Thermal comfort in residential buildings by the millions

Early design support from stochastic simulations

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Thermal Comfort in Residential Buildings by the Millions - Early Design Support from Stochastic Simulations

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Background

New requirements for thermal comfort in residential buildings in Denmark:

Indoor temperature in "critical room":

- Max. 100 hours > 26 °C
- Max. 25 hours > 27 °C

Challenges:

- 10–100 potential "critical" rooms
- Multiplied by 3–4 design proposals
- Time-consuming
- Conservative approach comes at the expense of daylight and outlook
- Design feedback needed early

Simplified hourly method, with roughly 15 inputs, is mandatory to use in Denmark.

Idea

Idea: extensive stochastic simulations to represent (almost) all design combinations for most common rooms.

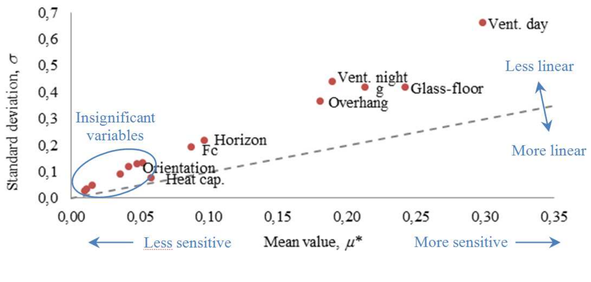
Sensitivity Analysis

Morris sensitivity analysis used to remove insignificant inputs.

Table 1. Distributions for 15 inputs

	Parameter	Unit	Discrete values					Min.	Max.
1	Orientation	-	W	SW	S	SE	E		
2	*UA*, envelope	W/K (m²)						0.1	0.3
3	*U*, windows	W/m² K						0.7	1.1
4	Recess	%						0	15
5	Ventilation, day	l/s m²						0.9	5
6	Ventilation, night	l/s m²						0	3
7	Ventilation, winter	l/s m²						0	3
8	Glass-floor-ratio	%						10	40
9	*g*-value	-	0.23	0.3	0.35	0.42	0.5		
10	Heat capacity	Wh/K m²	60	80	100	120	140		
11	F_c (shading)	-	0.2	0.4	0.6	0.8	1		
12	Overhang	°	0	20	40	60			
13	Horizon	°	10	25	40				
14	Fins, left	°						0	30
15	Fins, right	°						0	30

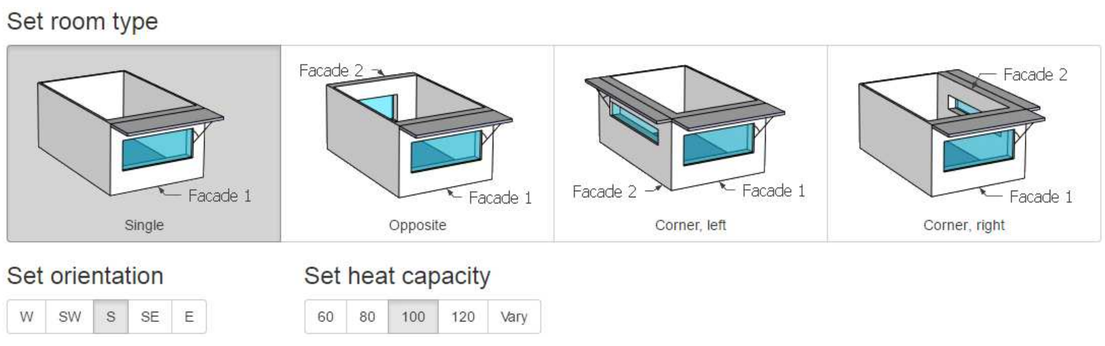
Figure 1. Plot of Morris sensitivity measures



Rapid exploration of millions of simulations

100.000 simulations have been performed for a each combination of common room types, orientation, and building heat capacity.

Figure 2. The design team chooses a combination of room type, orientation, and heat capacity.



Using an interactive parallel coordinate plot, the design team may rapidly test different designs and see how the design affects thermal comfort.

Figure 3. Interactive parallel coordinate plot showing inputs and outputs for 100.000 simulations

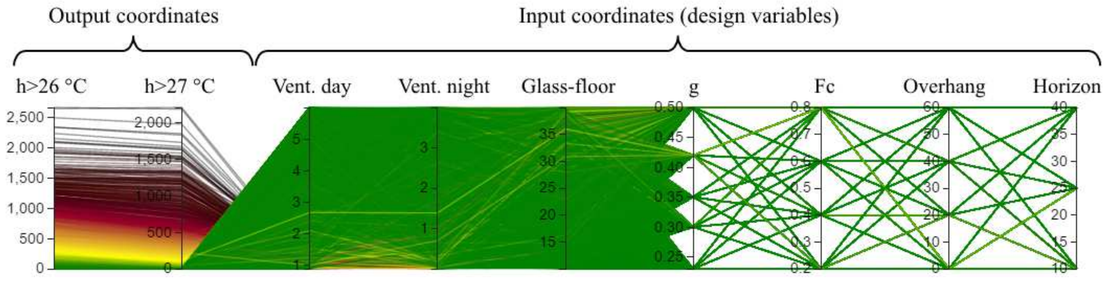


Figure 4. "Forward" approach to seek limits and test different design in early design stages

