IoT Based Energy Efficient Smart Classroom

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***Abstract*— This paper presents a cost-effective energy-efficient Internet of Things (IoT) based device controlling system that can be used with minimum user interaction, in the case of operating any electrical device. The proposed prototype of "IoT Based Energy Efficient Smart Classroom" is implemented to reduce the wastage of electricity in a lecture hall in the Sabaragamuwa University of Sri Lanka. The system controls the operations of electrical devices (such as ON/OFF) by identifying the presence of human in a specific area. In the system, a Microsoft Kinect sensor is used to track the presence of humans and the system can be responded to environmental conditions such as temperature, humidity, and light intensity at the human-occupied area. A DHT22 sensor and LDR are connected with the Arduino ATMega board to measure those environmental conditions. These sensors provide real-time data on environmental conditions in the lecture hall and a web application that is included in this system is updated using these data. NodeMCU IoT device is used to send all data to the host machine through the internet. Finally, the system was tested in 80 incidences using four students in a laboratory and the test results show 97.62% accuracy for the implemented prototype.**

***Keywords*— Energy saving; IoT; Smart classroom; Microsoft Kinect; Human detection**

I. INTRODUCTION

World electricity consumption is increased rapidly because of the development of technology as well as the growth of the world population. Extensive research efforts are lying down in most of the countries in the world to develop alternative, renewable and sustainable energy sources to generate electricity to satisfy the large demand for electricity. At present, a certain number of potential candidates as renewable and sustainable energy sources such as hydrogen, biofuel etc. are identified to produce electricity in developed countries [1], [2], [3], [4].

In the case of Sri Lanka, it has been reported an exponentially increasing demand for electricity and there should be immediate actions to implement low cost electricity generation projects to satisfy the growing demand of electricity [5]. Further, these projects should be in line with world energy policies for a sustainable future. According to the installed electricity generation capacity of the national power grid of Sri Lanka in 2017, the percentage of natural resources that used to generate power are; coal – 40.0%, oil – 37.0%, hydro – 16.0% and non-hydro renewable resources (Includes wind and solar) – 7% [6]. However, as a developing country, implementing new projects such as hydrogen etc. will be a huge challenge for Sri Lanka. In contrast to finding low cost, sustainable, and renewable alternative energy sources for electricity generation, simultaneously, Sri Lanka has to implement methods to reduce the electricity wastage.

University is a place where many people need electricity power. Important activities such as studies, laboratory experiments, lightning the lecture halls, etc. are failed if there is no electricity power. Hence, controlling power consumption in an effective manner is essential for everyone in the university. It is identified as one of the major reasons for electricity wastage due to the carelessness of people in the university. This happened because the manual switching system is not efficient, and the electrical equipment cannot be controlled without human intervention. Therefore, it is almost necessary for the university system to have an automated system instead of a manual switching system.

Consequently, in this research, the reduction of electricity wastage in universities has been addressed by introducing the IoT based smart classroom system. In many countries, researchers have introduced different solutions and applications using IoT technologies that provide valuable support to build new innovative systems for energy utilization. For example, the smart grid [7] is an intervention of IoT technology that allows electricity system to manage demand, protect the distribution network as well as save electricity wastage. These systems connect all the power resources and store information into centralized databases. Also, the power monitoring system based on IoT is another popular solution to reduce unnecessary electricity consumption. In this system, users can identify the power wastage remotely through the internet and control unnecessary electricity consumption. [8], [9] and [10] are few examples for them.

Fig. 1. *3D coordinate system of the Kinect sensor*

The proposed IoT based automated power-saving system can be introduced to control the electric devices such as light bulbs and fans in the lecture hall. In the operation process, when a person entering the lecture hall, the system identifies the location of the final destination of the person. Then the system automatically turns on a fan and light bulb in the human-occupied area of the lecture hall. During the activation of the particular electric device, the system will maintain comfortable lightning conditions and temperature in the classroom.

The remainder of this paper is organized as follows. A succinct analysis of related research is presented in the second section. Section 3 discusses the methodology and implementation of IoT Based Smart Classroom System. Section 4 discusses the results and observations. Finally, section 5 concludes the paper and presents directions for future work.

II. Literature Review

Previous studies in relation with our study are explained in this section. Nowadays, most research in the world are focused on energy utilization concepts as it is the most appropriate answer for saving energy. One major perspective of energy utilization is improving the quality of life. Using renewable energy resources like solar power and building green universities are few other solutions. Green universities reduce environmental pollution and facilitate whole university energy necessity [11].

