Occupancy Monitoring System for Workplace Washrooms

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Abstract

With regard to rapid technological advancements majorly influencing our daily lives, Internet of Things (IoT) has been a topic of broad and current interest in the recent years. The capabilities of IoT can assist in revolutionizing the way people live and work, thereby improving quality of life. With the impact of IoT only continuing to propagate in the future, it can be used as a means of easing our day-to-day struggles. Therefore, with the assistance of IoT along with a few hardware, the proposed system, addresses the displeasing reality of queues and several visits for the washrooms due to them coming forth occupied. Thus, the focus of the intended system is on delivering a pleasant washroom experience for employees in an office environment providing them with an at-desk indication on the occupancy of the washroom cubicles reducing queues and disappointments.

Keywords: *Internet of Things, Raspberry Pi, Message Queuing Telemetry Transport, Occupancy Detection, Publisher, Subscriber, Sensors*

1. Introduction

Nowadays, with highly active work environments, a customary issue faced by the employees is, having to make several trips to the washroom only to return back to their seats due to the cubicles being already occupied or wait around until a cubicle is free. Since, the occupancy of the washroom cubicles are not mostly visible at a glance once a person enters the washroom due to the inefficacy of the indicators attached the door locks, tenants often have to try each and every door to find an unoccupied cubicle. The issue is even more emphasized in case of the workplace having only a limited number of washrooms or the washrooms are being situated far from the employee desks. In a highly dynamic office environment where every minute counts, the matter could result in time wastage as well as bringing frustration to certain extremely pressurized employees.

As a solution for the aforementioned problem, a mechanism of informing the employees on the availability of the washroom cubicles while they remain in their seats, would be ideal. Using the potential of hardware along with the Smart Building concept, the proposed system provides the resolution. The Internet of Things or IoT, which plays a major role in Smart Building systems, refers to a network of devices or things. These devices can collect and send information, receive and act on information or do both. IoT integrates intelligence to otherwise dumb devices, giving them the capability of interaction without the necessity of human engagement. Hence, the application of IoT can assist in solving a number of real-world complications encountered by people in their daily lives.

The proposed system decides on the occupancy of the cubicles by detecting the motions inside the cubicles and placement of the cubicle doors. In case of a particular cubicle being occupied, the system would light up the bulb inside the cubicle in conjunction with the relevant bulb outside the washroom indicating the occupancy. Simultaneously, the cubicle door would be automatically locked and would only be unlocked upon a button press action performed by the occupant. Once the door is unlocked and the occupant leaves the cubicle, both the light bulbs placed inside the cubicle and outside the washroom would be turned off in order to save electricity and indicate cubicle unavailability respectively. While the lights outside the washroom would indicate the washroom availability status to the employees nearby, employees all around the office can also check the availability status of the washroom cubicles, as they remain seated, with the assistance of the web interface provided by the system. In general, the proposed system incorporates smartness to the conventional washrooms thus saving time as well as energy.

2. Background study

A. R. A. Rudin et al. [1] proposed a system that monitors the occupancy of campus sport facilities by using the concept of internet of things (IOT). The aim of this proposed system is to facilitate staff members and students to find out the information about available sport facilities which are already provided by the university. It

has been firstly implemented for campus badminton court. Monitoring occupancy of the sport facilities, booking the sport facilities and providing information about sports are major functionalities implemented in the system. In the system, Raspberry Pi 2 has been used as the system's main microcontroller. This microcontroller is the one who find out the availability of sport facilities, by detecting the movements near the doors of each facility. Also, the system has been used Passive Infrared (PIR) sensors to identify movements near the door. In order to book the sport areas for events they have used a web-based application system which is implemented using HTML. If the area is already booked at a particular time, the door will be locked, and it will be only unlocked when identification number is read by the RFID scanner.

