MC²025
PEOPLE & BUILDINGS
Proceedings of 14th Masters Conference:
London, 15th September 2025

Network for Comfort &
Energy Use in Buildings
http://www.nceub.org.uk

Sentient Buildings

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Abstract:
This paper explores the concept of Sentient Buildings, with a focus on office environments. This paper involves the energy and comfort challenge of a sentient office building. To support the research, a Sentient Building system was developed and tested. Before system deployment, both quantitative and qualitative literature reviews were conducted. Reflection on the literature review resulted in the development of comprehensive frameworks for sentient buildings and data collection methods. The Sentient Building system uses the concept of system workflow and conditional structure. The findings provide insights into indoor environmental measurements, the system workflow underlying sentient buildings, and a case study on an office building example.
Keywords: Sentient building, Indoor Comfort, IoT, System Workflow

1. Introduction

A sentient building is defined as a building that can understand and process indoor comfort measurements, interpret these data and provide a real-time self-regulatory response to maintain an indoor comfort environment. The main elements of sentient building included building information, self-actualising building models and application. The building information is the input that contains the current buildings' indoor environment qualities, sent to the self-actualising building model to interpret these data, provide a real-time decision, then a signal will be sent to applications to monitor or maintain the indoor comfort. (Mahdavi, 2005). A sentient building is not just able to self-interpreting and monitoring but also allows humans to interfere with the process to enhance the interaction between humans and buildings. Recent research on implementing artificial intelligence (AI) can help improve the building system. (Sebastian Stein, Vahid Yazdanpanah, 2023).
This paper aims to understand sentient building specifically in office buildings, focused on elements, energy and comfort challenges.

2. Methodology

To achieve the project aim and objective, the pathway for a sentient office building will be carried out by:

I. Literature review on a sentient office building.
A total of 79 research papers were initially screened. 58 papers were excluded due to irrelevance to the topic or lack of focus on office buildings. The remaining 21 papers were evaluated in detail and included as part of the study.

II. Develop a comprehensive framework of sentient buildings and systems using system dynamics.

Based on the literature review, a data collection approach was designed. Sensors were calibrated and installed in the case study building to capture occupancy, temperature, relative humidity, and CO_2 concentration. These measurements provided the foundation for constructing a framework for sentient building systems.

III. Deployment of a building system in an office building.
The building system was deployed using a workflow-driven and conditional structure approach to integrate data, platform functions, and occupant interaction. The system comprised three key components: (1) building information data, (2) a platform, and (3) occupants. Sensor data collected in the earlier phase—covering temperature, relative humidity, and CO_2 concentration were stored in a central database as building information data. The platform, implemented as a chatbot interface, enabled communication between occupants and the system by receiving user queries, processing queries through the back-office module, retrieving the relevant data, and returning results in real time. Occupants served as active participants in the system, providing inputs that represented occupants' needs and preferences.

IV. Testing the deployment of a building system in an office building using a usability test survey.
A usability test was carried out through a structured survey. Five occupants participated in the study, which was conducted in three stages: a pre-survey, a demonstration of the chatbot system, and a post-survey. The survey results provided insights into the usability, interaction experience, and feedback of the deployed system.

2.1 Case study

The meeting room inside Building 178 in the Boldrewood Campus, Southampton, United Kingdom, was used for the case study in this paper. Sensors were installed in the meeting room to collect the data needed for this paper.

