Building Management System with Integrated Facilities Management Using Computer Vision

Anand S[#], Sabu K[*]

[#]Research Scholar, APJ Abdul Kalam Technological University, College of Engineering Trivandrum, Kerala, India

[*]Associate Professor, APJ Abdul Kalam Technological University, College of Engineering Trivandrum, Kerala, India

***Abstract*—Building management systems (BMS) for monitoring and managing various psychometric conditions inside a building have been in development for along time. The recent advancement in wireless technology and the advent of IoT have caused a sudden popularity of BMS among general population and software companies. Tech giants like Google, Samsung, Microsoft, Amazon and others have developed their own automated management and monitoring software. But most of these systems only manage environmental conditions and does not control other facilities.**

In this paper a customised building management system with facilities management capacity is presented. The facility management is done by integrating computer vision technology with the BMS.

***Keywords*—Building management, Internet of Things, Facilities Management, Computer vision, Psychometric**

I. INTRODUCTION

Automated systems for the control of activities in a building have been in development for a long time. Earlier conceptualisation of "intelligent buildings" happened in 1980s in USA by the development in information technology [6, 7] and by the increased demand in comfortable living [4,16]. Earlier intelligent systems were propitiatory systems; each designed for a particular building and requires an operator. Users had less or no interactions with the systems. These systems used wired connections and were very expensive to install [17].

In the last two centuries, there has been an extensive research in the field of intelligent buildings [15]. With development in information technology and wireless data transfer, the building management systems have become widely popular [9]. Companies like Google, Samsung, Apple, Microsoft and Amazon are working in the field of intelligent building management and have developed automated management systems. Despite their popularity, these systems are still expensive for general populace [3].

Internet of things technology developed the method to connect more and more devices to the internet [5, 8]. With cheap microcontrollers andsensors the cost of control systems are coming down [1, 19]. Earlier BMS uses propitiatory control networks. The components of these networks operate on different protocols and inter-operability depends on compatibility or special control networks. With IoT, devices are adopting common network protocols and as a result, communication between devices has become easier [18]. This has led to the integration of facilities management with the building management system [15]. A building management system can provide services like (i) controlling micro environmental conditions inside a building, (ii) controlling air quality inside building and (iii) automation of building activities to reduce energy consumption. But with IoT many other functions like resource utilisation, security, hazard monitoring and resource planning can be provided by the system.

Even with the extensive research in the field, the problem of intelligent management and energy consumption is far from being solved [17]. Researchers are integrating newer technologies into the field of intelligent buildings to improve the system. The latest trend is using the cloud computing for storage and processing of data from the system. This can help in centralising data processing for a single building or for multiple buildings. New researchesare also integrating neural networks for the data processing in intelligent buildings [13, 14].

This paper presents a prototype of a customized wireless platform for sensing and monitoring light intensity, humidity and temperature with IoT for building automation along with integrated facilities management and security system using computer vision. A user interface which facilitates visualisation of the data andcontinuous monitoring and recording of the valuesis developed in firebase. This data can be used for analysing the system and to control its functions. The processing and storage of data is done as a cloud based approach.The system is subjected to experiments to verify that the results aresatisfactory.

This paper is arranged as different sections. Section 2 explains the structure of the prototype BMS. Section 3 presents the results obtained during the experimental implementation and validation of the system. Section 4 presents the conclusion and future works.

A. *System Development*

The proposed concept consists of a sensor layer, transmitter layer and a PC with a direct link to cloud storage using internet. The transmitter layer consists of a processing unit and is able to send control signals to the HVAC devices through the cloud platform. To cover alarge area, more sensors and transmitters are needed but they can be connected to a single gateway, depending on the range of the gateway device.

The proposed system uses a camera network for the additional purpose of facility management and security. This will reduce the human involvement in the process. The PC acts as a receiver node for the system and stores the data in spread sheet format. The transmitter node will also publish the data to cloud storage using MQTT protocol. The user can view and interact with the data using the interface made in Google firebase. Fig. 1 is the block diagram of the proposed system.

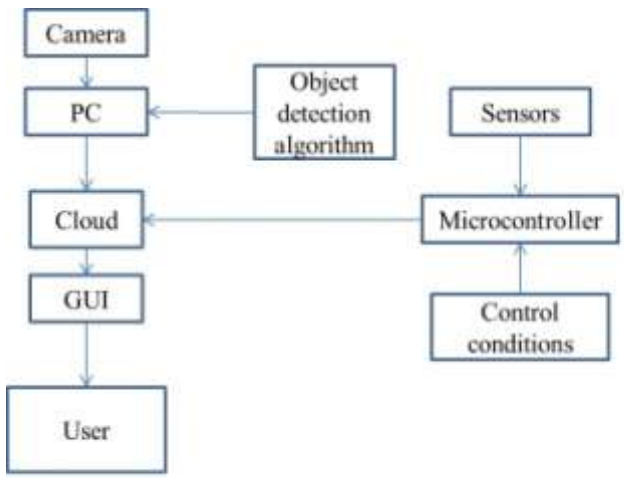

Fig. 1 Block Diagram of the Proposed System

1. *Level:* The wireless sensor level of the proposed system consists of a temperature and humidity sensor, a light intensity sensor and a micro-controller with a wireless transceiver. The sensors collect data and the micro-controller process it and make control decisions based on the rule conditions. The transmittersends the data wirelessly to cloud and through USB to PC. The data processing is done by a custom program code uploaded in the micro-controller. The micro-controller and sensors are powered by the PC using USB interface.

