Designing Intelligent Spaces: A Web-Based Simulation Platform with Conflict-Resolving AI

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Abstract The emergence of smart environments in homes, offices, and public spaces has introduced a new paradigm in human interaction with technology. This paper presents the design and implementation of a web-based platform for the creation, customization, and real-time simulation of intelligent environments. The platform enables users to define and manage physical environments, associate user profiles with adjustable incidence percentages, and configure individual preference cards related to environmental variables such as temperature, humidity, and luminosity. The simulation engine integrates artificial intelligence (AI) to compute optimal environmental configurations, resolving preference conflicts through weighted aggregation while enforcing physical constraints. The architecture, interaction model, and computational logic are detailed, along with practical insights into the scalability and application of the platform in context-aware ambient systems.

Key words: smart-environments, intelligent-spaces, user-preferences, artificial-intelligence

1 Introduction

The primary goal of our project is to develop a web application that allows the management and simulation of smart environments (home, work, public space). In particular, it allows the creation and customization of different contexts, associating users with them and their respective preferences. Finally, it automatically calculates the optimal value for each of the preferences to be applied in a given period.

Modern approaches to smart environments often face challenges related to limited customization, lack of real-time simulation, and static automation rules [9, 10]. These systems frequently overlook the nuances of user context, multi-user environments, and dynamic decision-making. Our project addresses these limitations by offering a flexible and scalable platform where users can simulate interactions between multiple users, devices, and environmental factors, ensuring more realistic and responsive smart spaces [1, 3].

This project also highlights the importance of integrating multiple data layers—user preferences, contextual parameters (e.g., time, occupancy), and device constraints—into a unified decision engine. By aggregating and interpreting these data streams through AI-driven logic, the platform can intelligently balance comfort, energy efficiency, and safety [6, 4].

Furthermore, a key feature of the platform is its intuitive and responsive web interface. Designed with usability in mind, the platform allows users to easily configure spaces, visualize simulation outcomes in real-time, and analyze how changes in preference or environment impact the system's response [8]. These insights offer valuable tools for developers, educators, and researchers interested in prototyping or studying smart environment behavior.

2 Materials and methods

At the following subsections we describe the web platform development process and the main functional modules that make up the smart space simulation system.

2.1 Description of the Problem

The evolution of modern lifestyles, marked by increasing mobility and an ever-increasing appreciation of comfort and automation in daily routines, has highlighted the importance of creating intelligent environments capable of automatically adjusting their conditions to users' preferences. This need becomes especially visible in the context of smart homes, but also extends to workspaces and public areas.

Given this scenario, the present project aims to design and implement a web platform dedicated to the configuration and simulation of intelligent environments.

This approach aims to simulate the real behavior of an intelligent system, allowing testing the impact of automated decisions in environments with multiple users and potential preference conflicts.

Furthermore, the system considers the management of priorities and hierarchies between users (e.g. administrators, visitors, children), as well as technical limitations of actuating devices, such as air conditioning or heater operating limits, ensuring safety and energy efficiency.

The use of artificial intelligence techniques, namely inference and optimization algorithms, is an essential element of this project, allowing the system's response to be adapted dynamically and predictively, based on contextual data such as time, number of people present, or preference history.

2.1.1 Architecture – Mobile Application

The diagram depicts the mobile application, built in React Native but adapted for mobile devices. In this case, the user accesses the application via a smartphone or tablet, where they can set or update their individual preferences. These preferences are stored locally and later sent to the mobile server, which shares the same communication base as the web server. The mobile server communicates with the backend using the same HTTP request mechanism, ensuring consistency and synchronization with the database. The backend logic remains identical, with the Node.js server being responsible for processing preferences and storing them in a structured way, just as occurs in the web application.

