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Data analysis of a smart house:
The person number determination in a room with CO2 sensor

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Abstract

The measurement of CO2 concentration is a relevant indicator for defining the occupation of indoor spaces. The real-time knowledge of occupation of such spaces is relevant both for maintaining indoor air quality standards and for energy efficiency purposes connected with the operation of heating, ventilation, and air-conditioning (HVAC) systems. The exact knowledge of occupation allows for rapid feedback from and the regulation of an HVAC system and the ventilation rate. Interesting applications include educational buildings and other buildings of the civil sector (e.g., shopping centres and hospitals).

However, CO2 generation rates can be derived from well-established concepts within the fields of human metabolism and exercise physiology, which relate these rates to body size and composition, diet, and level of physical activity.

In paper some graphical trends of the CO2 concentrations in indoor spaces are provided to determine the most important variables affecting such concentrations.

Keywords: Measurement, Carbon dioxide, Energy efficiency, Occupancy estimation, Indoor air quality

Introduction

In industrialized countries, civil–residential is often the largest energy consuming sector. Over 40% of the final energy consumption can be connected to this sector. As a consequence, buildings are a relevant source of CO2 emissions. The high energy use of civil buildings is often connected to a non-optimal management strategy. The accurate determination of building occupancy is a relevant factor for energy savings: A reduction in energy consumption of 30–40% up to 80%, in some special cases, can be expected.

Studying the energy demands of civil buildings was relevant importance to the topic of energy sustainability. The operation of the heating, ventilation, and air-conditioning systems responsible for indoor comfort and occupant wellness depends on CO2 and determines the largest amount of energy consumed in buildings together with the number of electrical and electronic devices used inside.

Human beings modify the conditions in the built environment passively (through heat and pollutant emission) and actively (using and controlling devices), cf. Fig. 1. The information about the presence of occupants in indoor environment can be used, for example, by a smart control device to correctly operate heating, ventilation and air conditioning systems (HVAC) and lighting devices, and simultaneously maximize occupant's comfort.[1]

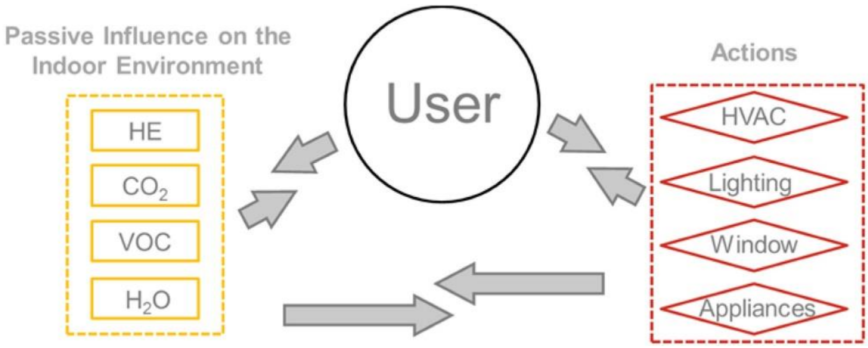

Figure 1 General schema of user impact on buildings. [2]

The detection of human beings in indoor environment can be conducted through the use of several sensors, such as passive infrared (PIR) sensors, video-cameras, infra-red cameras, light beams installed in door frames, device-free localization (based on radio signals) and carbon dioxide concentration measurements.

Carbon dioxide concentration is usually monitored in buildings in order to assess the indoor air quality and it may be used to properly operate building services; therefore it is often available in monitored indoor environments. Where not available, carbon dioxide sensors are easy and relatively cheap to install, if compared to other techniques for occupants detection, which may reveal more information than necessary for occupancy detection and can therefore be a greater risk for data privacy.

Case Study

In this paper I use data collected in The Expe-smarthouse project. This project was created by Jerome Ferrari in 2018 to provide information on measurements taken in a house inhabited by a family of 5. As a result, 340 sensors were installed in the house which provide data for researchers in real time through access via the Grafana portal and Influxdb database.

The building consists of several rooms: a kitchen, a hallway, three rooms and a living room. However, CO2 sensors were placed only in the rooms on the second floor and in the living room. Unfortunately, the dimensions of the rooms, the number of windows which the rooms have are not available for me.

