Scalable Adaptive Air Conditioner Control in Real Sleep Environments

"A Pilot Deployment with Lightweight Reinforcement Learning"

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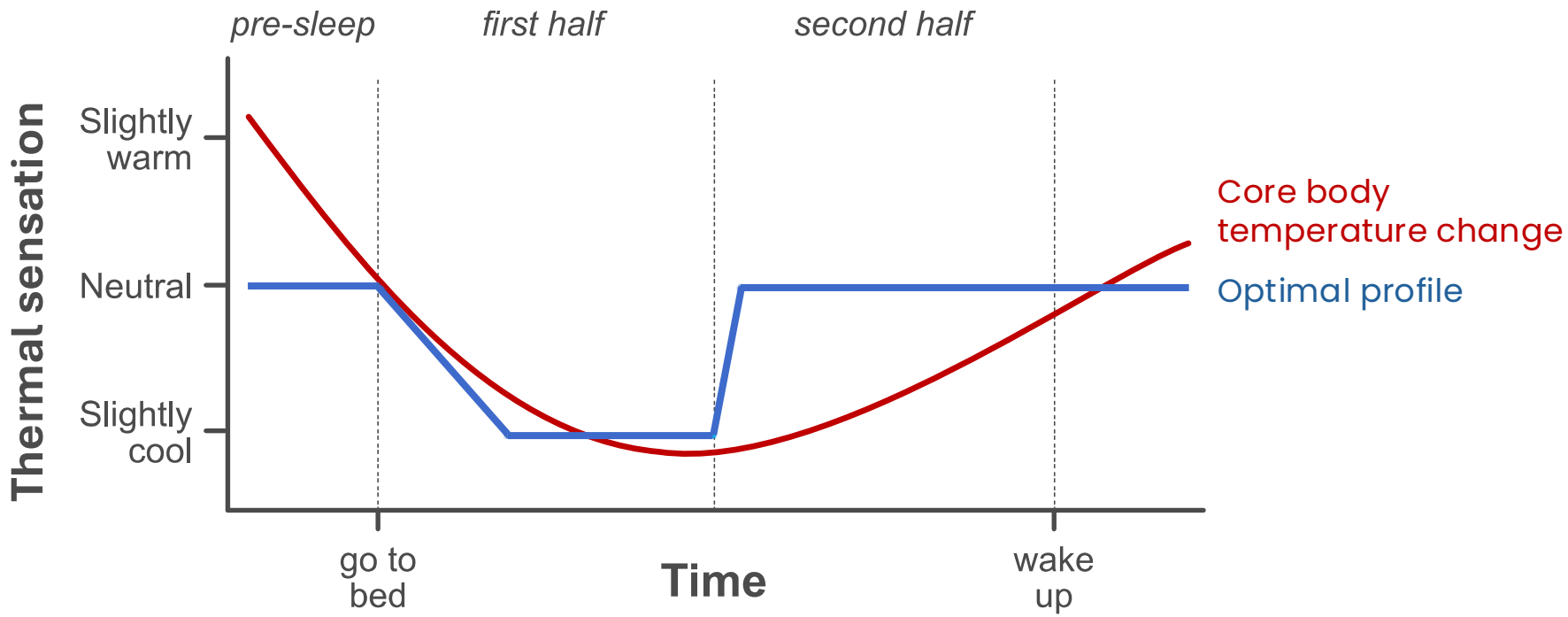
Background

Sleep thermal comfort is dynamic and guided by neutral thermal sensation



Field Translation of Sleep Setpoint Control Curves

1. Real bedrooms differ from lab settings
   - Real homes are more complex, with variable thermal conditions, less precise temperature control, and diverse occupant behaviors and preferences.
2. Neutral setpoint is not fixed
   - It can change due to the factors like physiological state, sleep stage, bedding, outdoor weather, and AC performance.

Research gap:

Lack of a scalable field research tool for studying occupant-centric control in real homes.

