Sustainability recommendation system for process-oriented building design alternatives under multi-objective scenarios

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Introduction

"Evolutionary algorithms are a great tool for exploring the dark corners of design space."

- MIT Technology Review, 2005

Sustainable building design is a complex, multidimensional challenge: It requires **balancing:**

Energy Performance

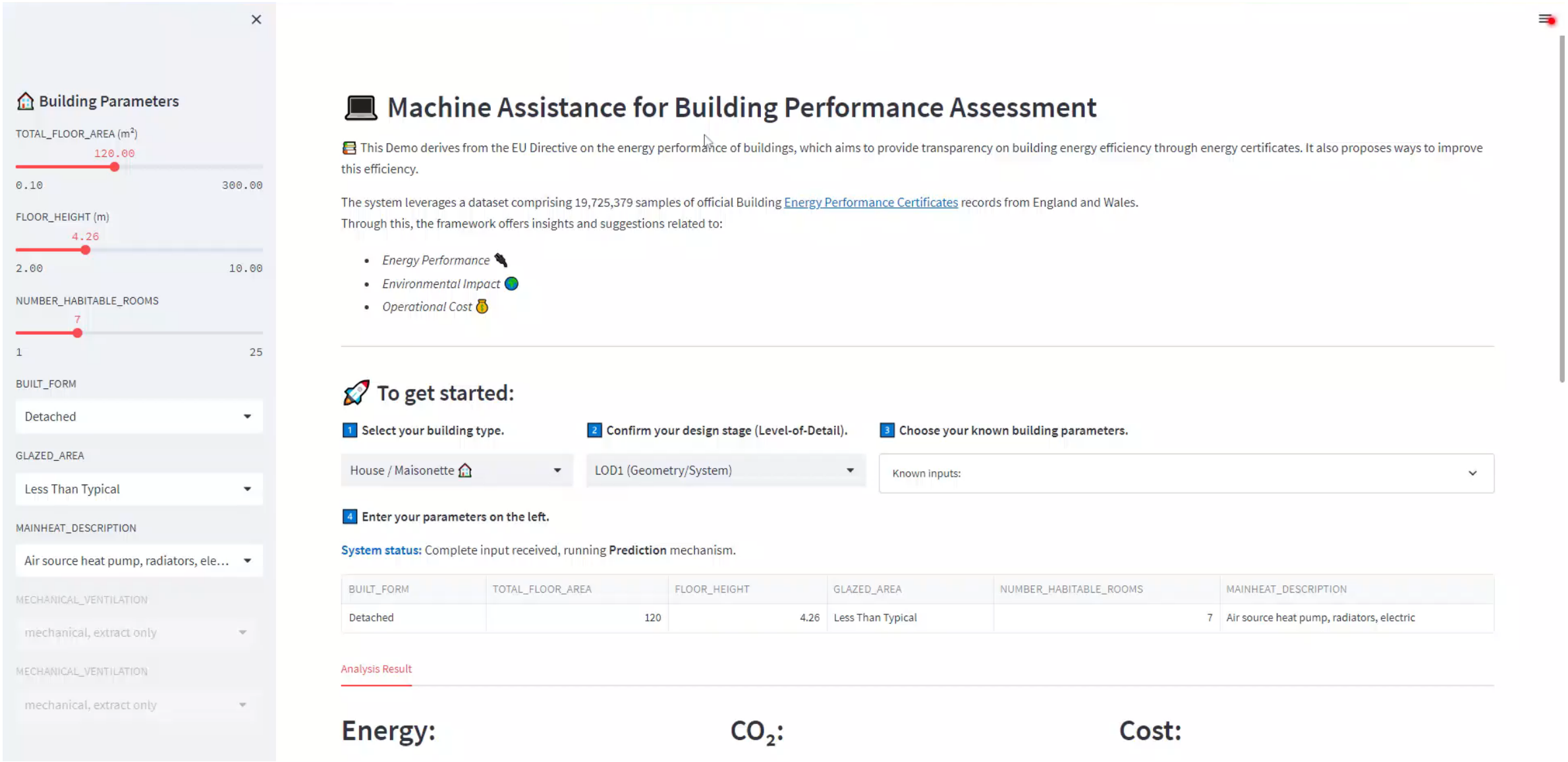
Environmental Impacts

Life Cycle Costs

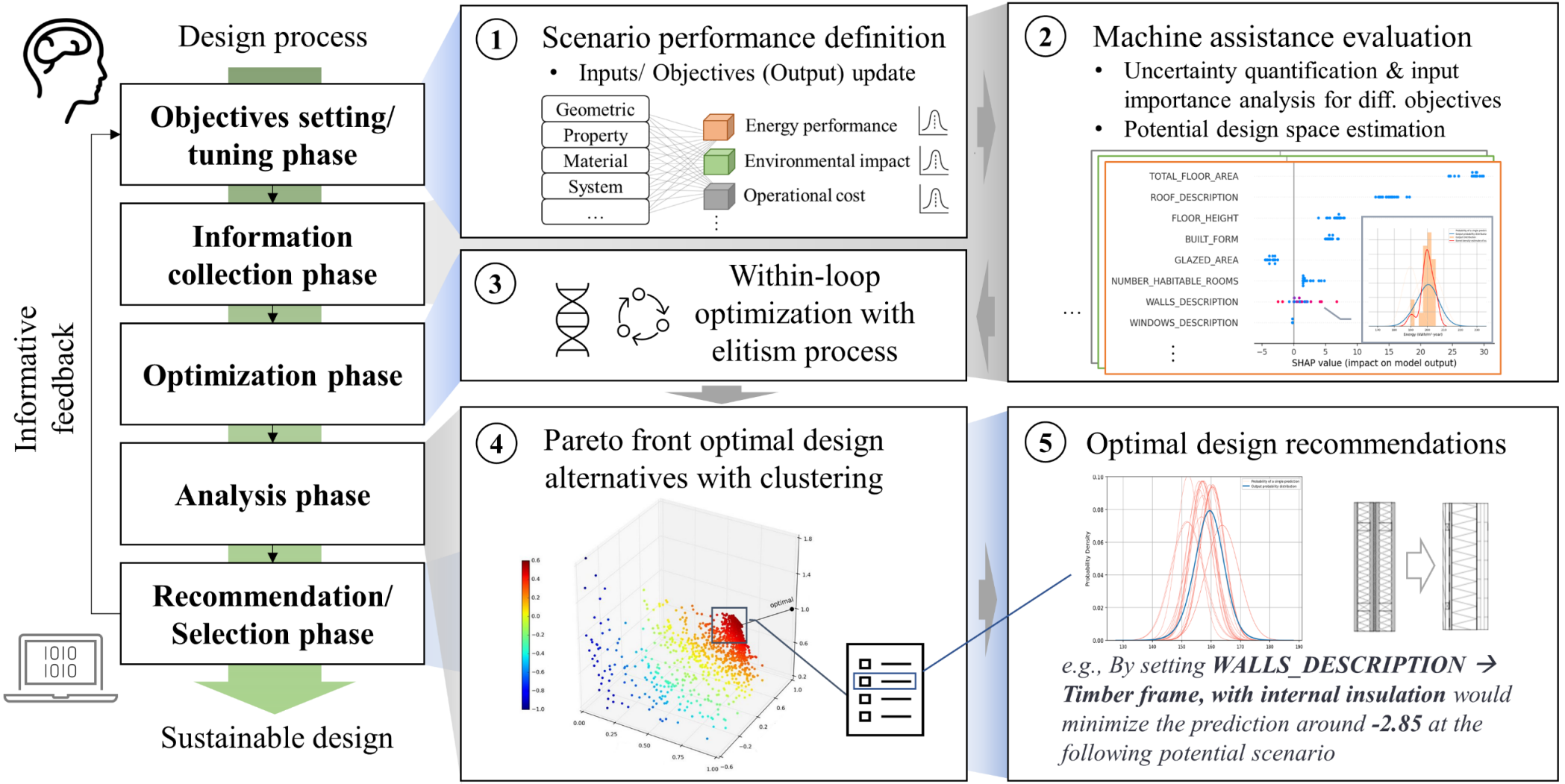
Challenge

- Current requirement for interpretable design space exploration across multidisciplinary domains.
- Existing tools are limited by dependence on designers' prior knowledge and computational bottlenecks.
- A need for a system that can provide rapid feedback, handle trade-offs, and adapt to various building engineering evaluations.

Sustainability recommendation system



Proposed Solution



- Chen, X., & Geyer, P. (2022). Machine assistance in energy-efficient building design: A predictive framework toward dynamic interaction with human decision-making under uncertainty. Applied Energy, 307, 118240.