The sensor used for the measurement was the Neetamo intelligent measuring station. It is characterised by the possibility of measuring outdoor temperature in ranges between -40 to 65°C, with a +/- 0.3°C accuracy. It is also used to measure humidity from 0 to 100% with a +/- 3% accuracy; and the most important for us carbon dioxide concentration in a range between 0 to 5000 ppm (parts per million) with a +/- 50 ppm or +/-5% accuracy. The accuracy of the CO2 sensor is ± 50ppm to 1000ppm and ± 5% for measurements greater than 1000ppm. Communication with the Raspberry Pi minicomputer is via Netamo transmission protocol. [3]

Data processing and calculations

In order to determine the number of occupants, I downloaded the data stored on the Grafana server for a period of one week. After cleaning and removing outliers, the result is shown in the figures below:

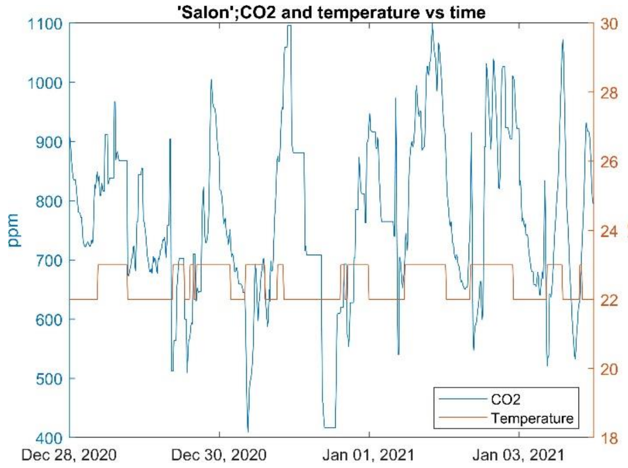

Figure 3 CO2 and temperature for Salon

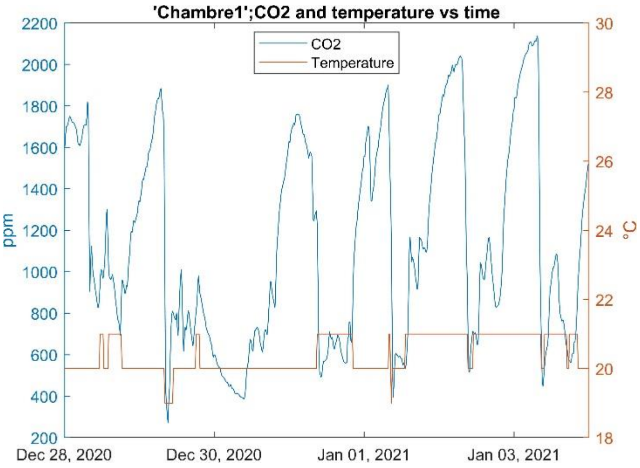

Figure 2 CO2 and temperature for Chambre 1

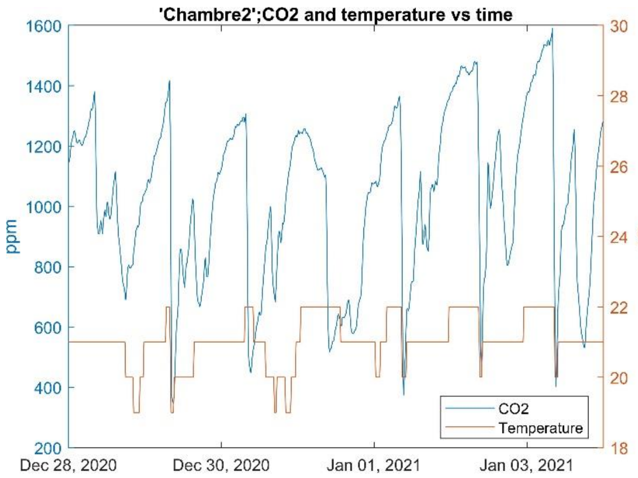

Figure 4 CO2 and temperature for Chambre 2

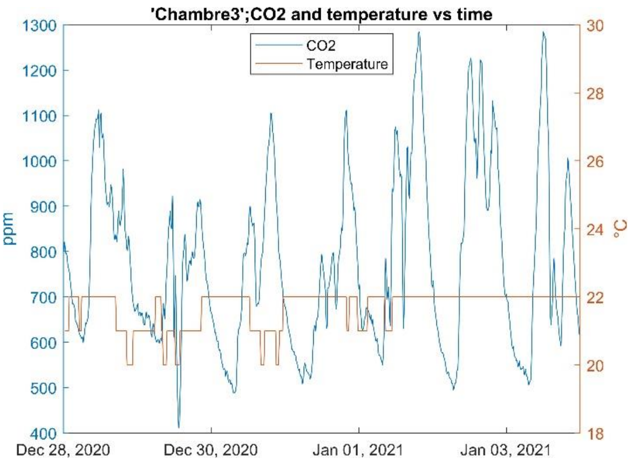

Figure 5 CO2 and temperature for Chambre 3

