SMROOM - A smart room monitoring system

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***Abstract*—The goal is to build a home/room monitoring system that can dynamically adapt to its settings to maintain an optimal environment for increased levels of productivity and better quality of life. All this should be achieved through minimal human intervention.**

***Index Terms*—Internet of Things, Smart Room, Smart Home, Sensor, Actuator, Monitoring system.**

Fig. 1. Logo

I. Introduction

Several factors affect our immediate surroundings, such as light, pollution, and humidity. Due to the pandemic, most people are spending increased amounts of time in their home environment. Lack of an optimal setting is affecting people mentally and physically. Sub-optimal air quality could lead to short-term illnesses such as headaches, dizziness, eye and throat irritation. Suppose these sub-optimal conditions persist and people are exposed to bad Air Quality Index (AQI) for a more extended period. In that case, it could lead to severe illnesses such as skin allergy, respiratory diseases and even cancer. Similarly, sub-optimal humidity and light intensity levels could lead to adverse effects on the human body, such as low energy, lethargy, and hyperthermia. On the other hand, optimal air quality levels, light intensity and humidity could go a long way in bettering the overall quality of life by avoiding the previously mentioned ill-effects. Also, recent studies have proved that it also leads to increased productivity. Though most houses have the appliances to achieve the optimal environment, they lack the "smartness" to adapt to the environment dynamically. As a solution to the problem, consumers could replace their old appliances with new devices. However, this is not environmentally sustainable as it would lead to increased wastage. A "greener" solution would be to build a system that can turn old "dumb" devices into "smart things". In addition to this, the system should add to the convenience of the user. This can be achieved by adding extra functionalities such as remote monitoring devices and taking verbal input.

II. Previous Work

Most of the previous room monitoring systems implement it using new smart technology along with smart appliances to create the most optimal room settings for a user[1][2]. This application [1] implements a smart home by using smart pressure sensors, automated fall detection floors, etc to create a perfect room setting. But these types of applications are very uneconomical in the sense that the smart sensors as well as the computing required are very expensive. An application that is closely similar to the one this paper hopes to implement is [3]. This approach builds an application SMROOM, the goal of which is to transform a typical meeting room into a smart meeting room. The room's state is continuously monitored and either manually, remotely, or even through automatic processes, decisions are made to control the room lights, cooling, heating, and projector operation. The paper aims to minimize environmental impact, monetary costs and wastage through minimizing unnecessary heating or cooling and light usage. This approach works closely with the way we wanted to solve the problem of reducing unnecessary wastage of older appliances and creating smart monitoring systems using those pre-existing appliances.

III. Design

The focus of this project will be to turn older "dumb" devices into "smart things". In addition to this, the system will have added functionality of taking user verbal input to control the devices. There are existing commercial solutions that can achieve the above-mentioned functionalities, but in addition to not being sustainable, they also have high costs at the offset in terms of hardware (smart appliances) and software (monthly subscriptions) costs. Our design is to use Raspberry Pi, along with various sensors on top of an easy-to-use modular system like GrovePi to create a cost effective room monitoring system.

IV. Architecture

Figure 2 shows the architecture of the Smroom system. The asset layer consists of all the traditional non-smart devices such as the air purifier, fan, humidifier and lights. The device layer consists of all the actuators that control