Jing He et al. [2] proposed a smart resource management system which is based on Internet of Things (IOT). Proposed system mainly focused on checking the occupancy status of the chairs. In the intelligent chair system, all the physical chairs with embedded sensors are connected to a network for collecting relevant information. This is conducted by the functionality of IOT. System has used a cloud architecture to upload that collected information. They have used the cloud architecture to access the data from anywhere when they need. Firstly, the system is implemented to a single chair and they are going to expand the implementation to connected chairs as an intelligent chair system. Proposed system has three main components. First one is the assembled Arduino system which has the major functionalities like scanning user ID, gaining chair occupancy status and to send all that information to the cloud server. Second component of the system is the cloud server which is the place they have been gathered all the collected data. Final component is the mobile application which has been developed using Android technology. Main functionality of this application is to display and monitor the chair occupancy states and user information. They have used RFID readers to identify users. It has been automatically done from the reader by using the user's identification (User ID). Then system passes the collected information to the Arduino microcontroller. Also, there is a pressure resistor to check the pressure levels. If the pressure level exceeds the pre-set threshold, timestamp is passed to the Atheros AR9331 microcontroller. This process has been done using a bridge library. Lastly, the bridge library provides a HTTP POST to the cloud server along with the User ID which has been scanned from the RFID reader.

Xiao Ling et al. [3] proposed system to identify vehicle parking spaces and detecting occupancy using vision based IOT devices. Aim of this project is to visible free parking spaces to the drivers. System has been developed with the concept of smart cities. Proposed system developed using a camera-based space identification system. It has been used a single camera connected with IOT device. The purpose of having this camera and the edge device is to identify and monitor the status of available parking areas within the covering view. System contains with two major components. They are parking lot topology learning and parking lot occupation detection. In parking lot topology learning system, car-driven strategy has been used to identify the parking points. To do that they have used Haar-featured object identification algorithm which is included in OpenCV library. From the second component system identifies the occupied parking slots. This system has been developed using Raspberry Pi and by using an occupation detection pipeline. It identifies the available parking slots correctly.

3. Methodology

The main focus of the system is to detect and indicate the occupancy of washroom cubicles and automating the door locks and lights. A prototype model has been created in order to simulate the scenario.

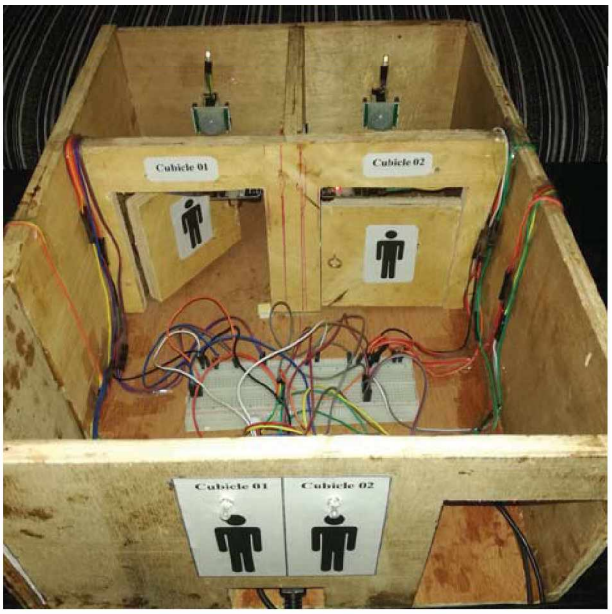

Figure 1. Prototype Model.

Two types of sensors have been used in implementing the prototype. PIR (Passive Infrared) Motion sensors, as the name itself implies, are small, light, low-cost sensors capable of detecting human movement in or out of its range, with the assistance of variations in the infrared light, is used. IR (Infrared) Proximity sensor, is a multipurpose sensor capable of sensing obstacles by continuously transmitting infrared light and identifying