According to Walter Simpson, an aggressive university energy conservation program can reduce university energy consumption by 30% or more by addressing the supply side of the energy equation. It means shifting to clean, renewable, noncarbon based energy resources, and technologies. Developing university energy policies, coping with the computer explosion, avoiding the pitfalls of electric deregulation, buying green power, and implementing green building design are all parts of the solution [12]. As implied by this study, technological solutions are an important way to reduce university energy consumption.

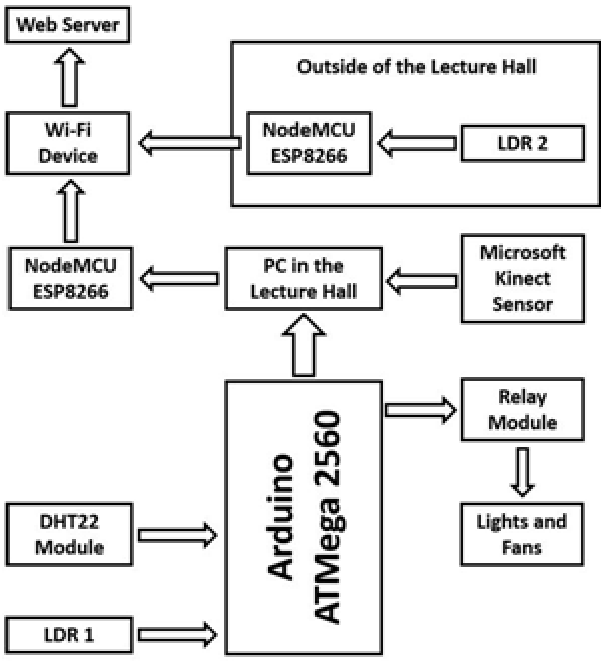

Fig. 2. *Smart classroom system design architecture*

Also, Yuvraj Agarwal et al. have introduced a design and implementation of a low-cost and incrementally deployable occupancy detection system using battery-operated wireless sensor nodes. In their work, they used passive infrared sensors (PIR) to identify the occupancy. Using this occupancy information as input to a simulation model of a building, they showed that the heating, ventilation, and air-conditioning (HVAC) energy consumption can in fact be reduced from 10% to 15% using their system [13].

Monika Lakra et al. have introduced an automated system to control electric devices, considering the number of occupants in the lecture hall. They have developed an intelligent energy-saving system for the university lecture halls, using PIR where electronic devices can be controlled automatically. They were able to control the wastage of electricity in the university, after implementing the system [14].