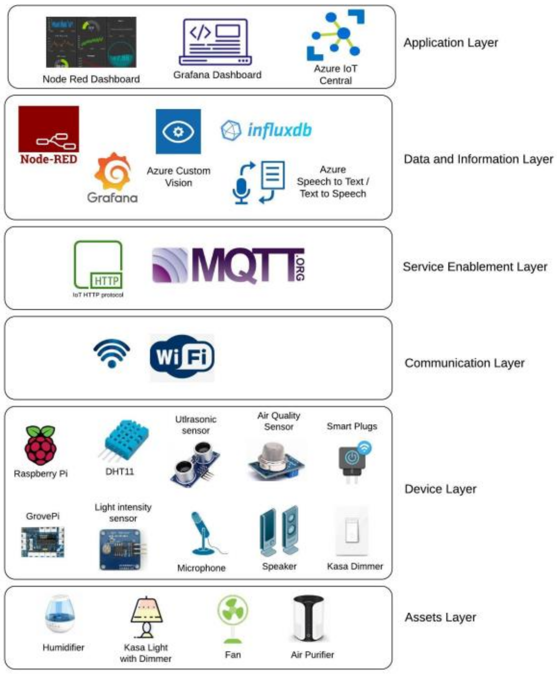

Fig. 2. Architecture

the assets such as Kasa dimmer, Kasa smart plugs. It also consists of sensors that monitor the environment such as DHT11 (temperature and humidity), light intensity and air quality sensors. It also contains other sensors/actuators to implement other functionalities of the system such as the camera, ultrasonic sensor and speaker and microphone. Then comes the communication layer which serves as a bridge to the next layer. This system uses Wi-Fi for communication. HTTP and MQTT protocols are used for performing tasks such as sending the data to Azure IoT Hub or sending images to the Azure Custom Vision for processing. This system follows an edge-based design as some of the processing power is outsourced to cloud services such as Azure Cognitive services (Speech service, Custom Vision). The data and information layer consists of other services such as Influxdb which is used to store the sensor data periodically. This is analyzed by Grafana. The data is visualized, and further analysis is done to implement functionalities such as checking for malfunction of appliances. The entire orchestration is achieved using NodeRed which receives data from the sensor and performs local processing where necessary and outsources other functions to the cloud services. The application layer consists of the Azure IoT central application dashboard and other local dashboards which is used for end-user consumption. The data is neatly visualized and displayed to the user.

V. Functionality / Implementation

A. Monitoring

The system uses an ultrasonic sensor to monitor the environment. The camera module is activated whenever presence is detected, and image recognition is done to verify the user. If the user is verified, the system activates the voice module, which listens for instruction from the users and acts accordingly. The voice module uses Azure Speech to text service. The changes to the system are relayed to the user via an audio conformation. This is implemented though Azure Speech to Text service.

B. Humidity

This module uses the DHT11 sensor to monitor the humidity levels in the room continuously. It is also responsible for controlling the humidifier. The humidifier is automatically switched on whenever the user is identified. The humidifier can also be manually activated through a button in the dashboard.

C. Temperature

This module is similar to the humidity module as it uses the same sensor but extracts the temperature information from the sensor. The control aspect is implemented in the same way, the only difference being - the module controls a fan instead of a humidifier. The humidifier can also be controlled manually thorugh the Node-RED dashboard. The system automatically switches off the humidifier when the humidity crosses the optimal humidity level set by the user.

D. Air Quality

Air quality is monitored continuously through air quality sensors. This module controls an air purifier the same way as the humidity and temperature modules control the humidifier and the fan.

E. Lights

This module controls the room lights through a Kasa dimmer. As soon as the user is identified, the lights switch on and automatically adjust the brightness. The brightness adjustment is based on the light intensity reading from the light sensor. The optimal intensity can be changed through the Node-RED dashboard. Upon changing this value, the system will automatically adjust the lights brightness so that the light intensity of sensor matches the optimal intensity set by the user.

F. Appliance/Device Problem Indicator:

The sensor readings are analyzed to detect any problems. The system can notify the user in such a case through the dashboard. The average of the sensor readings is analyzed to alert the user of possible device malfunction. The alerts are sent in the Grafana dashbaord.

G. Database

The system will store all the relevant readings in a database in InfluxDB, which will be accessed by grafana dashboard to show various time series as well as to detect any problems with the appliances (purifier and humidifier). For instance, the average sensor reading over a specific time interval can be compared with the average sensor reading in the preceding interval. If the sensor reading is not maintained or if the sensor reading gets worse, this could mean that the appliance is not working optimally. The system can notify the user in such a case to check the working condition of the appliances.

