A System for Classroom Environment Monitoring Using the Internet of Things and Cloud Computing

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Abstract. A classroom environment monitoring system was developed as a demonstration to Computer Science and Information Technology undergraduate students to enhance their learning experience. Monitoring and controlling the classroom environment, including the lighting and temperature levels in real-time was the primary functionality of the system. Using data on the optimal light and temperature setting, the demonstration system was able to monitor and assess the environment to ensure the comfort of the students. The system demonstrated to the students the concepts and practices of the Internet of Things (IoT) and cloud computing can be beneficially applied and to provide services in specific application areas, this time in education, with simple system design and implementation. While such an application is not new in concept or implementation, the important features of similar systems discussed in previous systems related to the classroom environment monitoring were identified and analysed, and the best and most important features incorporated in our system, together with our own ideas, to provide the students with a significant learning experience based on a real application, which we implemented and presented as a prototype. The attributes of our system are discussed, and the success in providing a good learning experience for the students are discussed. We suggest that argue that more research is needed on this topic, and encourage other researchers to participate in the topic.

Keywords: Classroom environment monitoring · Internet of Things · Cloud computing

1 Introduction

Our purpose in this project was to build a prototype system using current technology to demonstrate to students a modern approach to system development, including the significant range of development tools now available within the technological context of the Internet of Things (IoT) and the Cloud. As such it is an exercise in project-based learning, which is an aspect of Teaching and Learning that was considered important to enhance student learning. For our purpose we selected a familiar environment, the classroom, and a useful system type, environment monitoring and control, to ensure the students could see an example of a real world, useful, potentially commercialisable system.

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As students, the classroom is an important place in which they spend a significant amount of their time. It is essential that the classroom environment is conducive to studying and is comfortable and an optimal studying environment is created. As has been noted elsewhere, inappropriate environmental factors, particularly light and temperature levels can reduce students' ability to study [1]. The selection of this system type met all the education criteria we considered important, and therefore, as discussed in [7], an environment monitoring system is entirely appropriate for our educational purposes. Using technology to monitor the indoor environment of buildings has been an application of computing and communication technology for many years, but the quite recent advent of the Cloud and the Internet of Things has provided the opportunity to create more sophisticated systems, and these technologies are now an imperative part of ICT students' learning.

Our project therefore leveraged the combination of these two recent technologies. The Internet of Things or IoT refers to the ability to combine smart objects with the Internet and enable these objects to interact with other objects connected to the Internet [2]. Cloud computing provides on-line computing resources such as storage, operating systems, applications and infrastructure, allowing these resources to be accessed via the Internet [31], importantly without the need for expensive local infrastructure. We investigated previous reported development of similar systems to identify the essential elements of this type of system, and also to identify what aspects of our thinking had not been included. For example, in [4], two aspects which we consider important, measuring of ambient light levels and the availability of comparison data were not mentioned. Our comparison with various other prior studies is discussed more fully in the following Literature Review.

According to [5, 6], the optimal temperature range for studying is between 20°C and 23.33°C and the optimal light levels range between 400 lx and 600 lx, lux being the SI (International system of units) unit which denotes luminous density [10] (also stated as lx). A classroom environment monitoring system should be able to assess the classroom environment as being at these desirable levels and provide a feedback system with constant, or frequent, manipulation of these environmental factors. To simplify our system prototype we did not include this full feedback mechanism, but included a display of the current temperature and light level readings to provide this information to classroom caretakers who could then take action, manually, to adjust the settings. The further development of our system will include this more extensive feedback and control system.

Summary of Contributions: We consider that there are two main aspects to our contribution to the field. First, there is the educational contribution in that we demonstrate the effectiveness and success of our project-based learning approach. The students were introduced to the concept and practice of prototyping as a successful development approach, they were able to gain in-depth knowledge of the contemporary development environment including the Internet of Things and Cloud computing, and the principle of system usefulness was clearly embedded in their learning. As well, the student's knowledge of the marketplace for software development tools was significantly enhanced, and the symbiotic relationship between modern development tools and contemporary development methodologies, such as prototyping, was clearly demonstrated.

We do admit to the possible over-kill in the selection of tools, but this was done to ensure a wide understanding of the marketplace; this was not a commercial development demanding a lean approach. From a technology point of view we have applied these two relatively recent technologies, The Internet of Things and Cloud computing to a previously well understood application thereby enhancing that system type and extending our understanding of the applicability of these technologies, and the advance in development productivity offered by these tools. The proposed system, and the method of development, illustrate how the Internet of Things and Cloud computing benefit applications and services in the education area with simple system design and implementation.