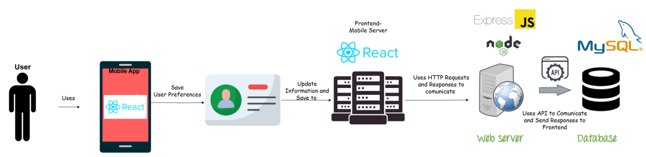

Fig. 1 Mobile App - Architecture

2.1.2 Solution Architecture – Web Application

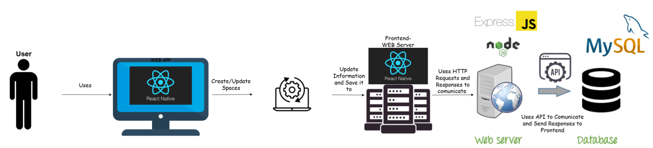

Fig. 2 WEB App - Architecture

The diagram represents the architecture of the web application, through which the user interacts with the platform from a browser. The app, built with React (React Native on the frontend), allows the user to create and update smart spaces. The data provided is sent to the frontend server, which processes the information and establishes communication with the backend via HTTP requests. The backend, in turn, is implemented in *Node.js* with *Express.js* and is responsible for handling received requests, interacting with the database (*MySQL*) and returning responses to the frontend, using a *RESTful API*. This architecture ensures fluid communication between the application components, guaranteeing the persistence and updating of data in real time.

2.2 Developed Dashboards

The following subsections detail the main dashboards developed as part of the intelligent environment management platform. These interfaces were designed to support both regular users—who interact with the system to configure preferences and participate in simulations—and system administrators, who manage users, preferences, and environments at a global level. Each dashboard is tailored to its audience, providing intuitive controls and relevant data visualizations to facilitate smooth interaction with the platform's core functionalities.

2.2.1 Mobile Dashboards

The following figures showcase the primary screens of the mobile interface, which was developed to provide users with a convenient and accessible way to interact with the platform. Through this interface, users can register, log in, and define their environmental preferences—such as ideal temperature, humidity, and lighting—within a specific context (e.g., home, office, leisure). The mobile app was designed with simplicity and responsiveness in mind, enabling real-time submission of preferences and seamless synchronization with the platform's backend services.

This screen allows the authenticated user to access the application by entering their email address and password. The interface is simple and clear, with a focus on usability, also including a direct shortcut to registration if the user does not yet have an account.

The second screen enables authenticated users to log into the application by providing their email and password. This data is then sent to the backend where it is validated and stored in the database. The form was designed in an intuitive way, facilitating the onboarding of new users and ensuring a fluid experience from the first access.

Finally, the third screen (Figure 3), where the user can choose the environment from a dropdown as you can see at (Figure 4) and set their preferences for a choosen smart environment, including temperature, humidity and brightness. These values are selected using interactive sliders, providing a straightforward and customized experience. Once defined, the preferences can be saved and later used by the platform to calculate the optimal configuration for each space.

Fig. 3 Page - User Preferences

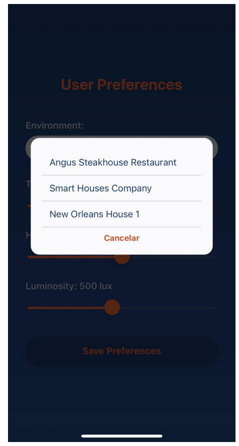

Fig. 4 Mobile - User Preferences

2.2.2 Web Dashboards

This section presents the web dashboards developed for the management and operation of the smart environment simulation platform. These dashboards provide intuitive interfaces for administrators and users to interact with the system's functionalities efficiently.

Following successful authentication, users are directed to the *Page - Environment Creation* (Figure 5), which allows them to define new intelligent environments within the platform. This interface provides a streamlined process where users can assign a name to the environment and select its category from three predefined types: Business, Domestic, and Leisure. Visual icons assist in guiding the user's selection, enhancing usability and clarity. Upon successful creation of an environment, users are redirected to the *Page - Environment Creation* (Figure 6), which provides immediate confirmation of the action. The page displays a representative image corresponding to the selected environment type: Business, Domestic, or Leisure, offering clear visual feedback.