Aim & Objectives

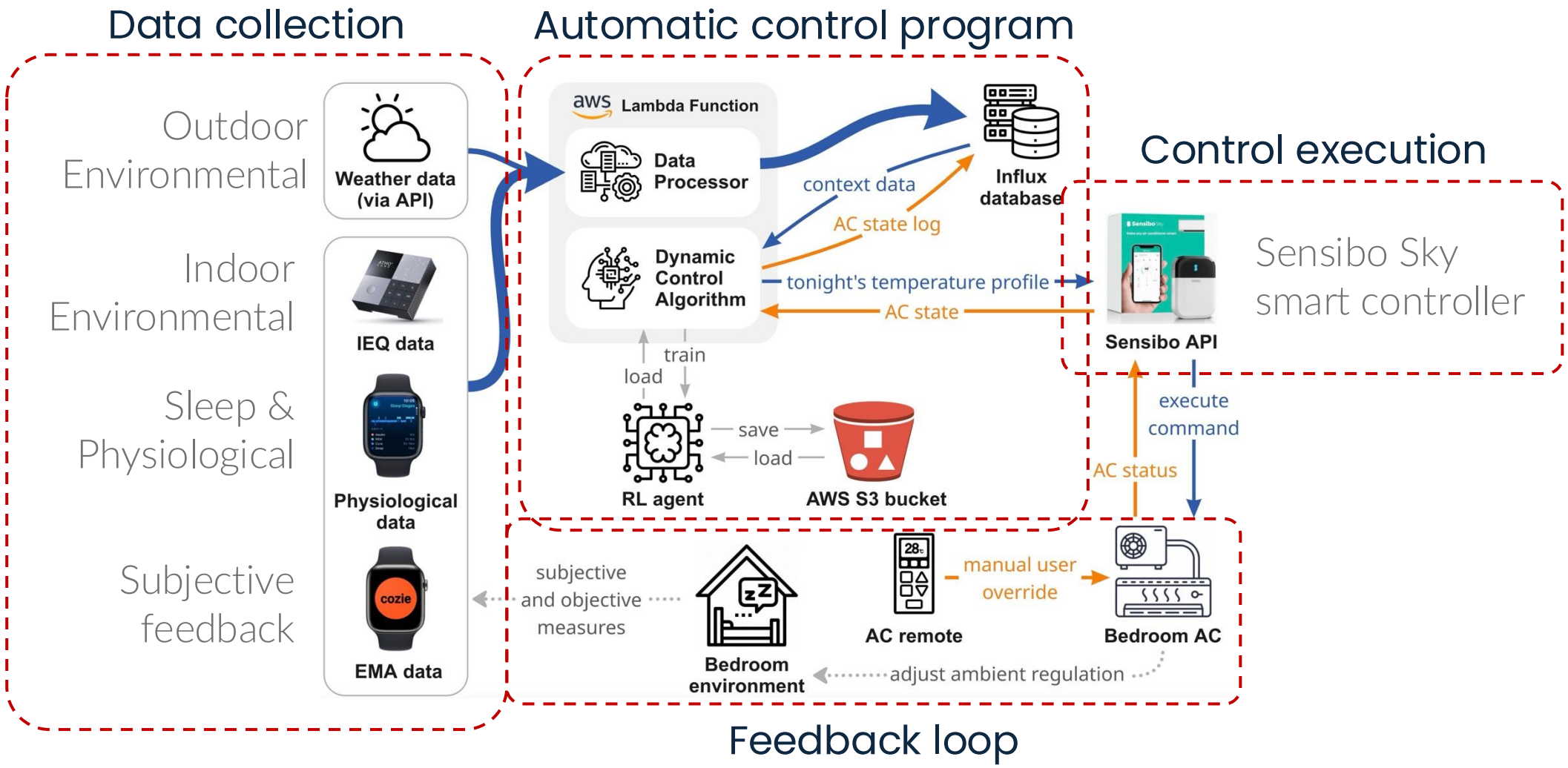
Develop a scalable research prototype allow us to study occupant-centered adaptive AC setpoint control in real bedrooms over time