Assistance in a case study

Energy Performance of Buildings Data: England and Wales, 19,725,379 samples with dwellings' detail across most UK regions and connects to the *domestic EPC (Energy performance certificate)*

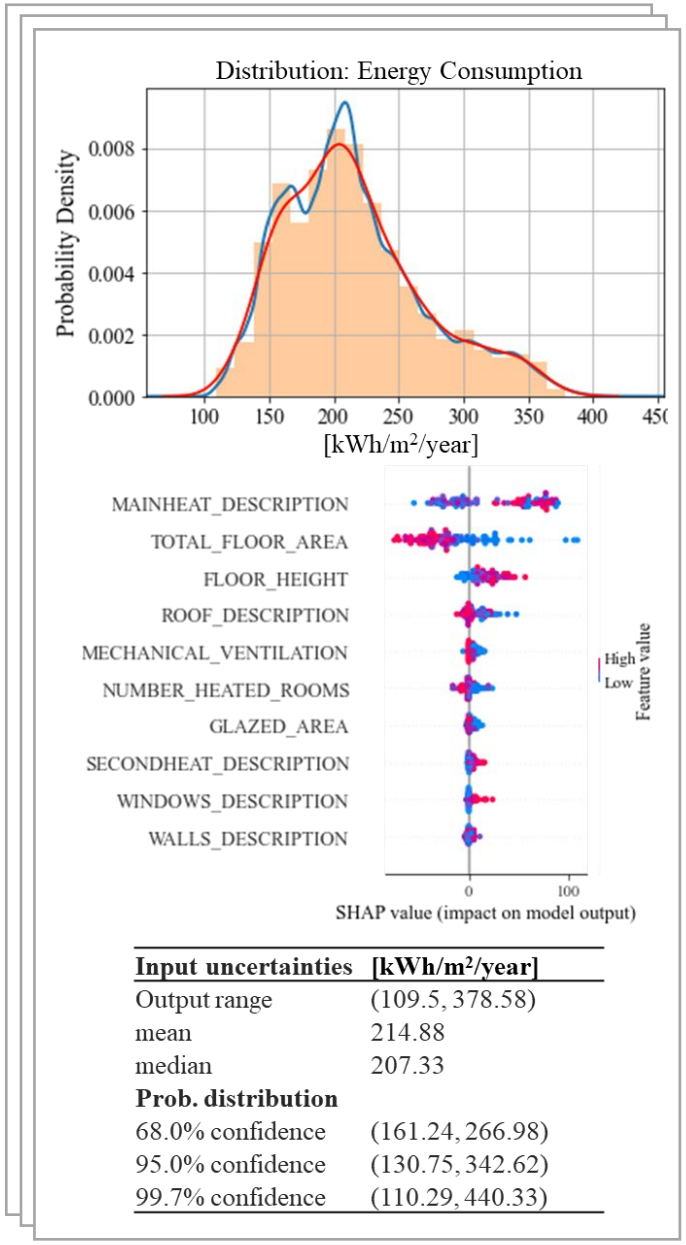
Input features in categories (Potential design space):

- *Geometry*
- *Component material property*
- *Energy system*

Outputs:

- *Energy Consumption* in kWh/m^2/year,
- *Environmental Impact* by *CO_2 Emission* equivalent in kg/m^2/year.
- *Operational Cost* in £/m^2/year.

