81.01</td>
<td>&lt; 0</td>
<td>-13.83</td>
<td>52.26</td>
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<td>2.25</td>
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<td>-3.82</td>
<td>8.33</td>
<td>13.62</td>
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<tr>
<td>Engineered</td>
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<td>-0.10</td>
<td>3.22</td>
<td>8.77</td>
<td>0.9951</td>
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<td>3.76</td>
<td>7.10</td>
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<td>1.93</td>
<td>2.60</td>
<td>0.9971</td>
<td>-0.43</td>
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Performance

Buildingenergy.ninja

BUILDING ENERGY DOT NINJA

by the Energy in Cities group, University of Victoria

http://206.12.93.86/
Conclusion and future research
Conclusion

- Concept of **reusable surrogate models** as **building simulation 2.0**
- Showcased large scale generalization potential
Ongoing and future research

• One “universal surrogate” to replace simulations
  • Span the entire globe and more types of outputs (hourly!)

• Retrofit analysis of existing buildings
  • Building model calibration

• Urban building energy modelling (UBEM)
  • Urban retrofit analysis
References

• **Introduction:**

• **Research study I:**

• **Images:**
  Books: https://www.springer.com/de/book/9783319208305?gclid=EAIaIQobChMltb3lO_i96wIVj9eyCh1YZwDFEAQYBSABgJLWfD_BwE; https://www.exlibris.ch/de/buecher-buch/english-books/daniel-kahneman/thinking-fast-and-slow/id/9780141033570;
  ID3-factory: https://www.sueddeutsche.de/auto/bmw-daimler-vw-software-id3-1.4856930
  Construction site: https://www.letsbuild.com/de/blog/bauprojektmanagement-eine-checkliste-der-grundlagen
  Image of office CAD model: https://evermotion.org/shop/show_product/building-45-am62-archmodels/5029

All other images were made available for free use.
Thank you!!

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