DEMO: Web-CozyBench - A Web-Based Platform to Benchmark Thermal Comfort Provision using Digital Twins

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***Abstract*—Providing individual thermal comfort to occupants while minimizing energy use is a significant challenge in smart building management. Simulation-based benchmarks such as Co-zyBench have been developed to evaluate occupant-centric thermal comfort provision systems using Digital Twin (DT) models of buildings and occupants. In this paper, we present Web-CozyBench, a web-based platform that extends Co-zyBench by offering an intuitive, user-friendly interface for configuring experiments, running co-simulations, and visualizing results. Web-CozyBench lowers the barrier to entry for researchers and practitioners to benchmark thermal comfort provision systems by eliminating the need to directly handle complex simulation configurations. We outline the system design of Web-CozyBench and demonstrate its usage through a step-by-step scenario. The demonstration showcases how users can easily set up building and occupant digital twins, select a control strategy, run the simulation, and analyze performance metrics such as comfort and energy efficiency through the web interface.**

***Index Terms*—thermal comfort, digital twin, HVAC, benchmarking**

I. Introduction

Heating, Ventilation, and Air Conditioning (HVAC) systems contribute substantially to building energy use and carbon emissions, yet maintaining occupant thermal comfort remains essential for health and productivity [1]. The challenge becomes even greater when accounting for the diverse thermal preferences of occupants, requiring a delicate balance between individual comfort and energy efficiency. To address this challenge, novel occupant-centric thermal comfort provision systems have been proposed [2]. These systems use pervasive sensors and devices to monitor thermal sensations, determine optimal temperature setpoints balancing comfort and energy use, and adjust the HVAC accordingly. However, evaluating these systems in real buildings is difficult due to high deployment costs, privacy concerns, and uncontrolled conditions. Simulation-based evaluation has emerged as a promising alternative, enabling repeatable and safe testing of control strategies under realistic scenarios. Nevertheless, ensuring the realism of simulations remains a significant challenge.

Co-zyBench [3] was introduced as a benchmarking tool that addresses these evaluation challenges. It uses Digital Twins (DTs), virtual replicas of a building and its occupants, to accurately simulate the interactions of the building and the occupants. Co-zyBench also provides reference building and occupant DT models based on real data, such as historical weather records and standard building material properties, to facilitate realistic scenario creation. Users can also input their own building models and occupant profiles, which Co-zyBench can convert into simulation-ready DTs. Co-zyBench realistically emulates how a thermal comfort provision system would perform in the building and occupants scenario and generates comprehensive performance reports, including individual thermal comfort, comfort equality, energy usage, and carbon emissions, facilitating comparative analysis across different strategies.

Despite its capabilities, using Co-zyBench originally requires significant technical expertise in setting up simulation-based DTs and interpreting results. In this work, we present **Web-CozyBench**, a web-based platform built on Co-zyBench as a natural extension to make thermal comfort provision system benchmarking more accessible. Web-CozyBench introduces (i) a browser-based GUI for simulation configuration and result visualization, (ii) automated transformation of user-uploaded data models into simulation-ready formats, and (iii) a backend orchestration layer enabling remote execution and session persistence. These enhancements collectively lower practitioners' barriers to evaluating their solutions. We demonstrate how users can easily configure a benchmark experiment, execute the simulation through the web interface, and visualize key outcomes.

II. System Overview

Web-CozyBench builds upon the core components of Co-zyBench's simulation environment, centered around two DT models and a co-simulation engine that together model interactions between occupants, the building, and the thermal comfort provision system. The Building DT is a virtual model capturing static properties (e.g., floor plan, insulation, HVAC specs) and dynamic behavior like temperature changes over time, responding to HVAC controls and environmental factors. The Occupant DT models occupants' characteristics (e.g., height, weight) and dynamic behaviors such as movement,

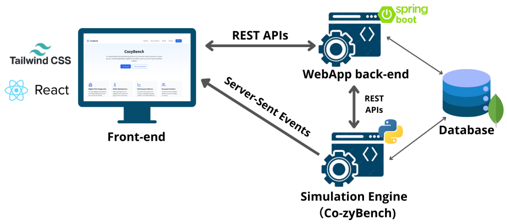


Fig. 1: System architecture of Web-CozyBench.

estimating thermal sensation based on environmental inputs from the Building DT. A Co-Simulation middleware synchronizes the two DTs, advancing the simulation in discrete steps and managing feedback loops such as occupant movement affecting HVAC settings and HVAC adjustments impacting occupant comfort.