Objective 1:
Build a prototype for field data collection and AC control

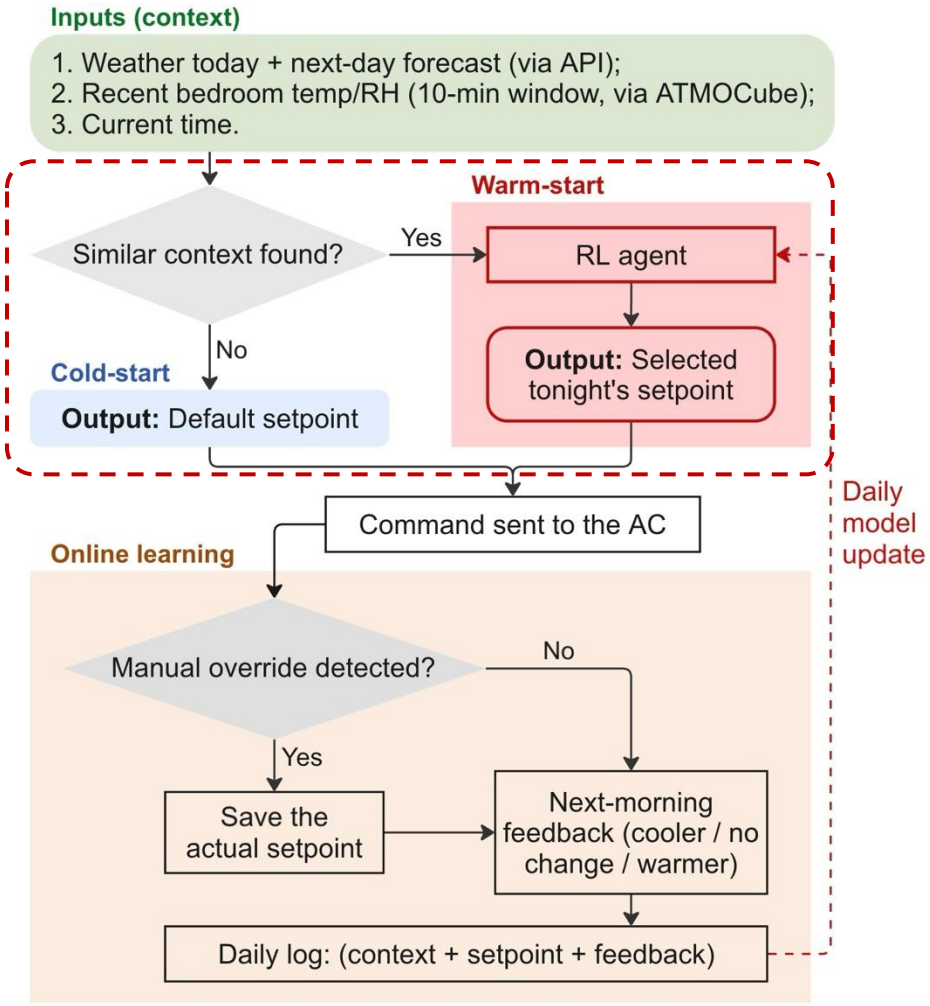
Objective 2:
Design an RL-based algorithm for AC setpoint optimization