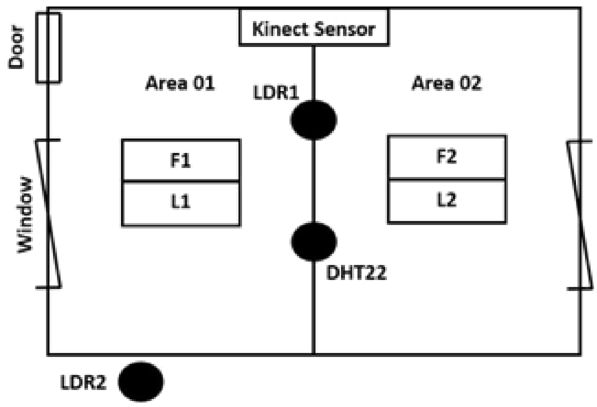

Fig. 3. *Sensors arrangement of the inside and outside of the lecture hall*

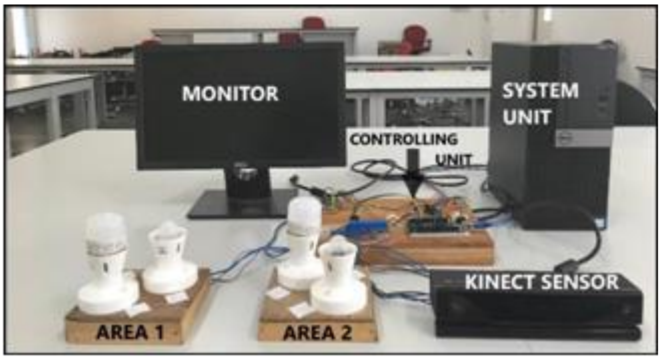

Fig. 4. *The overall prototype of the smart classroom system*

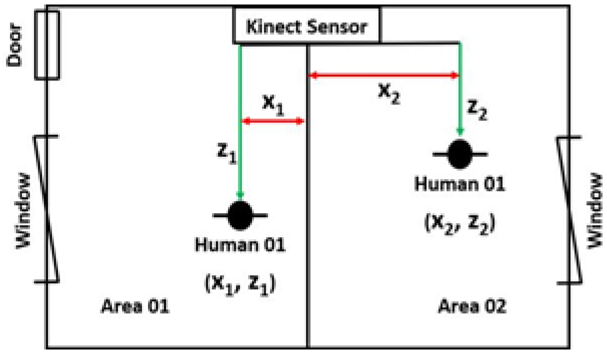

Fig. 5. *X and z coordinates of the human head provided by Kinect sensor*

Further, Ansiya Jabeen and Mahesh Kumar have introduced a controlling system for university lights with the help of campus card system, radio frequency (RF) wireless communications technology and ethernet. It is another solution to control the electric power in the university using IoT technology. In this research, allocating sensor nodes on the corresponding lights can help get the general position of the human body and then turn on the relevant lights to save the energy substantially on the premise of satisfying illumination demand [15].

Our proposed work is a combination of the above solutions. It is an energy-saving system as well as a classroom monitoring system. In the energy saving section, only people are correctly identified, and the electrical devices are automatically controlled. For this task, the Microsoft Kinect sensor V2 [16] was used. It can identify the human body correctly and provide the distance between the sensor and the object. Also, it provides the 3D coordinates for each pixel in the object using RGB-D images. Therefore, it can be used for various purposes in vision-based researches. Virtual mirror rooms [17], automated navigation systems [18] and smart home systems [19] are few examples. Also, the 3D coordinate system of the Kinect sensor can be explained as follows. In the center of the Kinect sensor, all x, y, and z values are equal to zero. From the center, the x value positively increases to the left of the sensor as well as the x value negatively increased to the right of the sensor. Also, the z value increases to the outside of the sensor (See Fig. 1).

III. METHADOLOGY

The proposed system was built to automatically control the traditional manual switching system utilizing different kinds of sensors. LDR was used for sensing environment light intensity level and subsequently control the light bulbs in lecture hall. Similarly, a digital temperature and humidity (DHT22) sensor captures environment temperature and controls the fans in the lecture hall. An Arduino board (ATMega 2560) was used to connect the LDR and DHT22 sensors in order to read and transfer inputs to the program which executes on the computer. The main feature of this system is the control of electrical devices in the human-occupied area of the lecture hall. Here, a Microsoft Kinect V2 (Xbox One) sensor was used to identify humans in the lecture hall. Kinect sensor is specially known for accurately distinguish people from other objects. Also, two NodeMCU ESP8266 open source IoT devices were used to provide real-time data (such as temperature and humidity in the lecture hall and lighting conditions inside and outside of the lecture hall) to users. The Kinect sensor, the Arduino microcontroller and one NodeMCU were connected to the computer in the lecture hall and the other NodeMCU was connected to an LDR which was placed outside the lecture hall. Fig. 2 shows the design architecture of the proposed prototype.

As the first step of the implementation process, an experiment was done to determine the comfortable living values (lighting condition and temperature) in the lecture halls using 25 students in the Sabaragamuwa University of Sri Lanka. It was estimated that the temperature should be less than 29 C and the light intensity should be over 300lx in order to involve the study activities comfortably at the lecture hall [20]. Those threshold values of temperature and light intensity were used when the prototype of our system was implemented. The system prototype was built in three subsequent stages as follows:

1. Smart Class Arrangement
2. Hardware Implementation
3. Software Implementation

A. *Smart Class Arrangement*

In this session, the arrangement process of the sensors in the lecture hall is explained. In the first step, the lecture hall was divided into two specific areas as shown in Fig. 3. in order to recognize each area uniquely (Area 01 & Area 02). The allocation for Area 01 and Area 02 were made as follows considering the x and z coordinates that are obtained by Kinect sensor data.