Additionally, the interface presents key navigation options, allowing users to seamlessly proceed with adding users to the environment, reviewing the list of associated users, or initiating the simulation. This design supports an efficient workflow by facilitating direct access to subsequent management and operational features following environment creation.

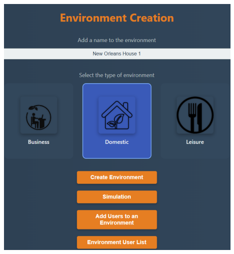

Fig. 5 Page - Environment Creation

Fig. 6 Page - Environment Created

Following environment creation, the platform provides the *Page - Add Users* (Figure 7), enabling the owners of the environments to associate users to a choosen environment from the dropdown as you can see at Figure 8 . This interface allows the owner to input the user details, including name, email, the designated role within the environment and define the preference percentage at the adjustable percentage slider which is available to quantify the user's influence or priority in the environment's preference calculations.

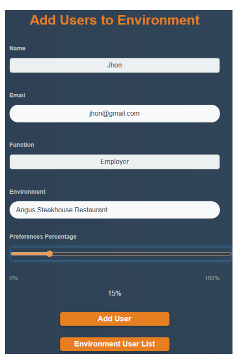

Fig. 7 Page - Add Users

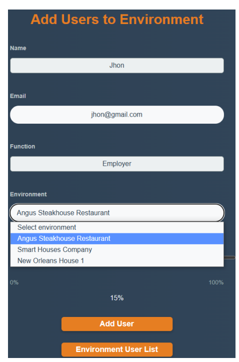

Fig. 8 Page - Add Users

Following user addition, the *Page - Environment User List* (Figure 9), provides an overview of all users associated on a selected environment. This page enable the owner to review and manage user environment list and edit their corresponding preference influence percentages within the environment.

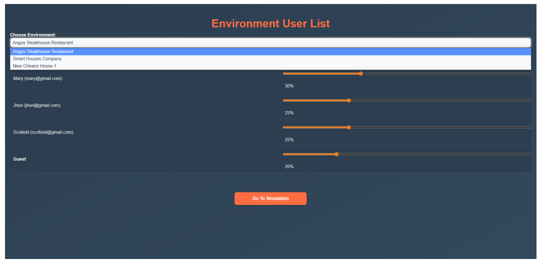

Fig. 9 Page - Environment User List

The *Simulation Page* (Figure 10) and Figure 11) represents the central interface of the platform responsible for executing real-time simulations of intelligent environments. Through this interface, the user initiates the simulation process by selecting one of the previously configured environments. Upon selection, the system dynamically retrieves and displays the list of associated users, each accompanied by their predefined preference influence percentage (weight), as configured in the Environment User List Page.

A key interactive component of this page is the ability to manage the presence of users within the environment. Users can be individually dragged into or removed from the simulation area, allowing for flexible, real-time reconfiguration of the simulation context. Moreover, the interface provides the option to include a "Guest" entity, whose preferences for temperature, humidity, and luminosity can be directly manipulated via sliders, along with a custom weight of influence, enabling the simulation of non-registered or temporary agents.

Once the simulation is triggered, the system executes a weighted aggregation of preferences, calculating the optimal environmental conditions based on all currently active contributors. These contributors include both registered users and the optional guest. The results are then presented in a horizontal table format, where each row corresponds to a user and each column to a specific preference (e.g., temperature, luminosity, humidity). For every user-preference pair, the table displays the individual value and respective influence percentage. A final row summarizes the system's optimized values, resulting from the inference engine's weighted computation constrained by predefined upper and lower bounds.

Complementing the simulation output, a real-time logging panel situated at the bottom of the page captures each simulation execution with a timestamped message. This mechanism ensures traceability and enhances the user's situational awareness regarding the dynamic balance achieved between potentially conflicting preferences within the shared environment.