Objective 3:
Evaluate the prototype in real bedrooms

Research Prototype Design



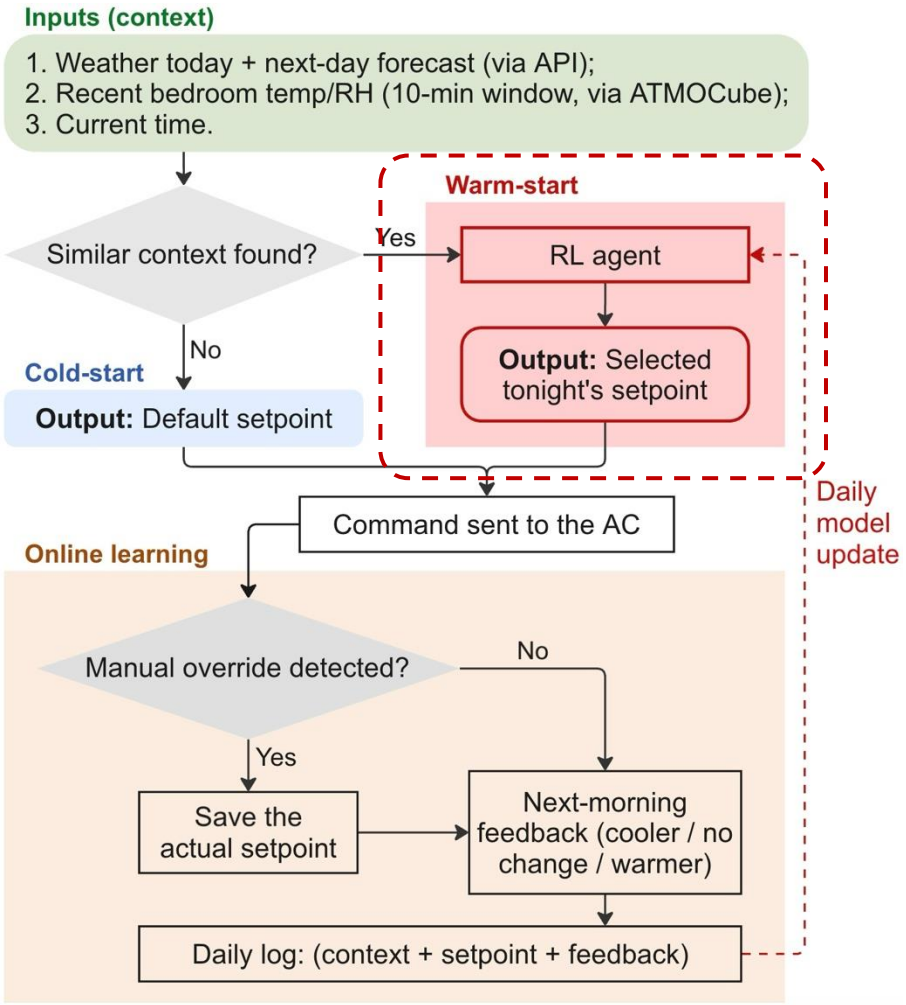
Feature 1: Customizable Control Algorithm



Context-similarity clustering (cluster days with similar weather and indoor conditions):

- Similarity < 0.8: Create a new cluster & use default setpoint
- Similarity ≥ 0.8: Assign to an existing cluster

Feature 1: Customizable Control Algorithm



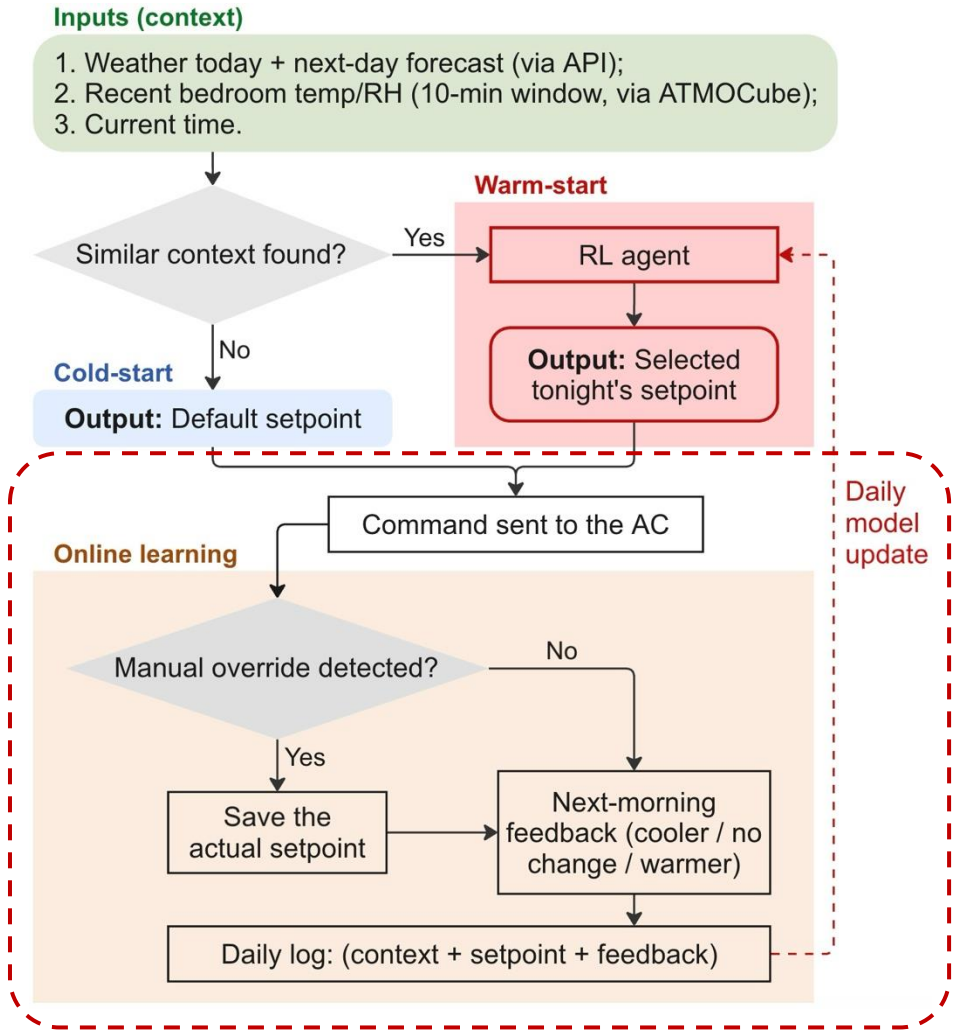
Bandit Q-learning (learn the optimal temperature setpoints under different contexts)