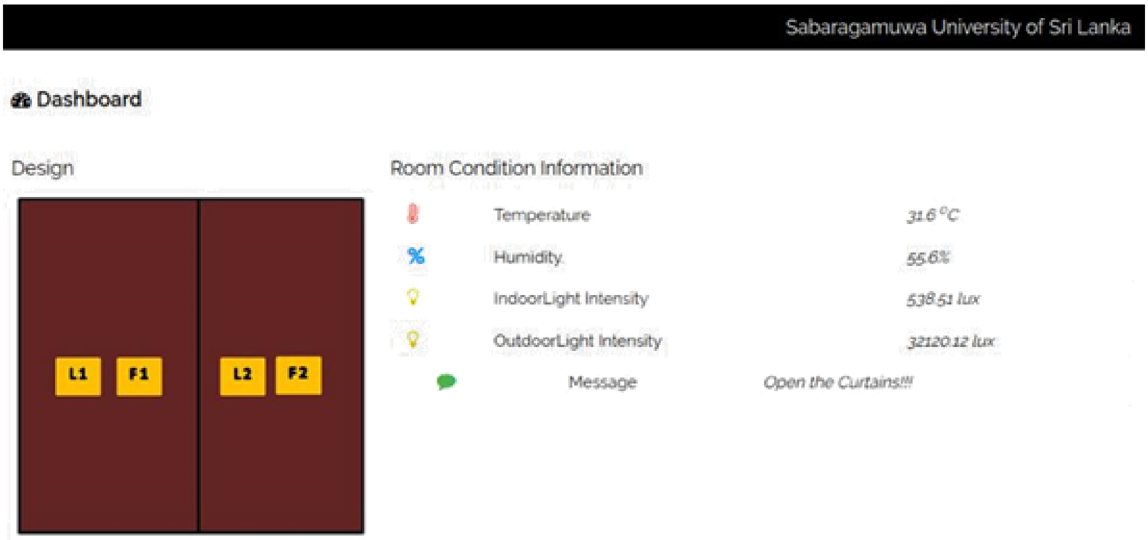

Fig. 6. *Web interface of the smart classroom system*

1. Area 01: $-2.0m < x < -1.0m$ & $0m \leq z < 4:0m$
2. Area 02: $2.0m > x > 1.0m$ & $0m \leq z < 4:0m$

Each area consists with one light bulb and fan which are labeled as L1 and F1 in Area 01 and, L2 and F2 in Area 02, respectively (See Fig. 3). As it is shown in Fig. 3, the Kinect sensor was mounted in the lecture hall 2.5m above the ground level with an angle of 60 downwards from its ordinary horizontal position. The height and the angle were determined considering humans must be occupied in the camera range of the Kinect sensor to identify them. To control lights bulbs in the lecture hall an LDR (LDR1) was used inside of the hall. Also, the DHT22 sensor was used to control fans in the lecture hall (See Fig. 3). Further, another LDR sensor (LDR2) was placed outside the lecture hall to get the outside light intensity information as shown in Fig. 3.

B. Hardware Implementation

The first step of the implementation procedure is to detect a person in the lecture hall using the Kinect sensor. Previous research has used different types of motion sensors to identify persons [13], [14]. But those systems failed because they cannot recognize humans without considerable motion. With the help of Kinect sensor, we have been able to overcome this problem. It identifies the human body in the shape of a human skeleton using RGB-D data that are provided by inbuilt RGB camera and IR sensor. Hence, Kinect has the ability to identify humans without motion [21]. As mentioned in Section A above, to implement the prototype the Kinect sensor was placed in front of the audience. It was connected to the PC using a USB 3.0 cable. The software that is built in our system identifies humans and their locations by using the Kinect sensor data. This software was installed on the PC in the lecture hall.

The next step of prototype implementation is connecting LDR sensors and DHT22 module to the system. LDR1 and the DHT22 were connected to the Arduino ATMega 2560 while Arduino ATMega 2560 was connected to the PC using a serial-USB converter cable. Three pins of DHT22 sensor namely data pin, VCC and ground pin were connected to the Arduino board where the second pin was given 5V and the third one was grounded. Then the LDR1 was connected to analog port (A0) of the Arduino board through 10k resistor. Similarly, LDR2 was connected to analog port (A0) of the NodeMCU through 10k resistor. Also, a 5V power pack was used to power the NodeMCU. Then the NodeMCU which was connected LDR2 was placed outside the lecture hall. The overall prototype of the smart classroom system is shown in Fig. 4.