***Design Scenario**: A flat building with detached built form* between *150-250 m^2*



Potential design space

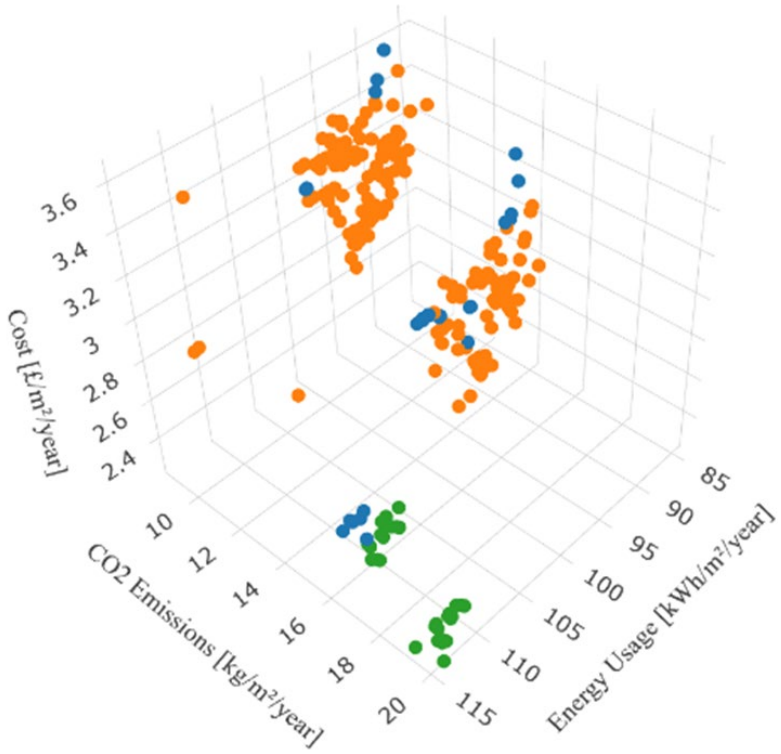
Feature interpretation

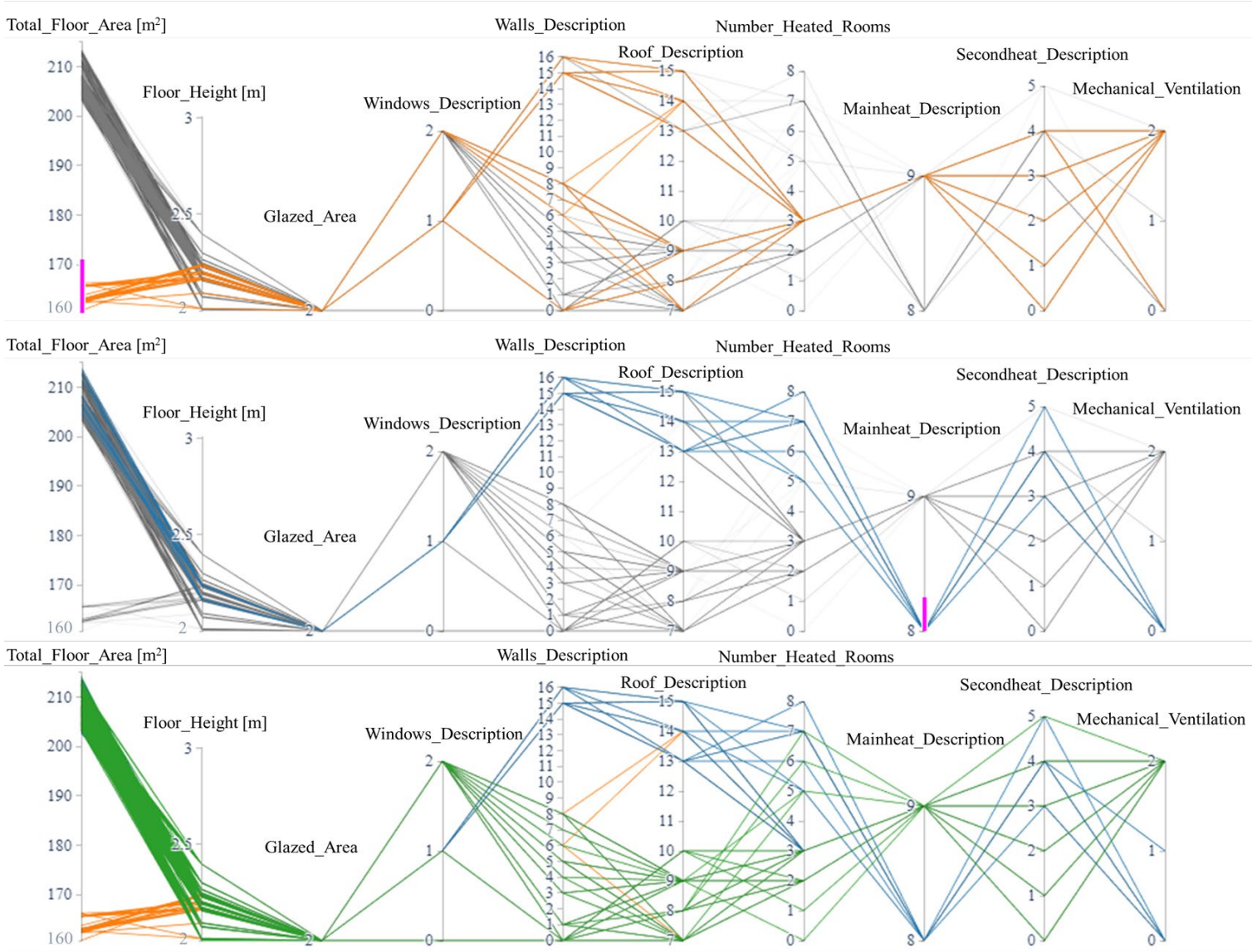
Result analysis

Machine Assistance evaluation

Optimization and Clustering Analysis

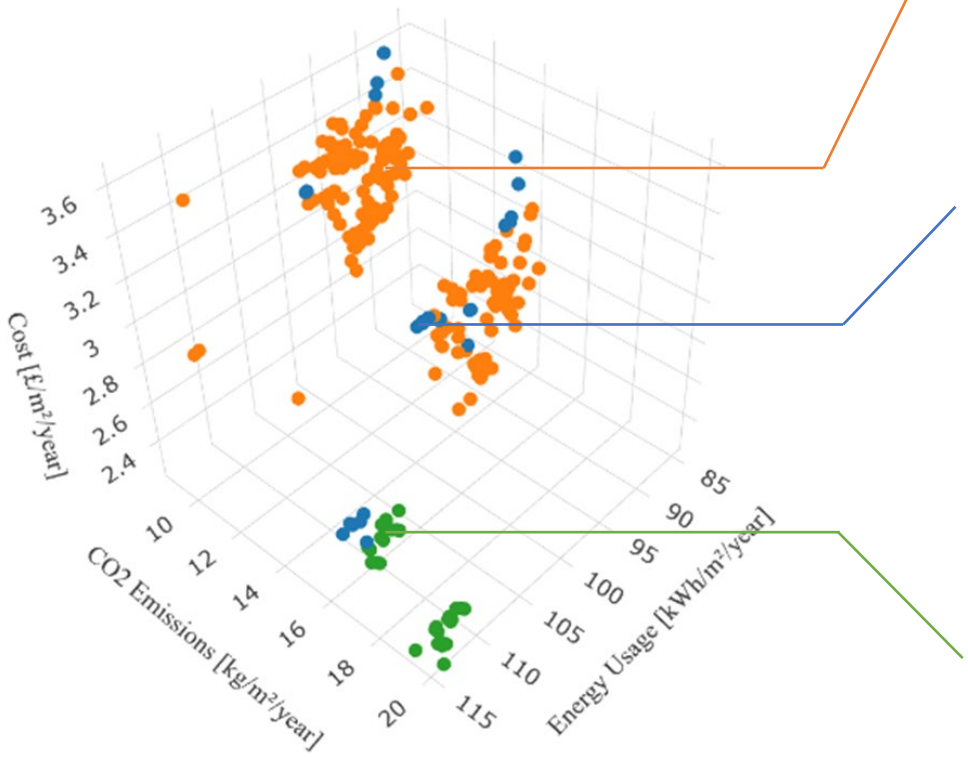
- **NSGA-II**: iterative elitism process to determine Pareto-optimal solutions
- **DBSCAN**: unsupervised clustering on optimal inputs set to discover design patterns.





Results and Recommendations

- **General patterns:** relatively low floor height (around 2.3 m), normal glazed area (10%-20% based on RdSAP), and triple/double glazing windows.



Orange cluster

- **165 m², three-room-heated**.
- Insulated **timber frame** walls.
- Main heating system: community scheme with main gas.
- Mechanical ventilation for extract.

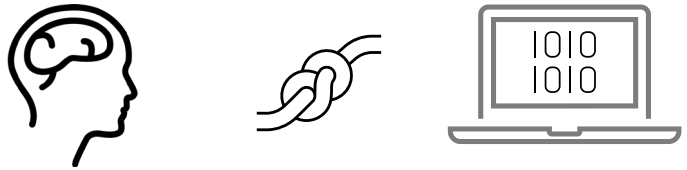
Blue cluster

- **210 m², 5-8 heated rooms**.
- **Fully triple-glazed windows**.
- Insulated **timber frame** walls.
- Main heating system: combined heat and power community scheme.
- Natural ventilation.

Green cluster

- **210 m², three-room-heated**.
- Insulated **cavity or granite walls**.
- Main heating system: combined heat and power community scheme.
- Nature ventilation.

Key takeaways



Sustainability Recommendation System: An innovative approach that supports sustainable building design by assisting designers in making informed decisions and optimizing design solutions.

1. **Flexibility in Design Space Exploration by Surrogate Models**
2. **Rapid Feedback & Interaction with On-going Design Process**
3. **Effective Trade-off Analysis and Pattern Discovery as Recommendations.**

Thank you!
Questions?

Demo address:
https://designaid-for2363.streamlit.app/

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