States: [All Inputs]

Action Space: $[T_{neutral} - 1, T_{neutral}, T_{neutral} + 1]$

Reward: No change +2.0; Warmer/Cooler -1.0

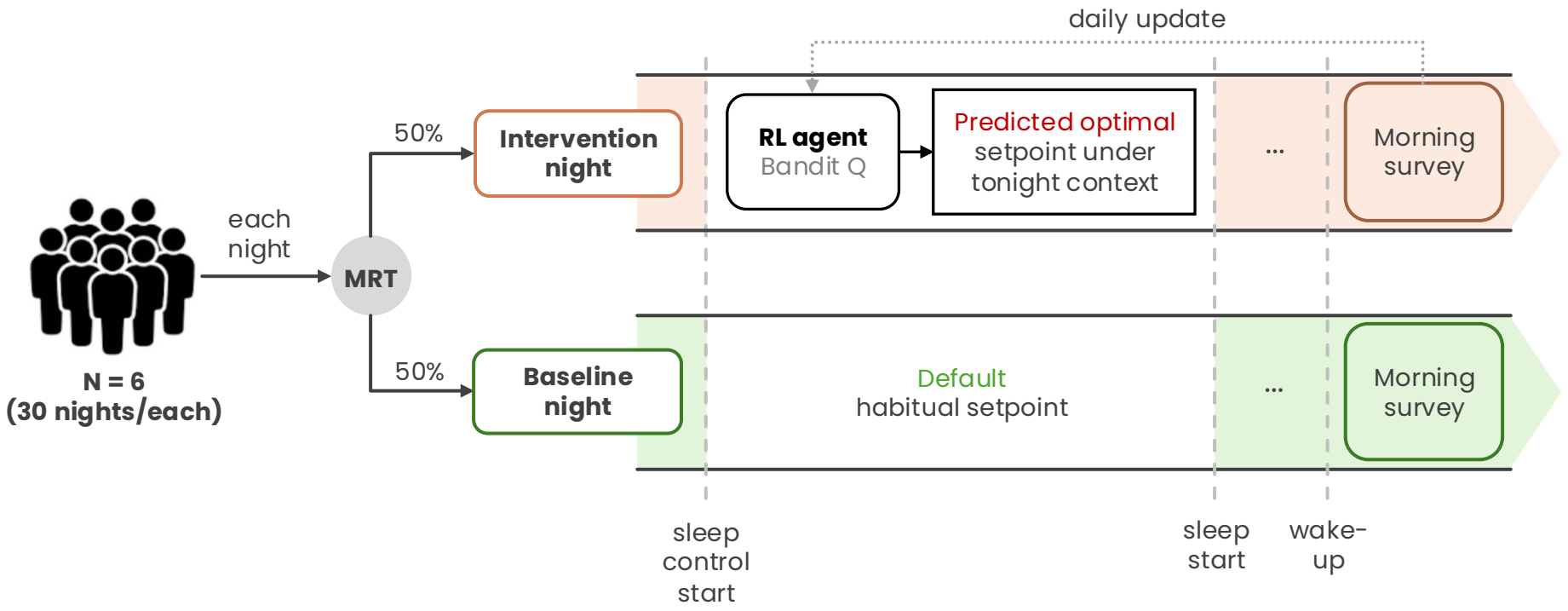
Feature 1: Customizable Control Algorithm