C. Software Implementation

As the initial step the program has to identify humans in the lecture hall through the Kinect sensor. Here, the Kinect sensor can identify the human body considering 25 body joints of a person [22]. Then the coordinates (x and z) representing the head (One of the 25 body joints above mentioned) of humans which are obtained by the Kinect sensor data are used to identify the human-occupied area (Area 01 or Area 02). These x and z coordinates are shown in Fig. 5. Here, if a human is identified in the area of 01 or 02 by the program, subsequently the temperature and light intensity values read via DHT22 module and LDR1 respectively. Accordingly, fans and lights are switched ON/OFF considering the threshold values of temperature and light intensity. The process will be continued as a loop while measuring the temperature and light intensity. Also, it automatically turns off light bulbs and fans in the lecture hall when humans leave the area. Simultaneously, the values of the LDR1 (light intensity in the lecture hall) and the values of the DHT22 (Temperature and humidity values in the lecture hall) are updated in real-time to the web server using NodeMCU by the program.

The Arduino ATMega 2560 and the NodeMCU ESP8266 were programmed using Arduino IDE. In the Arduino ATMega program, the DHT library was used to program the DHT22 sensor and the following equation (equation 1) was used to calculate the light intensity using the LDR.

$$LV = \left(\frac{250}{V_0}\right) 50 \quad (1)$$

Where,

LV: Light intensity value (lux)

V_0: The analog measured voltage (A0 pin)

The esp8266 library for Arduino IDE was used to program the NodeMCU ESP8266, as well as the same equation (equation 1) was used to calculate the light intensity using the LDR that connected to the NodeMCU outside placed.

Finally, a web application was implemented to store real-time data obtained by the sensors. Sensor data are sent to the server as a POST request via NodeMCU. Then the server will store data in a database. Later, it can retrieve them from the database and display via the web interface. It includes information such as temperature level, humidity level, indoor and outdoor light intensity values of the lecture hall and an alert message informing actions to be taken by users. Fig. 6 shows the web interface for the smart classroom system. Also, the web interface suggests opening the curtains of the windows in the lecture hall when the outside light intensity of the lecture hall is greater than the value of 32000lx (this value was found experimentally w.r.t. the chosen lecture hall). The reason is that the inside light intensity will be greater than the threshold value (300lx) after the curtains are open when the outside light intensity is greater than 32000lx. Then, the system automatically turns off the light bulbs in the lecture hall. Therefore, this method can reduce power consumption in the lecture hall.

IV. Results And Discussion

Finally, the smart classroom system was tested in a laboratory at the Sabaragamuwa University of Sri Lanka using four students. In this case, a model of the lecture hall was created in the laboratory and divided it into two areas namely Area 01 and Area 02 with sq. mt. of 4m x 4m each. The testing procedure is explained as follows. In the data acquisition, the testing was conducted 80 times. The number of students in an area is increased by one student at a time and each time the system was tested for 10 times. The same process was repeated for both areas. Fig. 7 shows real-time testing of the smart classroom system performed in the laboratory. Also, the web interface was tested by hosting in the WampServer software (localhost). According to the experiment results, the system was succeeded 75 times out of 80 instances where the accuracy rate was estimated to be 93.75%. The test results of the four cases with different number of students are shown in the TABLE. I.

The main challenge of the designing process was to find a better sensor to detect humans. There are PIR and IR sensors that can be used to detect humans [13]. However, these sensors are failed to response without any human movement. If a person sitting on a chair without a movement, the sensor cannot recognize the person in the area which implies the system is failed to control the electric device. Thus, we used Kinect sensor for system implementation and it was successful according to the results obtained.

The developed smart classroom system will be further improved in near future to monitor the functionality of electrical devices in the lecture hall using current sensors [23]. Using that information administrative team of the university will be able to track the devices which are not working. It will help to maintain process of the electrical system of the university. Another suggestion is to automate the curtains of the windows in the lecture hall based on the outside lighting condition.

TABLE I. Experimental Results For The Smart Classroom System

Condition	***Accuracy (No. of successful outputs/No. of iteration)***	***Accuracy as Percentage (%)***
One student at a time	20/20	100
Two students at a time	18/20	90
Three students at a time	19/20	95
All students at a time	18/20	90
Accuracy of the smart classroom system		***93.75***

V. Conclusions

We introduced an automated system using IoT technology, which can replace the manual switching system in the university lecture hall. This system can control the light bulbs and fans of the lecture hall considering the availability of human and through the access to environmental conditions. Thus, the system can be used to reduce the power wastage and it would be a solution to reduce excessive electricity demand that would be occurred in the future. In addition, this system can be installed easily with the existing manual switching system. According to the estimated value, the system can reduce electricity consumption in the lecture hall by more than 33%. Also, the system was tested in the laboratory environment and the test results were shown that the accuracy was greater than 93%.

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