2 Literature Review

2.1 Environment Monitoring Systems, the IoT, and Cloud Computing

An environment monitoring system includes one or more sensors and data storage [7]. To monitor the classroom environment, a system also requires sensors to continuously monitor the environment and send the data to a storage server. The classroom environment is the subject and focus of this paper. The IoT refers to the interconnectivity of smart objects over the Internet. The concept is to enable any smart object connected to the Internet to be able to interact with any other smart object or objects connected to the Internet [2]. In this paper, the smart objects being considered are environment sensors in the classroom which have the ability to connect to the Internet, and which are able to send data of changes in environmental variables (light and temperature level) to a cloud server, regardless of where the classroom is situated. Cloud computing offers computational resources to customers, such as networking, processing, and storage [32]. A server in the cloud allows remote access, and it includes both hardware and system software that can deliver services over the Internet [3]. The cloud can be remotely accessed by any Internet connected device at any time and from any location, and can send and receive data to and from the cloud through the Internet. Many previous work apply the cloud such as in [3]. With the benefits of IoT and the cloud, monitoring the classroom environment by using both is ideal. [8] state that IoT and cloud share their benefits to reduce IoT weaknesses. The IoT has four important problems of reliability, performance, security and privacy. To solve these problems, cloud computing provides at least a partial solution. One reason can be that the cloud has huge storage capacity, processing power and level of reliability. To deal with data generated by the IoT, cloud is the most convenient and cost effective solution to most information processing requirements and solves most of the problems inherent in IoT. This paper exploits the benefits of IoT and cloud, demonstrating ease of use, convenience and power of IoT coupled with cloud.

2.2 The IoT Technologies in Teaching, Learning and Basic Education Management

IoT technology is explored to assess its ability to improve learning, teaching and education management [9]. The application of IoT technology is classified under various headings such as health in education, teacher education, learner support, social mobilization and support services, planning and delivery oversight, quality assessment, inclusive education, curriculum policy, support and monitoring, and administration [9]. In [9] the learner support classification is addressed. It focuses on a climate-controlled classroom environment and lighting factors, as part of learner support. This paper also focuses on the learner support category.

2.3 Previous Works Related to Environment Monitoring

[4] describes a system using the cloud and IoT for monitoring the classroom environment. That system monitors humidity and temperature through sensors and sends the data to Google Drive® which is a cloud computing service provided by Google. This service stores the data as an excel file. Graphs of the data can be generated and presented on a website. The objective of this study was to show a solution by using Google Drive® and the possibility of using it for both data storage and especially for charting. [4] did not discuss the optimum values of the environment or conditions conducive to study. According to [11] the cloud and IoT are technologies that have been used to monitor the saturation line, water levels and possible deformation of dam walls in a tailings dam at a mine site. The system remotely monitors these aspects and creates pre-alarm information automatically and in any kind of weather conditions. [12] used various sensors for detecting and monitoring temperature, humidity and CO2 in an in-door environment. The system changes the colour of displayed pictures if these environmental conditions deteriorate to poor levels. This system did not connect to the cloud network, but used a local server.

The researchers in [13] give an example of using IoT, cloud and Near Field Communication (NFC) to control the environment in a classroom. NFC technology is used with the information being communicated over a radio frequency. The collected data are sent to the Internet and cloud. The outcome of this study is to allow the monitoring of classrooms and to display the status of each classroom graphically. This work did not discuss possible optimum values of environmental conditions conducive to study. [14] used IoT and cloud to monitor air quality of different classrooms at a university. Each classroom had a number of wireless nodes and each node had a number of sensors. This system monitored, stored and analysed the data collected. This work also did not discuss possible optimum values for the environment conducive to study. [15] Investigated the effect of temperature in call centres. Two call centres, each in a different time zone with different weather conditions, were investigated. This work did not involve light level measurement which is also an important factor.

2.4 Features Summarization and Comparison of Previous Systems

Regarding environmental monitoring systems, the appropriate features of some systems described in Sects. 2.1 to 2.3 are summarized. Then we will design and implement our system based on combination of these features, as this enables our proposed system to be applicable in the current situation of emerging technologies (such as IoT) and the meeting of educational needs. These features are as follows. (1) The proposed system should be a monitoring system used to continually receive environment values as agreed by [7], without continually monitoring the environment the environmental values could