Fig. 10 Page - Simulation

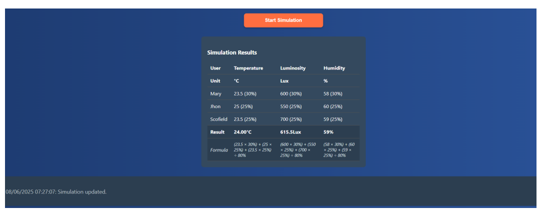

Fig. 11 Page - Simulation Results

Finally, the *Page – Admin Backend* (Figure 12 and Figure 13) serves as a centralized and robust administrative interface, granting system administrators full control over the core entities of the intelligent environment simulation platform—namely, users, environmental preferences, and environments themselves. Designed to ensure clarity, accessibility, and operational efficiency, this backend consolidates the maintenance and oversight functions into a unified dashboard.

In the Users section, administrators can seamlessly manage user accounts through an intuitive table that supports in-place editing and deletion. This enables real-time updates to user information (such as name and email), as well as the removal of users along with all their relational dependencies across simulation data and preference associations. This granular control ensures data integrity and avoids orphan records within the system.

The Preferences panel allows the administrator to define the fundamental parameters used in environmental simulations—such as Temperature, Humidity, and Luminosity—along with their respective units. Administrators can add new preference types or edit existing ones, adapting the system's inference engine to evolving use cases and measurement standards.

Lastly, the Environments section offers an overview and management interface for all simulation environments. Each environment is listed with its name, type (translated dynamically into Domestic, Business, or Leisure), and owner (user email). Administrators can edit or remove these environments, ensuring that the simulation scope remains accurate and up to date.

This backend module thus plays a critical role in maintaining system coherence, enabling administrators to execute essential configurations and cleanups, while also supporting adaptability and scalability of the simulation platform.

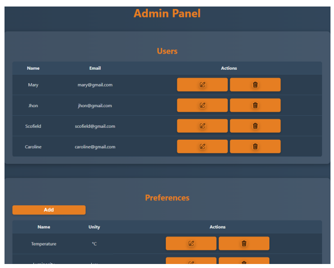

Fig. 12 Page - Admin Backend A

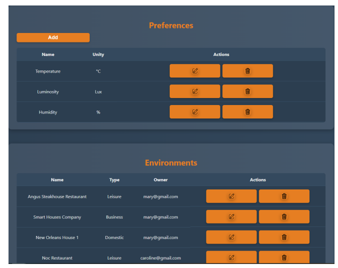

Fig. 13 Page - Admin Backend B

3 Conclusions

This project has successfully delivered a comprehensive web-based platform for the creation, management, and simulation of intelligent environments. By integrating user-centric features with advanced backend functionalities, the platform addresses the challenges of designing adaptive smart spaces that respond dynamically to diverse user preferences and contextual factors.

The modular architecture ensures scalability and flexibility, enabling seamless interaction between users, environments, and the underlying artificial intelligence mechanisms responsible for optimizing environmental parameters [6]. Through an intuitive interface, users can register, authenticate, and participate in the configuration and simulation of environments tailored to specific contexts such as business, domestic, and leisure spaces.

A key achievement of the platform is its ability to manage multi-user scenarios, incorporating preference conflicts and hierarchical roles to compute optimal settings that balance comfort, efficiency, and safety [9, 10]. The real-time simulation and feedback mechanisms provide valuable insights into system behavior, fostering transparency and user engagement.

Looking forward, the platform lays a solid foundation for further enhancement, including the integration of more sophisticated AI models, expanded device compatibility, and deeper contextual awareness. Such advancements will contribute to the evolution of truly intelligent spaces that anticipate and adapt seamlessly to human needs.

In conclusion, this project not only demonstrates the feasibility of a unified, user-driven platform for smart environment simulation but also opens new avenues for research and practical application in the fields of ambient intelligence, human-computer interaction, and sustainable automation. The results affirm the potential of leveraging technology to create more responsive, personalized, and efficient living and working spaces.

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