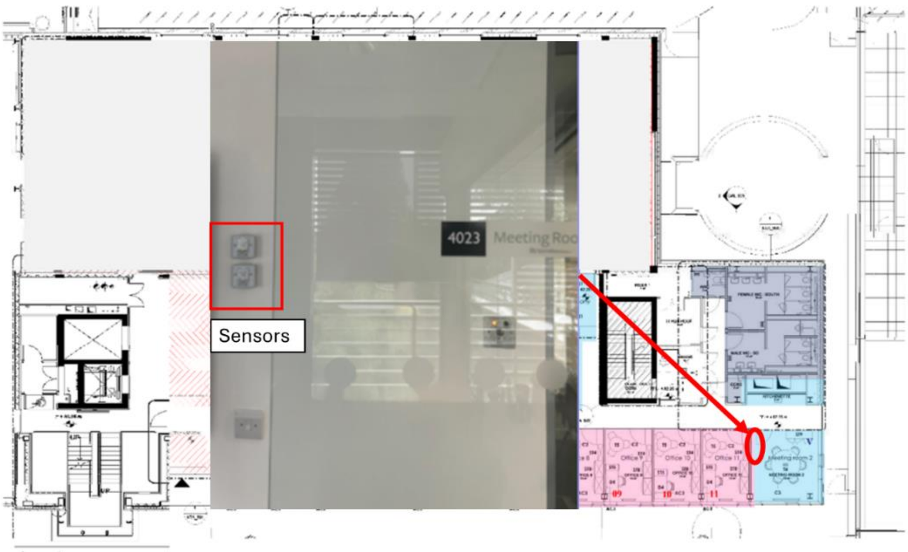

Figure 1 – Sensor installed in the meeting room

Figure 1 shows the sensor installed in the meeting room. The sensors were installed near the entrance to avoid direct solar radiation from nearby windows, which can affect the temperature measurements and compromise data reliability.

2.2 Indoor Environmental Aspects

The sensor shown in Figure 1 is the indoor environmental sensor, which can collect the temperature, humidity and the CO_2 concentration in the room and store in the database.

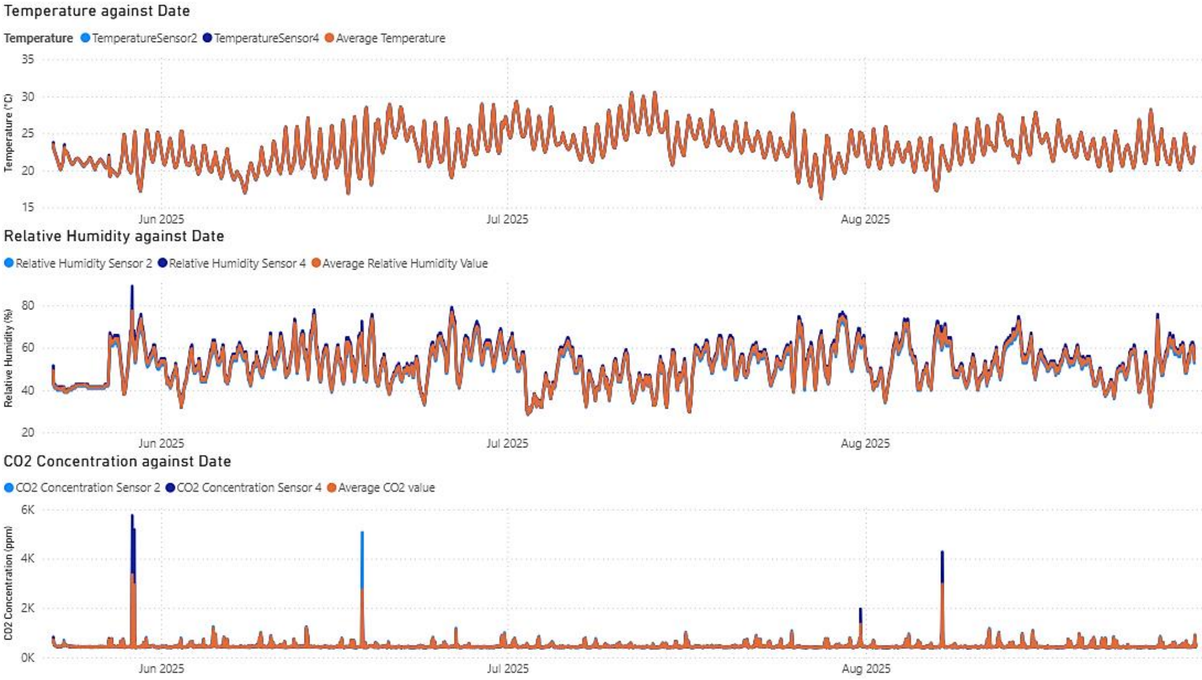

Figure 2 – Indoor Environmental Data

Figure 2 above shows the raw Indoor environmental data obtained from 2 identical sensors installed in the same room. Then, an average of these data was calculated for each Indoor environmental aspect. From the data obtained, the temperature of the office building normally falls between 20℃ to 30℃, the relative humidity in the building normally falls between 40% to 80% and the CO_2 concentration is normally below 2000ppm. The CO_2 concentration exceeding 4000 ppm was likely caused by occupants exhaling directly near the sensor. This assumption is supported by the fact that only one sensor recorded unusually high CO_2 concentration values, while the others measured much lower concentrations, resulting in an overall average significantly lower than the peak reading.

2.3 Deployed System workflow

Figure 3 below shows the workflow for the deployed chatbot system.

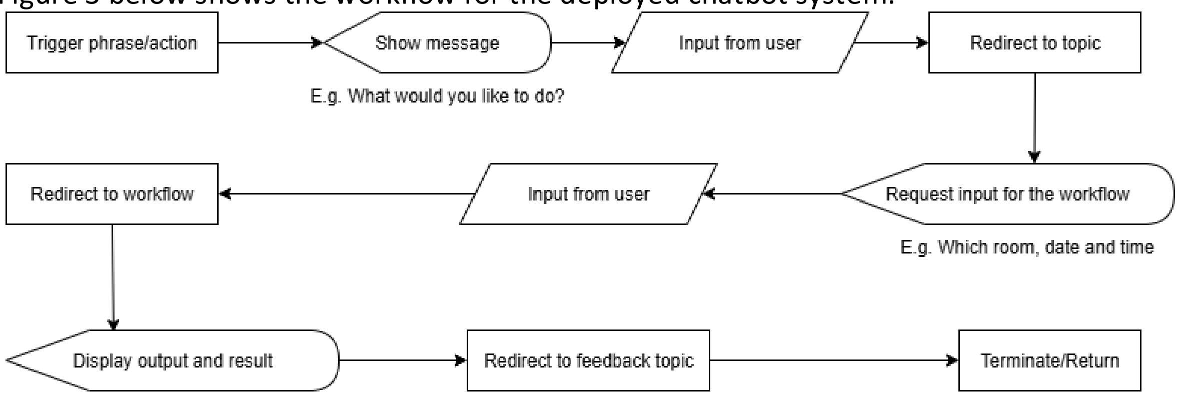

Figure 3 – Workflow for the chatbot system

At the beginning, the user activates the system by entering a phrase or opening a conversation. The chatbot then asks what the user wants to do and which room. After the user selects a feature, the chatbot directs them to the relevant topic. In the topic, the chatbot system may request the necessary information from the user. Once provided, this information is passed to the platform where the workflow is stored. The workflow processes the input by interpreting it, retrieving data from connected platforms, and generating a result. The chatbot displays this result to the user and then moves to a feedback step. Finally, the session ends, and the chatbot resets to the beginning, ready for the next interaction.

3. Result

Figure 4 below shows the data collected by the occupancy sensor. This data indicates the frequency of occupancy in the Meeting Room. The data is collected from August 2024 to May 2025.

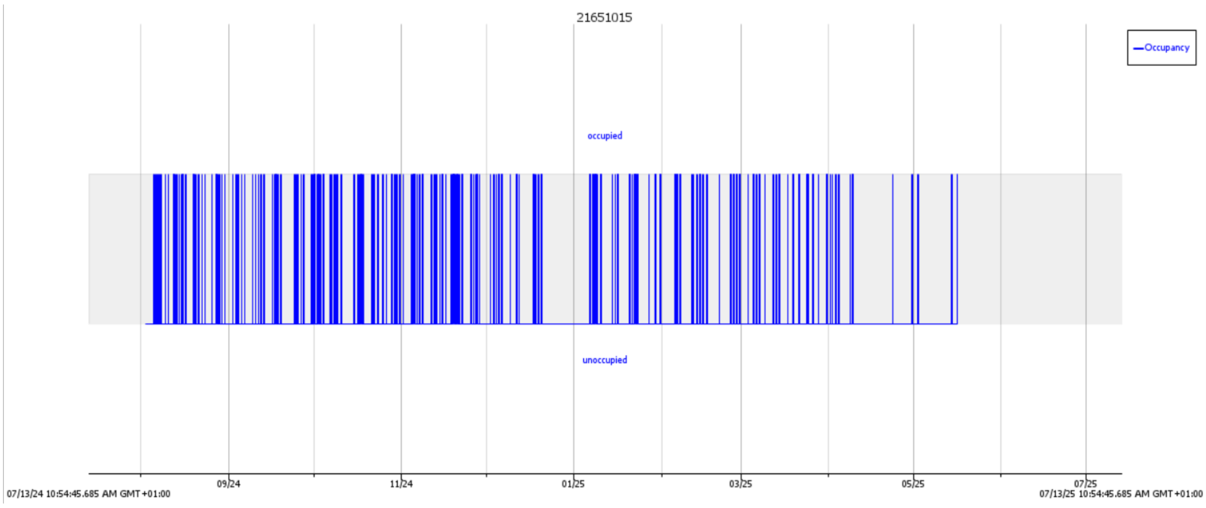

Figure 4 – Occupancy Sensor

Figure 5 below shows the Indoor environmental data within office hours. From the average sensor data, the data within the office hours was filtered out to calculate average values for each day of the week and recorded to allow the system to retrieve the data more efficiently.

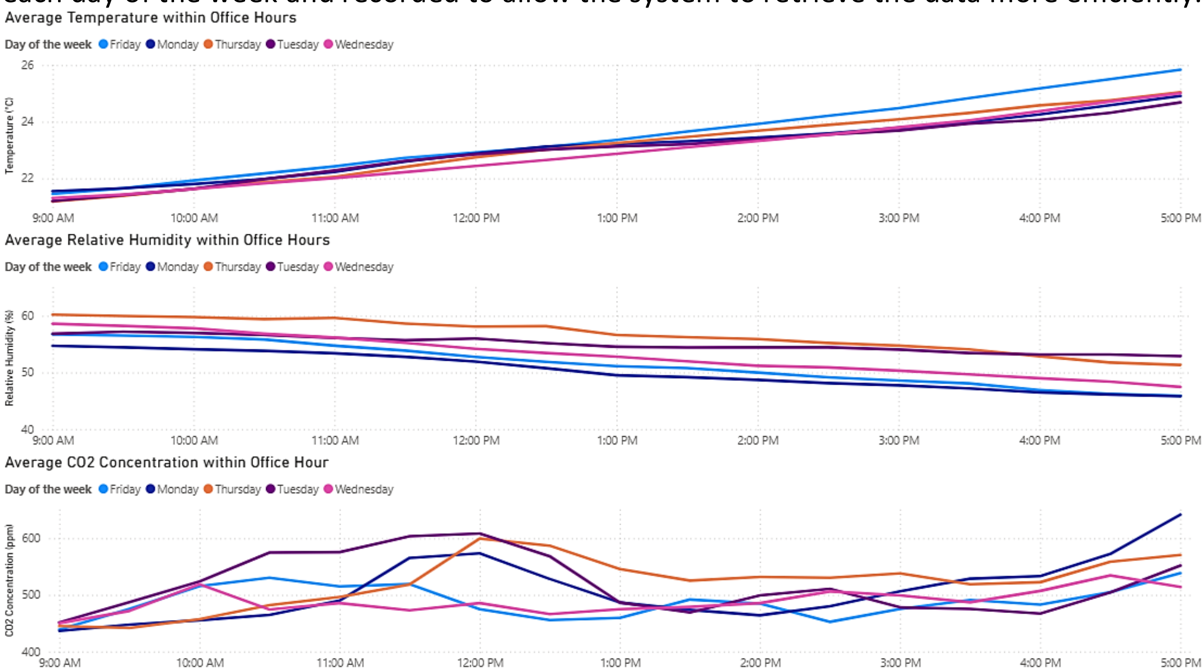

Figure 5- Indoor environmental data within office hours

Figure 6 shows the chatbot system's Meeting Room booking feature. After collecting the required inputs, the system executes the workflow by checking room availability and reporting the CO_2 concentration for the selected date and time. If conditions are suitable, the system books the room and sends a confirmation email to the user.

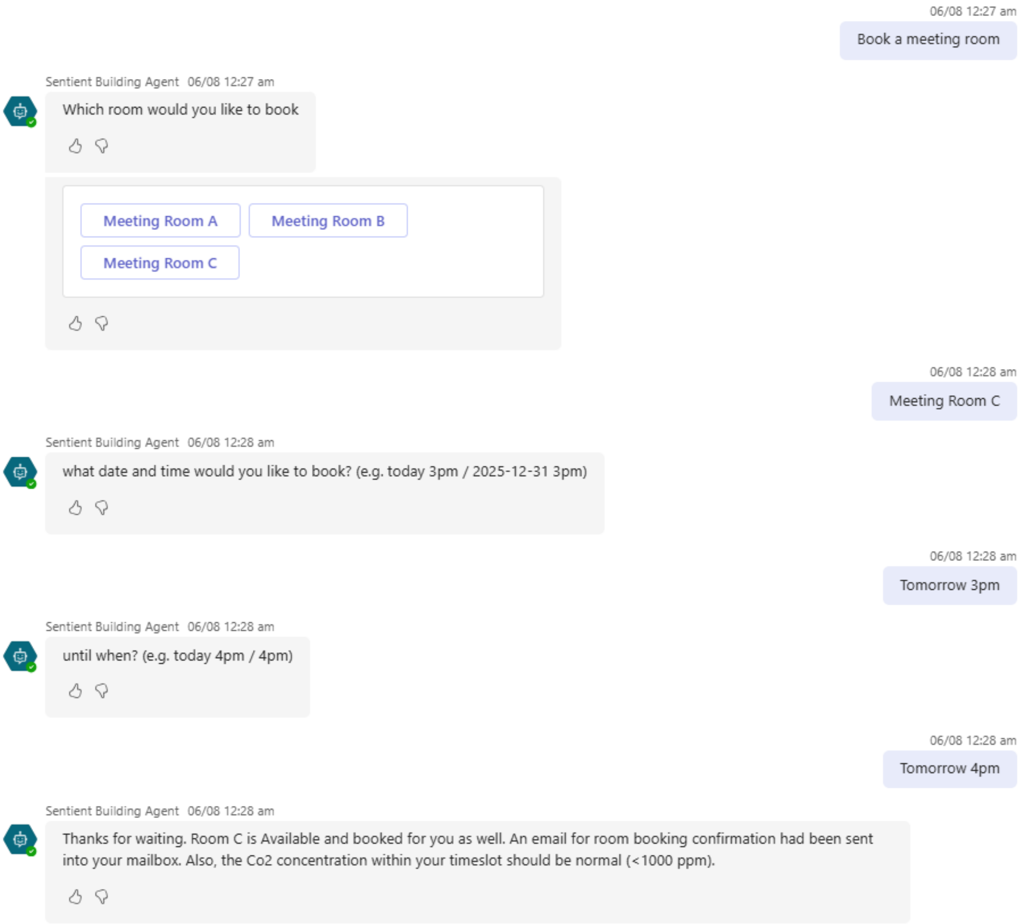

Figure 6 – Chatbot system

4. Discussion

The occupancy sensor data revealed gaps around 01/25 and 05/25. These gaps were most likely due to school holidays, specifically the Christmas and Easter breaks. This interpretation is supported by the timing of the gaps, which coincided with holiday periods, and by the sensor consistently recording "no occupant" over multiple days.

The upward trend in temperature during office hours is expected, given the building's southwest orientation, which allows more direct sunlight penetration from noon until sunset. As a result, indoor temperatures rose from 20 °C to 26 °C, a range considered comfortable according to ASHRAE Standard 55-2010, which specifies an operative temperature range of 18 °C to 28 °C for metabolic rates between 1.0 and 1.3 met. According to ASHRAE Standard 55-2010, the recommended relative humidity range is 30%–60%. The average relative humidity during office hours in this study consistently fell within 40%–60%. The indoor CO2 concentrations recommended by the ASHRAE are below 1000ppm (ASHRAE, 2025). The average CO2 concentrations in this study fell within 400ppm to 700ppm.

For the development of the Room Booking feature, the system was designed to automatically retrieve the user's email address and department through an online connector, with the user's consent. This approach minimises the need for repeated manual input and prevents misuse by restricting the use of other individuals' email addresses. From the example output of the Meeting Room booking feature, only the CO_2 concentration level is displayed. This is due to the limitation of the used platform, which prevented further updates or publications to the chatbot system once the maximum capacity for modifications had been reached.

5. Conclusion and Future Recommendations

In this study, a sentient building is defined as a building that senses indoor environmental conditions, self-updates, self-regulates, and interacts with occupants. Supported by sensors and system workflows, the building integrates components, processes, and occupants' input to interpret comfort levels, provide real-time data, and offer suggestions. Indoor measurements were collected through a sensor network, and multiple tools, platforms, and datasets were combined into a unified system. The concept was demonstrated through an office building case study.

For the future development of the system, the suggested feature by survey participants will be the starting point. Sentient buildings have the potential to enhance occupant productivity, and the proposed features from the participant reflect the needs of current users. Further research will require more datasets, as the present study was limited by the duration of data collection and lacked seasonal variation, which may result in changes in indoor environmental conditions and occupant behaviour. Additional functionalities, such as predictive maintenance to notify users of equipment or device issues before end-of-life, could also be considered. Finally, the integration of artificial intelligence may enable more advanced interactions, though this will require further study.

6. References

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