It is difficult to get the number of people in a room without additional data, but we may notice a clear correlation between plotted data, which are the temperature indicator and the CO_2 content. In Figure 6, with the time interval limited to the 2nd and 3rd January, it can be seen more clearly that the room temperature CO_2 concentration varies with the room temperature. By tracking the CO_2 concentration in the room, it is possible to get information not only about the number of people in the room but also about their daily routine, what time they sleep, what time they leave for work or school and what time they return to their place of residence.

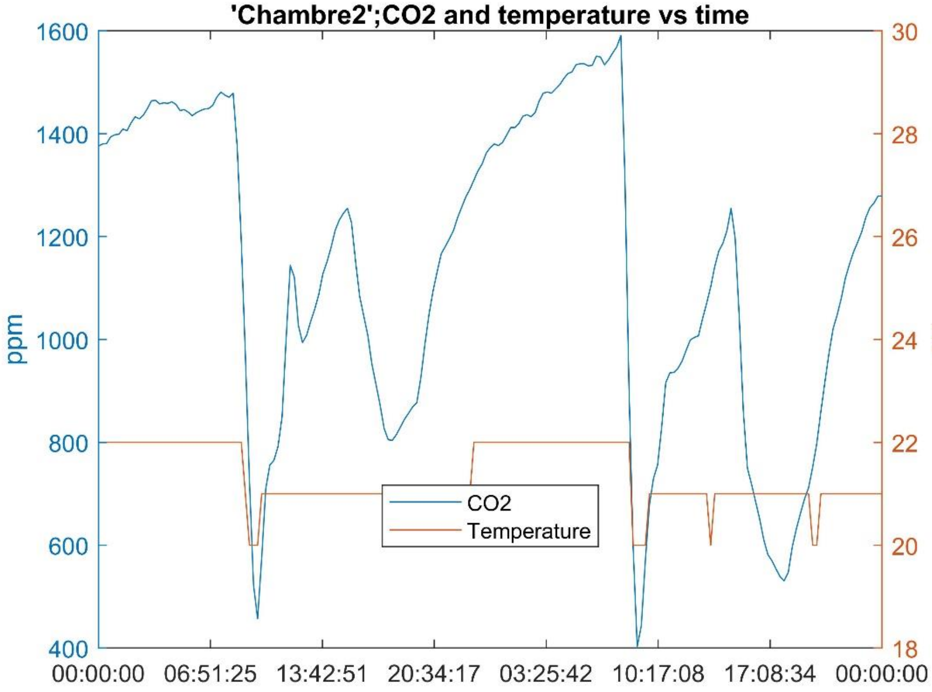

Figure 6 Zoomed time period for CO2 and temperature for Chambre 2

Conclusion

Research into the occupancy of rooms and buildings is becoming increasingly important. By understanding and knowing the number of people in a building, heating, cooling, light control, building energy consumption, security and utility of rooms can be made more effective. Mostly, predicting presence in a room requires the use of many sensors, which are expensive to install and maintain. In this experiment, I used data from only one type of sensor, which is widely available in Building Automation, and this reduces the cost of system implementation and makes it more reliable. In addition, estimating the number of people in a room using CO2 preserves privacy as no personal information is required.

Biblography

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[3] http://expe-smarthouse.duckdns.org/?page_id=7&lang=en