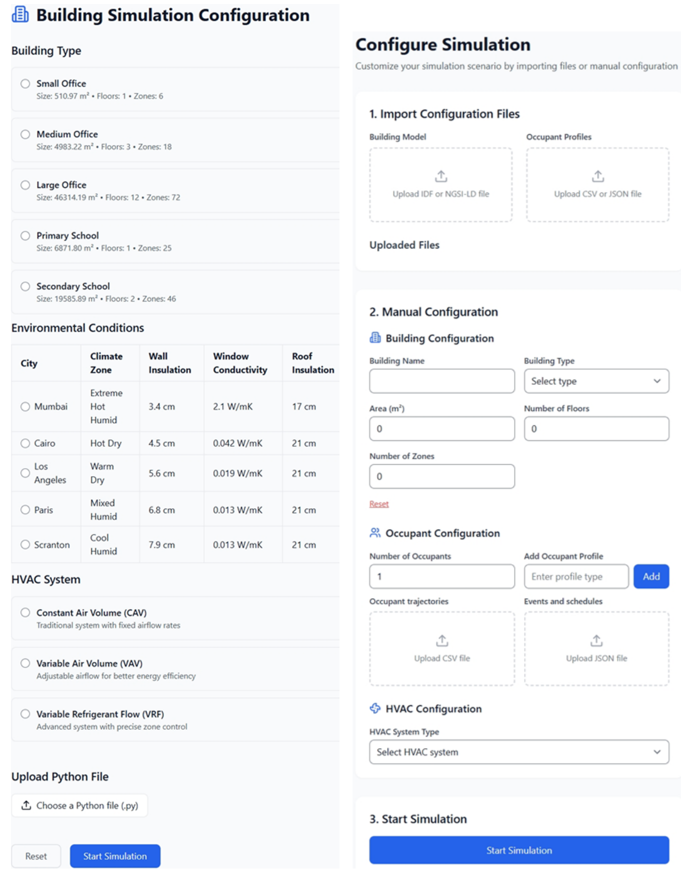
At the end of each simulation run, Web-CozyBench computes evaluation metrics to assess the tested thermal comfort provision system. Five key metrics are provided, aligned with Co-zyBench: Individual Thermal Comfort (ITC) for occupant comfort levels; Thermal Comfort Equality (TCE) for fairness across subgroups; Energy Consumption (EC) for total HVAC energy used; and Carbon Dioxide Emissions (CDE) for environmental impact. These metrics enable comparative analysis of systems in terms of comfort, efficiency, and environmental responsibility.

Web-CozyBench adopts a three-tier web architecture combining a frontend, a backend, and the Co-zyBench simulation engine, as illustrated in Figure 1. The frontend, built with React.js, provides an interactive interface for users to configure simulations, define building parameters, occupant profiles, and input thermal comfort provision systems, with results visualized through dynamic charts. The backend, implemented with Java Spring Boot, handles client requests, manages simulation orchestration, user sessions, and stores results. It exposes RESTful APIs to the frontend and invokes the simulation engine. The simulation engine, based on Co-zyBench core modules, runs the time-step simulations, integrating decision-making logic (such as occupant thermal sensation estimation or thermostat control strategies) and generating raw result data. A MongoDB database stores scenario configurations, simulation results, and user accounts to support flexible experiment management and historical comparisons.

This modular, web-based design ensures scalability, maintainability, and broad accessibility. Users can access Web-CozyBench through standard browsers without needing to install specialized simulation software or manage complex local environments. The architecture supports concurrent users, enables easy future extensions (e.g., new occupants or building models), and facilitates integration into research and industrial workflows for occupant-centric smart building development.

III. Demonstration Scenario

Web-CozyBench is publicly available on GitHub [4]. To illustrate Web-CozyBench in action, we present a demonstration scenario that users might follow to benchmark their thermal comfort provision system. The scenario is structured as follows:



(a) Reference scenarios. (b) Customizable scenarios.

Fig. 2: Screenshots showing the reference scenario setup and configuration interface.

Step 1: Configure the Scenario. The user begins by creating a new simulation scenario through the web interface. There are three ways to define the Building DT and Occupant DT parameters. First, users can select a reference scenario from five predefined models: small, medium, and large offices, primary and secondary schools. After choosing a building type, users select a suitable climate zone based on predefined environmental conditions, and an HVAC system that will automatically adjust its capacity according to building size and climate (see Figure 2a). These reference scenarios can meet most users' needs. For users requiring more variability or using their own building layouts, the system also supports uploading custom models. Users can provide NGSI-LD formatted models for both buildings and occupants, which the platform will automatically transform for co-simulation (see Figure 2b). Alternatively, users can quickly create a simple custom model by entering basic parameters like the number of rooms, floors, and occupants, with the system completing the detailed model automatically. Once the scenario is configured, it is saved and sent to the backend for processing.