- Allow users adjust the temperature when uncomfortable
- RL agent learns from the actual setpoint and next-day feedback

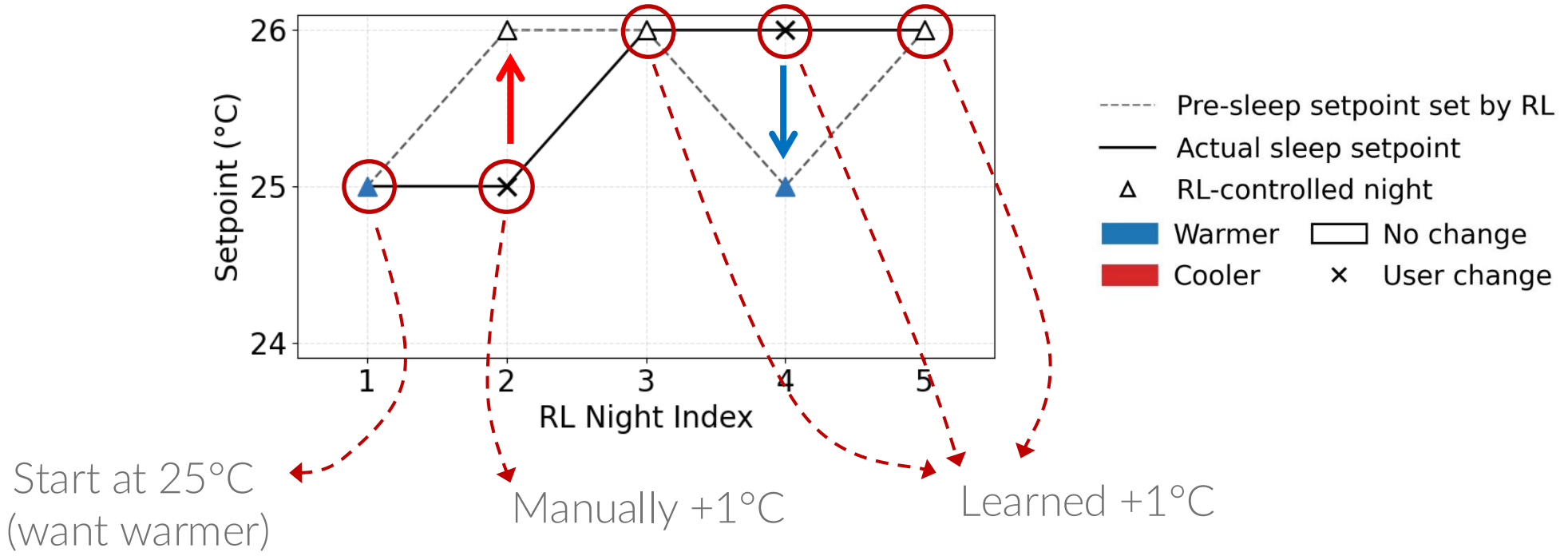
Feature 2: Micro-Randomized Trial (MRT) Support

Nightly randomization (MRT) helps reduce uncontrolled field effects



Preliminary Results

The system successfully learned temperature setpoints based on occupant feedback and behavioral adjustments



Ongoing Work and Future Directions

Ongoing Work:

- A field evaluation paper using this protocol for body thermoregulation-based dynamic bedroom air-temperature control is under review

Future Directions:

- Improve usability and extensibility through reusable control logic and broader smart-home device integration
- Convert the prototype into a standardized experimental platform for residential occupant-centric control research

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Thank you!

Any questions?

Contact me: