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An open source and low-cost Smart Auditorium

OQAIDI Mohammed[a,]*, AIT ABDELOUAHID Rachida[b], DEBAUCHE Olivier[c], MARZAK Abdelaziz[d]

[A,b,d] *Faculty of Science Ben M'sik, Hassan 2 University, Casablanca, Morocco*
[c]*Faculty of Engineering, University of Mons, Mons, Belgium*

Abstract

Universities have auditoriums, or amphitheaters, sometimes very large to accommodate many students. They hold numerous lectures and conferences there. In this article we are using a smart home system to intelligently manage and control autonomously each auditorium of the campus. This solution use ESP32 NodeMCU to acquire with sensors several environmental data such as air temperature and humidity, CO_2 level, light intensity, window closing, PIR sensors, and images with camera. Other ESP32 NodeMCU control ambient conditions by operating of air extractors and ventilation. While valves remotely controlled on radiators are directly connected on Raspberry Pi in Zwave. AI-Think are uses to film auditorium.

Keywords: Home Assistant, ESPHome, Smart Auditorium, Internet of Things, Smart Campus, Smart City

1. Introduction

Smart Campus usually refers to buildings, ground, and places where university is located. Emergence of smart environment technologies and the presence of digital native equipped lively student community have enabled the development of smart campus to improve experience of studying, sharing learning contexts, in time and space [1].

* Corresponding author. Tel.: +2126-6194-4452.
E-mail address: moqaidi@gmail.com

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The main technologies supporting the smart campus include Cloud computing and Mobile Edge Computing, Internet of Things, Augmented Reality, Artificial Intelligence and Machine Learning [2][3].

Abuarquoud et al have identified important benefits which can be obtained in a smart campus. Among this one, we keep up: (1) The promotion smart energy, water and waste management thought IoT-based services; (2) The monitoring of electrical device to notify automatically maintenance team to improve response time to operation; (3) The detection of non-authorized people in an area or opened windows and doors to prevent intruders; (4) The assistance of students and staff to find a parking place; (5) The automation of students attendance [4].

Smart Home Automation systems such as Home Assistant or openHAB have been developed to interconnect large wide number of sensors using different network protocols. Home Assistant is an open-source automation solution hosted on a simple Raspberry Pi or a similar computer. It allows to survey the state and control numerous devices from a simple and user-friendly interface which respect privacy and do not publish any information on the cloud. This platform can be diverted to be implemented in each auditorium, office, laboratory, room of the University. These platforms can publish and subscribe to MQTT topics to exchange between them and transfer data to a central point located in the building.

ESPHome is a system to control and manage ESP32 Node MCU and Ai-Thinker by simple yet powerful configuration files and control them remotely through Home Automation systems like Home Assistant. ESP32 code can also be updated through ESPHome in over-the-air programming (OTA).

This paper is based on our previous works on Smart Home and Smart City presented in [5][6][7]. In this paper, we propose to begin own Smart Campus by the improvement of learning conditions in auditorium. We develop a system to monitor de temperature/humidity on one hand and the rate of carbon dioxide to control environmental conditions of the auditorium. Specifics microcontrollers allows to film the auditorium to detect the presence of people before turning off the lights and reducing of the temperature.

The remaining of the paper is organized as follow: In section 2, we summarize some related works. Then, in section 3, we describe our smart auditorium proposition. Afterwards, in section 4, we implement our proposition to demonstrate how it operate in real conditions. In section 5, we discuss results obtains and limitations of our system. Finally, we conclude in section 6 and considerate future work.

2. Related Works

Numerous projects have been achieved to control intelligent electrical equipment in public places such as shopping centers, theaters etc. Sunil et al. [8] have proposed a solution to monitor and control all equipment and saved energy in public places such as auditoriums, shopping centers and theaters, etc. This solution is based on an Arduino microcontroller to control automatically electrical and electronic equipment. A metal detector is place in each door of the auditorium to ensure the security. Their system uses the MCS 51 family microcontroller, IR / LDR (Light Dependent Resister) sensors, a 16x2 LCD screen (Liquid Crystal Display) to display the values sent by the sensors. An alarm is triggered if a fire is detected. Nikita et al [9] have proposed a system to analyze the energy consumption in assembly rooms / auditorium by developing a visitor counter and an automatic fan control system.