2. *Sensor:* The system uses DTH 11, which is a temperature and humidity sensor. It gives a digital output. Its accuracy is tested in the laboratory at different temperatures using standard measuring instruments. The sensor has a temperature measurement range of 0 to 50 °C with ±2 °C error and humidity measurement range of 20 to 95 % RH with ±5 % RH error. The sensor can be used in low power applications as the operating voltage range is 3.5 to 5.3 V. The response time of the sensor is less than 50 ms, which is fast enough for the application. The sensor uses a single-wire bi-directional serial bus with an 8 bit resolution for data transfer.

   The next sensor used is BH1750 ambient light sensor which provides digital output through I2C interface. It has a light intensity range from 1 to 65535 lux. Its operating voltage is 4.5 V to 5.5 V. It has a 16 bit output and the data output of this sensor is directly in Lux (lx). Response time is 120 ms for high resolution mode and 16 ms for low resolution mode.

   The third sensor used in the system is a webcam (Logitech c270). It has a maximum resolution of 1280 x 720 pixels and transfer data through USB.

3. *Microcontroller:* The microcontroller used is NodeMCU with ESP8266 Wi-Fi module. It is an open source IoT platform programmed in Lua and has a 32 bit MCU with 80 Hz CPU, 128 mb memory and an integrated 10 bit ADC. It can store control programs for the sensors and can make decisions based on the data from the sensors. It has an integrated SoC Wi-Fi system and can transfer data through USB or over the Wi-Fi. It has a power usage of 3.2 to 3.6 V. Table 1 list the consumption of current by the sensors. Fig.2 is the connection diagram of sensors.

4. *User Interface:* Users can interact and control the data from the sensors by using an interface made in Google Firebase. It is an IaaS platform for application development.The data is uploaded to firebase in publisher subscriber model using MQTT protocol over Wi-Fi. The interface can also store the data for later use.

TABLE 1

Current Consumption of Sensors

Module	State	Current
DTH 11	Measuring Standby	0.3mA 60μA
BH1750	Measuring Standby	190μA 1μA
NodeMCU	Wake Standby	80mA 10μA

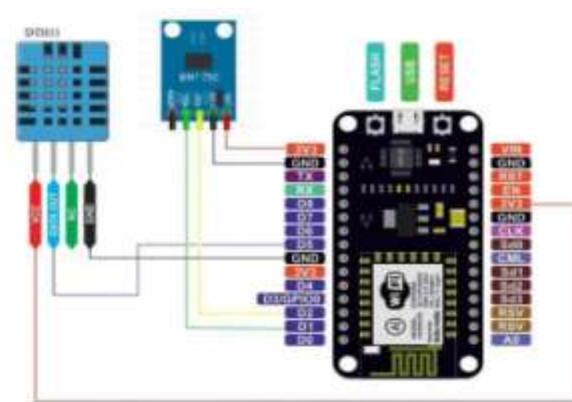

Fig. 2 Connection Diagram of the Sensors

B. Sensing, Transmission and Processing

The system has three operations (i) sensing (ii) transmission and (iii) processing of data. First the sensor DTH 11 and BH1750 are connected to the nodeMCU. The camera is directly connected to the PC. The nodeMCU is programmed such that it takes values from the sensors at intervals of one second and sends it to the PC through USB. The nodeMCU is also programmed to push the data to the firebase account as a publisher subscriber model. The camera is connected to the PC and the data is stored in local memory before processing.

The transmission of data from sensors is done by two channels, direct to cloud using ESP8266 Wi-Fi SoC on nodeMCU and through USB cable to PC. The transmission is done at the same rate of sensor sampling.

The nodeMCU also have a control program uploaded in it for the decision making in comfort condition of the area under monitoring. As the temperature value reaches a particular pre-set temperature, the nodeMCU will send signal to the HVAC system to turn on/off the air conditioner. The humidity is also controlled similarly.

The camera is used for resource monitoring. The system uses YOLO image detection algorithm for identifying object in the image [11, 12]. The camera provides a continues feed, which is used by the algorithm. The algorithm sample frames from the feed at a rate of one fps. The frame is then divided into quadrants and items and persons in each quadrant are detected. The number of persons in each quadrant is counted and is compared with the predetermined capacity of the area to find usage [2, 10].

C. Deployment and experimental results

The system is deployed in a cafeteria. The temperature, light intensity and humidity sensor along with nodeMCU is placed at the centre of the cafeteria and the camera is placed in the corner. The nodeMCU power the sensors through a 3.5 V converter plugged to the main. The program in the nodeMCU is such that it monitors the sensor values against a set condition and when the set condition is satisfied, it will turn a digital pin on/off. Three sensors have separate digital pins assigned to it. When HVAC devices are connected to the digital pin, they will also turn on/off depending on the pin. The nodeMCU then send the data to firebase application. The camera is connected to the PC and the YOLO algorithm runs on the PC and sends the result of image detection to the firebase.

The system is tested at different places with different lighting, temperature and humidity conditions. Value from the sensor is compared against measuring instruments like lux meter, thermometer and psychrometer. Taking the instrument values as actual values, the temperature sensor give an average error of 0.75 %, light sensor give an error of 1.2 % and humidity measure give most error of 5.5 % relative humidity.

The object detection using camera and YOLO gives an average error of 20 %.

II. CONCLUSIONS

The prototype of the system for monitoring psychometric condition and resource monitoringhas been successfully tested by implementingitin a cafeteria. The maximum error found from the sensor is 5%, therefore it can be considered as a robust system. The object detection system can be further improved by training the algorithm in more images.A high level of automation can be obtained as the human interactions for facility management and security purpose can be reduced.

The firebase platform shows the collected data from sensors and also shows the results from the object detection. It also helps in monitoring the conditions online.

Further improvement includes training the image detection algorithms with the images of employees for security purpose and accessibility restrictions and also including more shared resource to the algorithm library.

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