nearby objects via the means of reflected light, is also used. A PIR (Passive Infrared) Motion sensor is placed inside each cubicle which aids in detecting motions inside the cubicle. Furthermore, IR (Infrared) Proximity sensors are positioned at the top of the washroom cubicle doors, senses the status of the door identifying whether it is closed or opened. If both the PIR and IR sensors yield positive outputs, the cubicle is considered occupied [4]. The reason for checking positive outputs from both the sensors when deciding the occupancy is for better accuracy. For an instance, in case of the cubicle door being closed due to wind without a person inside, the IR Proximity sensor would detect positive inputs. Moreover, if a person goes inside the cubicle without closing the door perhaps with the intention of immediately returning, the PIR Motion sensor would yield positive inputs. In both the scenarios cubicle would be assumed occupied resulting in inaccurate outcomes provided that only one of the sensor data is taken into consideration. Hence, both the sensor inputs are taken into account when determining the conditions to check the occupancy. The sensor data would be utilized by the Raspberry Pi 3 which acts as the main microcontroller. Using the MQTT (Message Queuing Telemetry Transport) protocol which is a lightweight publish-subscribe based messaging protocol widely used in IoT applications, the Raspberry Pi acts as the publisher and publishes the data gathered through the PIR and IR sensors under a single sensor data topic for each cubicle [5], [6].

```
Motion_IR_status_1 =
str(GPIO.input(Motion_1)) + ';' +
str(GPIO.input(sensor_1))

mqttc.publish("topic/Motion IR status",
Motion_IR_status_1)
```

The publisher continuously checks and publishes the sensor data in order to process real time data. The MQTT broker, which is a separate computer, plays the role of the subscriber. Once data is published under the corresponding sensor data topic, it would be redirected to a callback function which processes the data published. If both the PIR and IR sensor results are positive, it means that there is motion detected inside the cubicle and the cubicle door is closed, implying that the particular cubicle is occupied. Since both the sensor data are checked in order to decide on the occupancy of the cubicle, both sensor data are published under a single topic. The occupancy of the cubicle suggests that the door lock should be automatically locked and the relevant light bulbs; both inside and outside the cubicle should be turned on simultaneously. Therefore, the callback function publishes topics indicating what the status of the lock and lights should be.

```
if Motion_01 is "1" and IR_01 is "1":
mqttc.publish('topic/Light_1_status', 1)
mqttc.publish('topic/Door Lock 1', "Lock")
```

The subscriber in the Raspberry Pi is subscribed to the corresponding topics and accordingly, it automatically locks the door with the assistance a Servo Motor connected to the door lock and in the meantime, turns on the light bulb inside the cubicle and one outside the washroom, representing the specific cubicle [7].

```
if "UnLock" in Lock 1 status:
    p.ChangeDutyCycle(12.6)
else:
    p.ChangeDutyCycle(6)
```

Once the occupant inside the cubicle wants to leave, he or she can press on a button placed inside the cubicle. The publisher in the Raspberry Pi publishes the status of the aforementioned button under a specific topic when publishing sensor data. The subscribed MQTT broker has a separate callback function to be executed in case of a message from the particular button related topic. The Raspberry Pi subscriber unlocks the cubicle door according to the messages published by the callback function. When the cubicle door is unlocked, the relevant light bulbs are also turned off indicating the availability of the cubicle. While the light outside the cubicle denotes the availability and unavailability status of the cubicles to those nearby, the same occupancy status can be monitored by tenants via the use of a web interface. The provided web interface exhibits a statistical view of occupancy state along with the time durations. The web application is implemented using Node-RED which is an open source visual tool developed by the IBM's Emerging Technology Services for wiring together hardware devices, APIs and online services [8]. Node-RED is widely used for IoT applications.

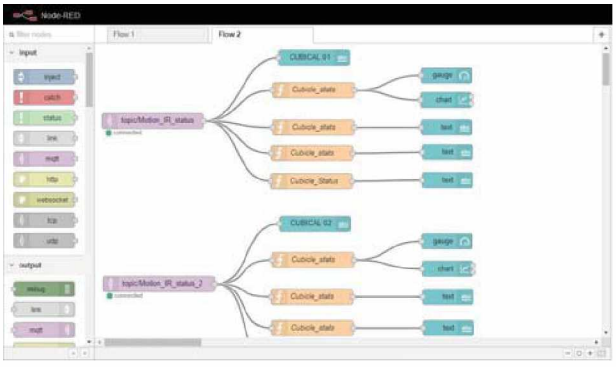

Figure 2. Node-RED Flow.