Sukanya et al. [10] have suggested a solution which offers a smart way to control electrical and electronic devices to save energy in auditoriums, shopping malls and theaters, etc. all cities / areas, we have shopping malls, theaters, and auditoriums. Thanks to monitoring and control devices, regulation can be done finely. Indeed, if fewer people enter the auditorium, no need to turn on all the devices. If all devices turn on, there will be a loss of power. If a maximum of people enters the auditorium, then automatically all devices will be turned on.

3. Our Proposition

We propose to divert a Smart Home solution to manage an auditorium by controlling of air temperature and humidity, carbon dioxide rate using ventilation system and connected valves on radiators. We acquire also with AIThinker video of the auditorium. The system is composed of a Raspberry Pi 4 which hosts the last released of Home Assistant and its add-on ESPHome. This one allows to manage a network of ESP32 NodeMCU distributed to different places in the auditorium (See Fig. 1).

Figure 1: Figure 1: Raspberry Pi 4 and ESP32 NodeMCU

Home Assistant proposes a large amount of various integrations of sensors, actuators, and systems functioning with different protocols of communication. It also allows the achieve of automation to activate actuators when threshold value of sensor is reached. Values collected by sensors can be visualized and actuators can also manually activate. Sensing node is composed of an ESP32 NodeMCU equipped of DHT 22 to measure temperature with and accuracy of ±0.5°C and humidity with an accuracy of ±2%. MH-Z19 is a CO_2 sensor measuring rate between 0 to 5000ppm and connected to the UART bus a 9600bps (See Fig. 2).

Figure 2: DHT22 and MH-Z19 Sensors

Contact and HC-SR501 a PIR Motion sensors with an adjustable sensitivity which allows to verify respectively that windows are closed and detect presence to prevent external intrusion when the auditorium is empty (See Fig. 3).

Figure 3: HC-SR501 and contact Sensors

Actuating node is equipped of an ESP32 NodeMCU connected to a relay card to activate / deactivate actuators such as lights, air extractors, audiovisual material, and electric blinds. Zwave radiator valves (Fig. 4) are directly connected on the Raspberry Pi which ensures the interoperability between the different protocols.

Figure 4: Zwave valve and AI Thinker microcontroller

AI-Thinker are used to film the auditorium following different angles (See Fig. 4). The punctual analyze of images with Tiny Yolo v3 to detect the presence of persons in the auditorium and verify that it is empty before turning off lights, reducing temperature and stopping ventilation. The TSL2591 (Adafruit Industries LLC) is a high dynamic range digital light sensor which can detect light range from up to 188 µLux up to 88,000 Lux (lumens per square meter).

4. Experimentation

We have implemented a network of four sensing nodes connected to the Raspberry Pi by means of the university Wi-Fi using WPA2 – Enterprise security protocol. The Raspberry Pi 4 4gb hosts the last release of Home Assistant and ESPHome and is connected to the local network by Ethernet.

Two AI Thinker placed towards the entrance allow to control the presence of people in the auditorium. If nobody is detected in the auditorium lights are turned off and temperature is reduced.

An automation has been implemented in Home Assistant which respect following semantic rules (See Table I).