Fig. 3. User Dashboard

H. Hardware/Software

The prototype consists of the following components:

1) Hardware:

- Raspberry Pi Board
- GrovePi Board
- DHT11 Sensor (Temperature and Humidity Sensor)
- Air Quality Sensor
- Light Intensity Sensor
- Raspberry Pi Camera
- Ultrasonic Sensor
- Microphone
- Speaker
- Kasa Dimmer

2) Software Components:

- Python modules - GrovePi, PiCamera, PyAudio
- Node Red development tool
- Azure Custom Vision
- Azure IoT Central Application Dashboard
- Grafana Dashboard

The prototype works on the following appliances:

- Humidifier
- Kasa Light with Dimmer
- Electric Fan
- Air Purifier
- Speaker

Figures 4 and 5 show the two additional dashboards apart from the Node-RED dashboard. These dashboards show the user analysis based on the data received from the various sensors. The Grafana dashboard in Fig 4 shows three time series graphs based on Temperature, Humidity and Air Quality readings. The Azure IoT dashboard shown in Fig 5 shows the temperature, light intensity, and humidity readings. Along with this it also shows other parameters such as 'motion detected' and 'user-identified' in real time.

VI. Challenges

Consolidating a dashboard which shows real-time status, historical data and analyzes the working status of the appliances is difficult to implement. This is because dashboards that are used for data analysis lack two-way communication. It is

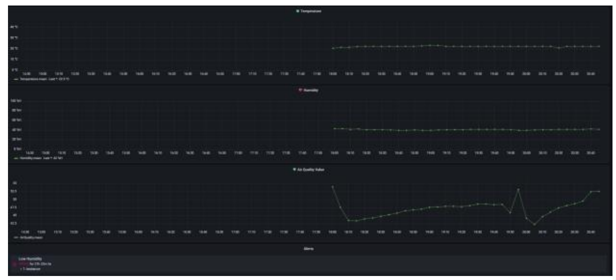

Fig. 4. Grafana Dashboard

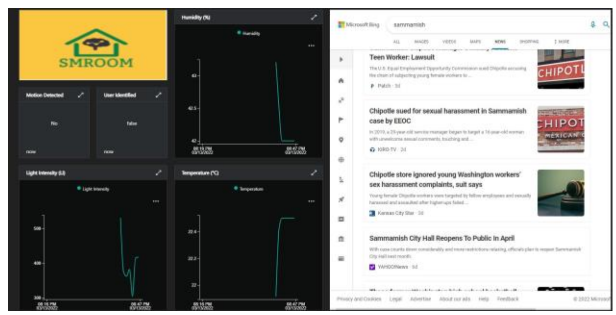

Fig. 5. Azure IoT Dashboard

not possible to control the appliances from such dashboards as data only flows in a uni-directional way. Currently, the system uses 3 dashboards, so the application is not streamlined. Due to the limited range of the light sensor reading, it was a challenge to test the automatic brightness adjustment functionality. Due to the limited processing power of the Raspberry Pi, parsing information from video using OpenCV was not efficient. To make the performance real-time and lag free, local processing was replaced with cloud processing through Azure Custom Vision.

VII. Future Work

The system can be improved by utilizing better sensors with output range that is suitable for real-world applications. Also, the Raspberry Pi model can be upgraded so that local processing of video for user-identification can be lag-free. Instead of having multiple dashboards for separate functionalities, the system can be made more streamlined by implementing a single dashboard. The security of the system can be enhanced by ensuring that the user authorizes themselves while accessing the dashboard. Currently, the system can only switch on/off the appliances. So, improve the system advanced actuators can be added to control the settings of the appliances. For instance, the system can add a motor to move the dial of the humidifier to change the humidity setting.

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