A MQTT node is used in order to connect to the MQTT broker. Based on the topic data, the wired function nodes decide on the output projection in the web interface.

4. Experimental results

The result of the system is an at-desk indication of the availability of the washroom cubicles. Initially, PIR and IR sensor data along with the button status are published from the Raspberry Pi. The MQTT broker is subscribed to these topics and therefore the messages published are received by it.

```
Motion 01 = 1

('Received message Button 01 =', '1')
('Received Message =  ', '1;0')
```

Figure 3. Messages received by the Subscriber.

According to the data published by the topics, the relevant callback functions publish topics indicating whether to lock or unlock the door and turn on or turn off the lights. Then the Raspberry Pi subscriber performs the actions accordingly. For an instance, if cubicle 02 is considered occupied, as demonstrated in Figure 4, the door is automatically locked, the light bulb inside the cubicle is turned on and same happens with the light bulb outside the washroom to denote the occupancy.

Figure 4. Model showing occupancy of Cubicle 02.

In the meantime, with regards to the node-RED application, the occupancy status is illustrated along with the time durational statistics. As an example, in case of cubicle 01 being occupied, the unavailability is represented through the web interface using a gauge and a chart as shown in Figure 5.

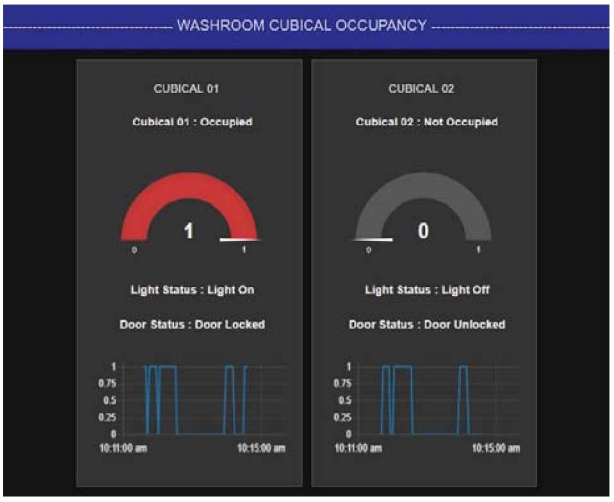

Figure 5. Web interface showing occupancy of Cubicle 01.

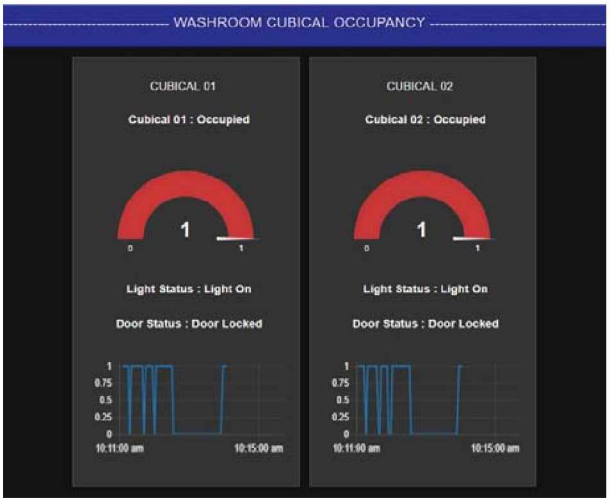

Figure 6. Web interface showing occupancy of both Cubicles.

5. Conclusion

Present-day, with the emergence of Internet of Things or IoT, almost all the devices are interconnected via the internet which sends and receives data. Proposed washroom occupancy system was developed with the assistance of IoT concepts incorporated with a few hardware items. The system is mainly focused delivering an at-desk indication on the availability status of the washroom cubicles in the organizations, eliminating the need for the employees having to physically go there. In order to decide on the cubicle occupancy status, system

has considered two main conditions. The motions inside the cubicles are captures using PIR motion sensors and the cubicle door being closed is detected via the use of IR proximity sensors. Accordingly, occupancy is detected and door locking or unlocking and turning on or off lights are automated. The results of the system indicate that the system was able to achieve the expected goal. The system can be further expanded to be implemented in several other public places in the future.

6. References

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