Table 1. Comparing table

Topic	(1) Monitoring system	(2) Focusing on the classroom	(3) Using IoT	(4) Incorporating cloud	(5) Measure temperature	(6) Measure light level	(7) Compare data to be suitable for studying
A cloud solution for monitoring classroom environmental conditions in a smart university [4]	/	/	/	/	/	x	x
The IoT and cloud computing based tailings dam monitoring and pre-alarm system in mines [11]	/	x	/	/	x	x	x
The IoT at school and at the CES in Las Vegas [12]	/	/	/	x	/	x	x
An IoT Example: Classrooms Access Control over Near Field Communication [13]	x	/	/	x	x	x	x
Indoor air quality monitoring though software defined infrastructures [14]	/	/	/	/	/	x	x
The effect of air temperature on labour productivity in call centres – a case study [15]	/	x	/	x	/	x	x

not be known in real time. (2) It should focus on a classroom environment to improve student learning because the classroom environment may affect student learning ability as argued by [1]. (3) The system should use IoT to detect environmental values and send the values to the Internet. This should enable the system to easily send the values to a cloud server as agreed by [2]. (4) The system should be incorporated into the cloud server to solve problems of IoT [8] and reduce costs [3]. (5) It should measure the temperature as inappropriate temperature conditions may reduce student learning [1]. (6) The system should measure light levels because unsuitable light levels may reduce student learning [1]. (7) The proposed system should compare the captured temperature and light values to accepted optimal values to ensure that the environment is not too hot or too cold, therefore suitable for studying. Regarding the environmental monitoring systems, Table 1 shows the appropriate features of some systems as described in Sects. 2.1 to 2.3. The notation '/' in the table means that a system applies that particular feature, and 'x' is otherwise. From the table, there is no systems that achieve all these features. Our proposed system aims to meet all the features.

3 Design and Implementation of the Proposed System

3.1 System Architecture of the Proposed System

The proposed system is designed to meet the features described above. Figure 1 illustrates the architecture of the proposed system. There are 4 steps in the figure and each step is in a small circle with a number 1, 2, 3, or 4. Each step can comprise related components. Each component is in a pair of brackets such as (1). The system deploys a light sensor [17] as used by [18–20], in similar research. The system also deploys a temperature sensor [21] to detect temperature levels as used by [22–24] in similar research. The cloud server from [25] is used by researchers and system developers, including IBM, HP, MIT, and etc. The system is connected to a wireless USB adapter [26] for Internet connections. Lastly, Raspberry Pi 2 model B v1.1 which is a small low cost, computer [16] is used to control the sensors, and connected to the Internet via the USB adapter. Pi also has a program for sending data to the cloud server. The cloud has MongoDB [33] which is a free and open source database program.

Step 1, the light sensor (see (1)) and temperature sensor (see (2)) send data of the classroom environment to a Raspberry Pi, see (3). Pi receives the data and sends it to the cloud server (see (5)) through the adapter, see (4). Then, the wireless USB adapter receives the data. Step 2, the adapter forwards the data to the cloud server. Step 3, then the program in the server that received the data stores it in the database. Step 4, when users of the system (see (6), (7)) request a monitoring information webpage, the information can be transferred through HTTP (9) by the cloud server, regardless of the device or operating system; such as a personal computer running Windows (see (6)) or a mobile device running Android or IOS (see (7)).

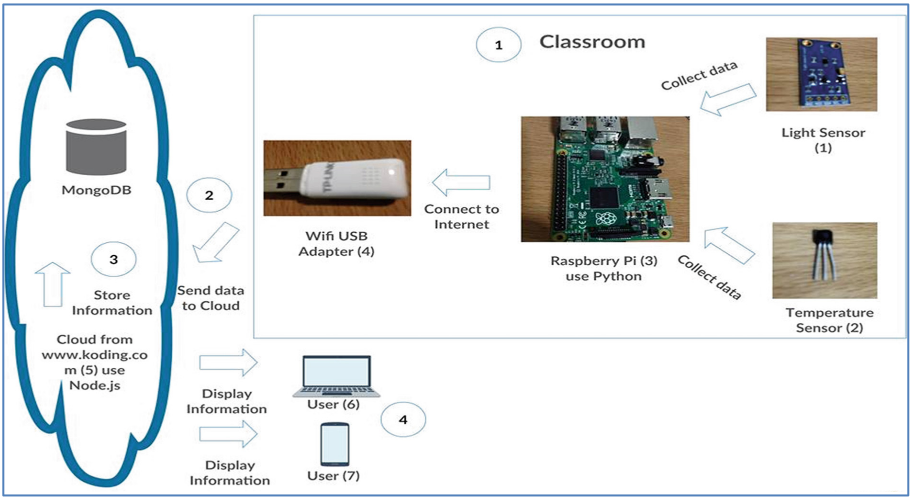

Fig. 1. System architecture

3.2 Implementation

Raspberry Pi is connected with the light and temperature sensors by following the instructions in [29, 30] respectively. A Python program to collect data from the sensors and send the data to the cloud server is created and in Pi. For this program, it is necessary to install Node.js to run JavaScript files and MongoDB program to store captured environmental data. Note that, Node.js is a JavaScript runtime built on Chrome's V8 JavaScript Engine, and is used to create a web server in the cloud server (see (5)) in Fig. 1 Then we create three files as following. (1) Server.js, this file is used to create a server with functions to receive data from Pi and store it to MongoDB. The file also creates a HTTP server to serve the monitoring information website. (2) Index.html, this file allows users to see the structure of the classroom and its monitored information. (3) Function.js, this file is used to receive data from the cloud server and compare it to the optimal ranges. All the files can be found in [34].