Table 1. Automation expressed in Semantic Rules

Fact	Triggering Rule
FanStart	Observation hasTemperature > 23°C ∨ Observation hasHumidity > 70% ∨ Observation hasCO2 > 1500ppm → ns:FanStart
FanStop	Observation hasTemperature < 20°C ∧ Observation hasHumidity < 40% ∧ Observation hasCO2 < 1000ppm → ns:FanStop
ValveUp	Observation hasTemperature < 20°C → ns:ValveUp
ValveDown	Observation hasTemperature > 22°C → ns:ValveDown
LightOn	Observation hasPeopleDetected true → ns:LightOn
LightOff	Observation hasWindowClosed true ∧ Observation hasPeopleDetected false → ns:LightOff

BlindsUp	Observation hasLightIntensity > 1000lux → ns:BlindsUp
BlindsDown	Observation hasLightIntensity <= 1000lux ⋀ Observation hasWindowClosed true → ns:BlindsDown

5. Results and Discussion

Home Assistant proposes for each sensing nodes (ESP32 NodeMCU) a graph with the different values acquired.

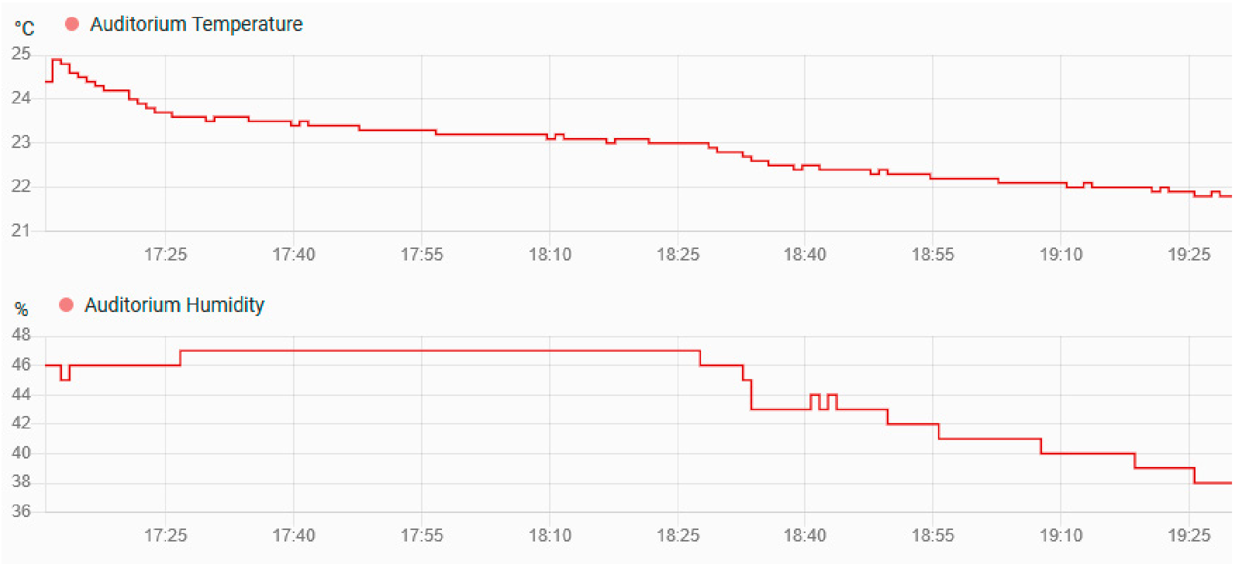

Figure 5: Example of graph proposed in Home Assistant

In the end, our system allows to manage an auditorium independently. At this stage, each Home Assistant must be configurated independently and adapted at the auditorium monitored. But in term of temperature regulation the actual system does not consider the thermal inertia of the building. In fact, when the connected radiator valves are actuated, the temperature rise, or reduction takes more than an hour before being felt. In decreasing temperature, you can speed up the cooling process by injecting fresh air into the auditorium. Moreover, internal temperature in the auditorium is always dependent of the number of people present and external temperature and humidity conditions.

6. Conclusion and Future Work

In our future work, we will develop a distributed architecture scalable to integrate all rooms of the campus namely auditorium, offices, laboratories, meeting rooms, refectories, etc. We will implement Artificial Intelligence on one hand to cure data et monitor sensors in terms of fails, derives and on the other and to predict evolution of environmental parameters to improve management of temperature. We will integrate LoRaWan, an outdoor protocol to connect outside devices such as weather stations.

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