The Smart Room Causal Discovery System

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1 What is this project about?

Imagine a modern "smart room" where temperature, humidity, and air quality are automatically controlled to ensure both comfort and energy efficiency. For such a system to work effectively, it needs to understand how changing one factor affects others. For example, how exactly does increasing the temperature impact both energy consumption and overall comfort?

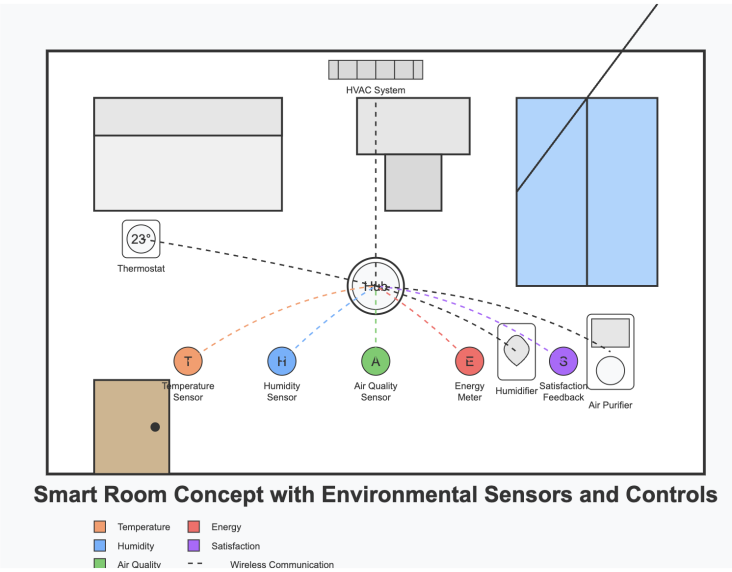


Figure 1: Smart room concept with environmental sensors and controls

2 The Smart Room Simulation

The system creates a virtual "smart room" with:

- **Control Variables**: Things we can directly adjust
  - Temperature (18-30°C)

  - Humidity (30-70%)
  - Air Quality (measured as 0-500, where lower is better)

- **Outcome Variables**: Things we care about but can't directly control
  - Energy Consumption (how much energy is being used)
  - Overall Satisfaction (how comfortable the room feels)

This virtual room follows realistic physical principles - when temperature goes up, the energy needed for cooling increases, and comfort levels change based on complex combinations of all variables.

3 The Problem: Finding Cause and Effect

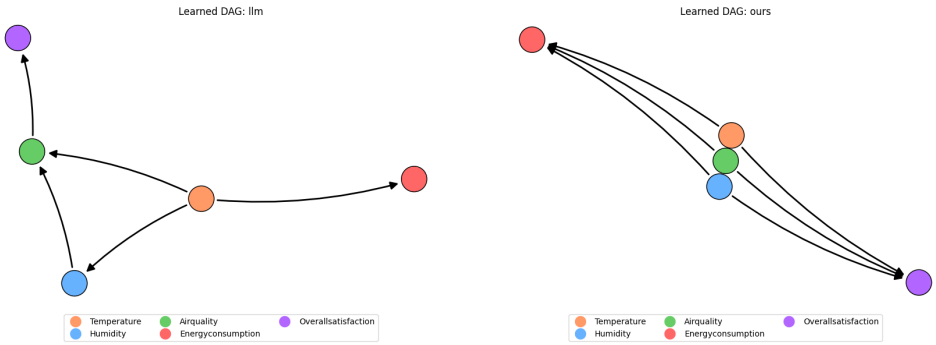
The challenge is to discover the exact cause-and-effect relationships in this system. While some relationships might seem obvious (like turning up the heat uses more energy), the precise connections and their strength are not always clear.

Figure 2: Smart room simulation interface showing control variables and outcomes

4 The Solution: Learning Through Experimentation

The system takes a methodical approach:

1. **Initial Guessing**: The system starts with three different methods making their best guesses about how the room works.
2. **Finding Disagreements**: It identifies relationships where the methods disagree (for example, one method might think humidity strongly affects comfort while another doesn't).
3. **Testing Through Experimentation**: The system performs virtual "experiments" in the smart room - changing one variable at a time and carefully measuring what happens.
4. **Building Understanding**: After each experiment, the system updates its knowledge, focusing next on testing relationships it's most uncertain about.
5. **Final Model**: Eventually, the system builds a reliable map of cause and effect in the room that can be used to make better decisions.



(a) Initial DAG hypotheses (b) Final learned DAG after interventions

Figure 3: Directed Acyclic Graphs (DAGs) showing causal relationships

5 Why This Matters

This approach mimics how scientists discover causal relationships in the real world, but does it automatically. For real smart buildings, understanding these relationships can lead to:

- Better comfort for occupants

- Reduced energy consumption
- More effective building management systems
- Optimal automation of environmental controls

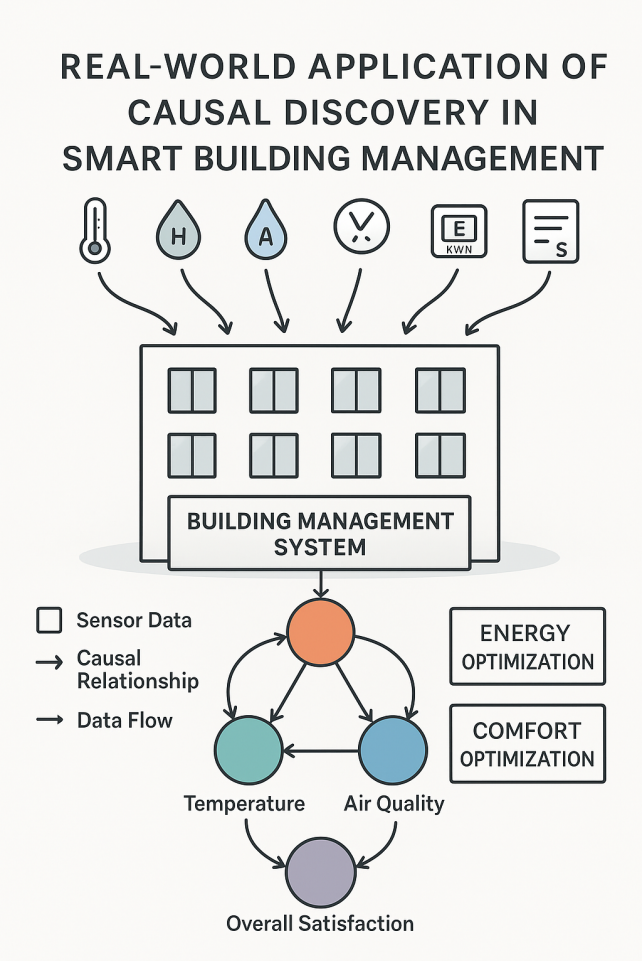


Figure 4: Real-world application of causal discovery in smart building management

The techniques developed here could be applied to many other systems where understanding cause and effect is important, from healthcare to economics to environmental science.