4 Research Results and Discussion

4.1 Results

After running the proposed system, there are two main parts to the results, as illustrated in Fig. 2. Firstly, from the figure, A1–D3 represent student tables in a model of a typical classroom. Each table, such as the one labelled 'A1', has its own light and temperature data. Both data can be seen in the figure as 438.33 lx and 29.12°C respectively in the first line text under the labelled text. Again according to [5, 6], the optimal temperature and lighting ranges for study is between 20.00°C–23.33°C and between 400 lx – 600 lx respectively. These ranges are illustrated at the top right of the figure. Thus, A1 table has a 'GOOD' light level and a 'TOO HIGH' temperature level, see in the second line text under the labelled text ‘A1’. In this case, the temperate level is not suitable for study and may reduce student learning according to [1].

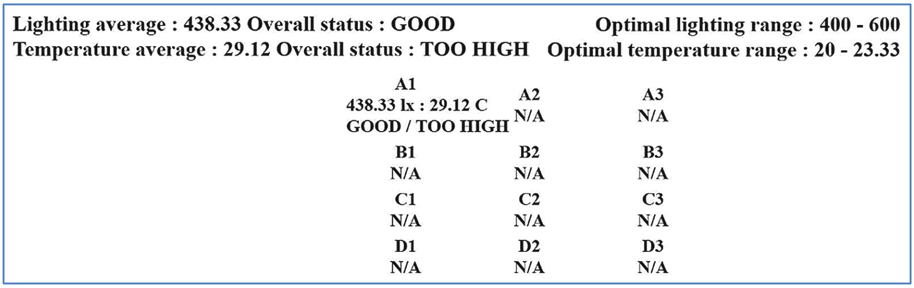

Fig. 2. The results

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Secondly, the summarized information of temperature and light averages and the status of all tables in this classroom can be seen at the two text lines on the top left of Fig. 2. In this case, this information is spurious due to the limitations of equipment and the fact that only table A1 was fitted with sensors in this experiment. Then only the table’s light and temperature level data is taken to calculate the overall averages and status as illustrated on the top left of the figure. Each table of A2–D3 shows the text ‘N/A’. This is because they do not have their own sensors. When all are fitted with appropriate sensors, all the texts will be changed to the correct ones in the same way as table A1. Then, the overall averages and statuses will be given according to the available recorded information. Thus, this information can be used to decide whether the classroom environment is suitable for students to study or not.

4.2 Discussion

Due to the system storing light and temperature level data, the data can be used to calculate the amount of energy consumed. Researchers in [28] studied energy consumption by placing sensors in classrooms to monitor indoor climate conditions. Their system can calculate the energy consumption of this classroom. We could enhance our system based on the guide lines from their research to calculate efficient energy consumption. This could plan an effective energy consumption in classrooms, while theses classrooms are suitable for studying. Due to the system being able to monitor not only light and temperature factors, new sensors can be added to monitor other appropriate factors to improve student learning ability. According to [1], sound can reduce student learning efficiency, also [5] states that acoustic and air quality can reduce student learning. The proposed system can apply to monitor these new environment factors. This can enhance our system to collect all significant environment factors, enable students to study in comfortable and appropriate environment, then increase student learning ability. In Fig. 2, if the system can automatically adjust the temperature and light levels of table A1 to the optimal range for study, the student in A1 position may yield a higher learning ability. Additionally, when a classroom has a table layout that differs from the one in Fig. 2, the proposed system in this paper could apply the new layout. Lastly, we believe this paper can apply to the monitoring of the environment in other types of room such as meeting rooms, based on the rooms' conditions and the appropriate optimal ranges of levels of temperature, light, or, other essential factors.

5 Conclusion and Recommendations

This paper summarizes important features of previous systems used in similar research which can be considered as relating to classroom environmental monitoring. These features are important for applications and services in developing classroom monitoring environment systems. Based on these features, a prototype system was designed and tested. Lastly, we discuss the proposed system and its results in other aspects. For example, the proposed system can achieve all the important features, such as the measuring of light and temperature and the use of a cloud system. Moreover, with further research, the system also can be enhanced to yield more of its abilities such as automatic environment control to reduce energy consumption. The proposed system demonstrates how Internet of Things or IoT and cloud computing could benefit applications and services in education with simple system design and implementation. [27] discuss an air conditioning control system. Based on guide lines of this study, one of the future research directions could be to enable our system to automatically control the monitored classroom environment to be continuously suitable for studying in real time. This same possibility could be extended to other applications such as monitoring the conditions in libraries and meeting rooms.

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