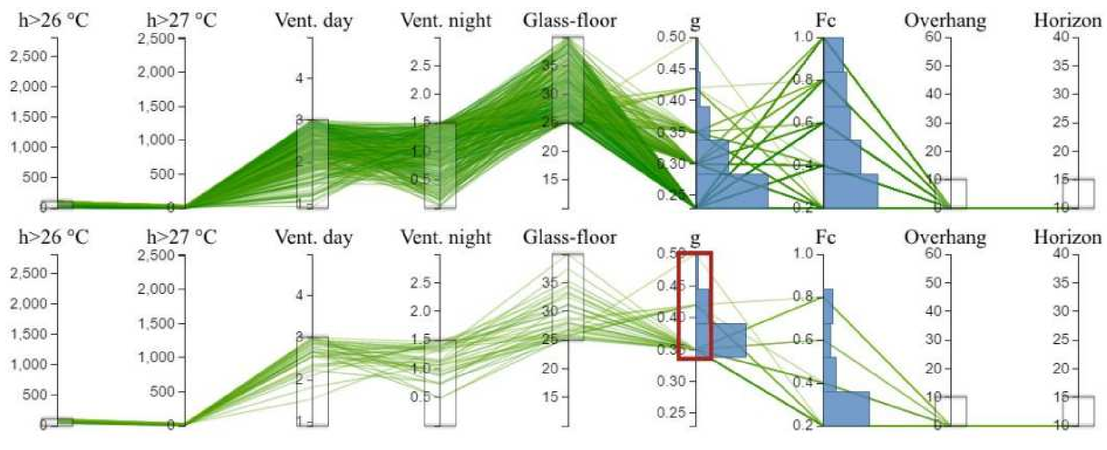
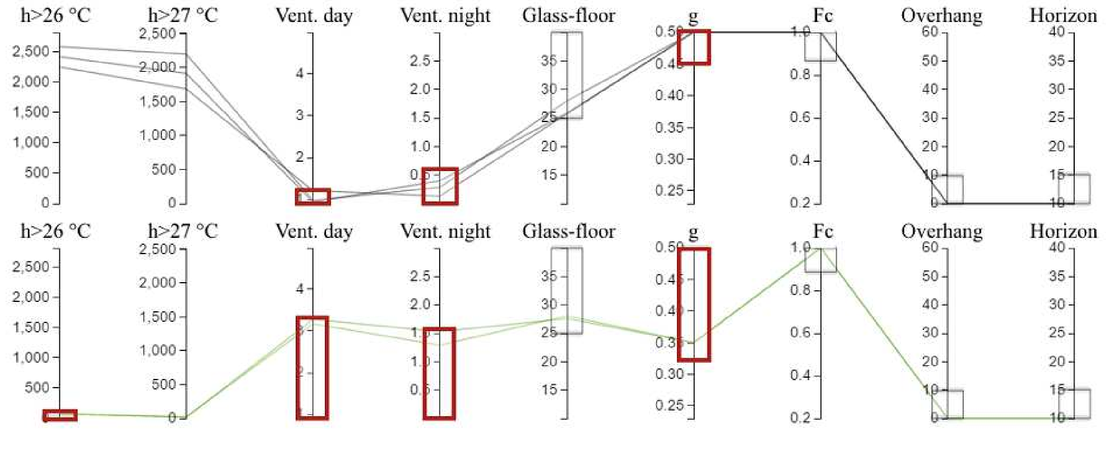


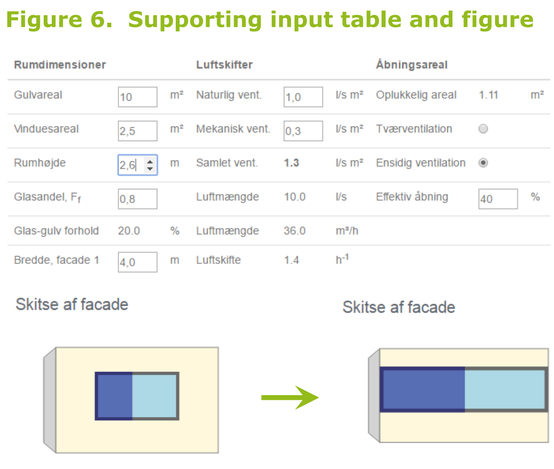
Figure 5. "Backward" approach shows the results for a "bad" design and how to find solutions



Regulation input values

A table and corresponding interactive figure help translate regulation guidelines into input values. The dark blue area shows how much of the window that must be openable in order to use the desired venting rate.

Figure 6. Supporting input table and figure



Discussion

The proposed method is not intended for final documentation but for rapid identification of limits and for testing of various design paths.

The code compliance software only assess thermal comfort. It may be substituted with detailed building performance software to address energy, illuminance, draught, etc. This increases the level of detail and the number of inputs which requires more simulations. Again, sensitivity analysis can help reduce the number of inputs.

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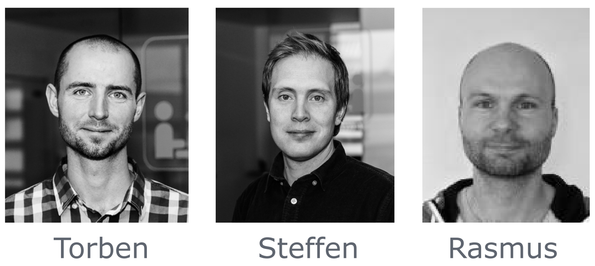

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