Step 2: Select Control Strategy. After configuring the DTs, the user selects which thermal comfort provision system to

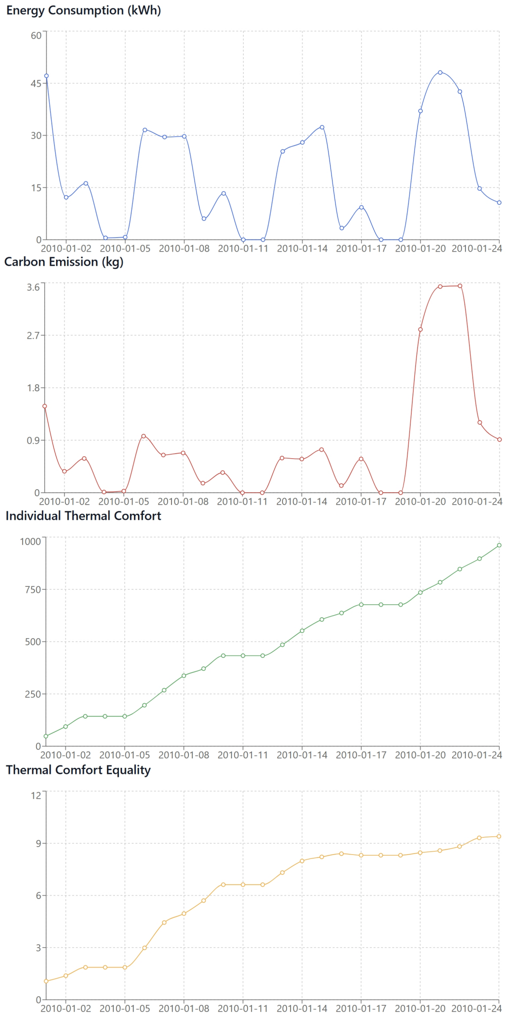


Fig. 3: Web-CozyBench demonstration workflow.

evaluate. In the demo, the user can choose from built-in baseline strategies (for instance, an energy optimized strategy vs. an occupancy comfort focused system) or upload their own system module. This choice is recorded, and the system loads the corresponding system into the simulation engine. The user can also set simulation parameters such as the simulation duration and simulation timestep (e.g., how many iterations each hour).

Step 3: Run the Simulation. With the scenario and control strategy defined, the user initiates the simulation run by clicking a *Start Simulation* button. The web interface then transitions to a monitoring view where the progress of the simulation is displayed. The backend launches the Python-based co-simulation using the specified configuration. As the simulation runs, the user may see live updates on the interface: for example, a real-time plot of current evaluation results. Web-CozyBench's asynchronous design allows the user to remain on the page and watch updates, or even close the browser and reconnect later to check results (since the backend will store the outcome). For the purpose of the demo, the simulation might be sped up to complete within a short real-time period. Once finished, the user is notified that the run is complete and the results will be stored in the database.

Step 4: Analyze Results. During and after the simulation, the platform automatically computes the performance metrics (ITC, TCE, EC, CDE as described in Section II) and generates a results dashboard as shown in Figure 3. The evaluation results are stored in the database for future reference. Users can download the evaluation results locally. They can also access the History page to review previous evaluations, where Web-CozyBench displays their performance metrics side by side, allowing users to easily compare the results.

Through this step-by-step scenario, the audience can see how Web-CozyBench simplifies the process of evaluating a thermal comfort provision system. The web platform abstracts the intricate details of simulation configuration and data processing, presenting the user with an intuitive workflow to obtain meaningful insights. During the live demo, attendees would be able to interact with the system, try adjusting parameters, and immediately observe the impact on results, emphasizing Web-CozyBench's utility as an educational and research tool.

IV. Conclusion and Future Work

We presented Web-CozyBench, a web-based benchmarking platform that makes it easy to assess occupant-centric HVAC control systems using digital twin simulations. Built on CozyBench with a web interface, Web-CozyBench lets users configure building and occupant scenarios, run co-simulations, and view metrics without simulation expertise. In this Demo Track contribution, we showed how Web-CozyBench can be used to compare HVAC control strategies in a realistic scenario. We believe Web-CozyBench will accelerate the development of smarter, more sustainable building management solutions.

For future work, we plan to expand Web-CozyBench's features and reach. In upcoming releases, we will release a public online version to foster community contributions. We are working on incorporating additional comfort models (e.g., humidity and air quality factors) and more diverse building and occupants reference models to broaden the applicability of the benchmark.

Acknowledgment

This work is partially supported by the Horizon Europe project PANDORA under grant agreement number 101135775 and the China Scholarship Council (CSC).

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