IoT to Enable Remote Collaboration in Robotics Class of Mechanical Engineering Technology

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Abstract

The distance/online robotics classes are currently implemented wildly all over the world due to the pandemic. Robotics classes are the ones that require intensive hands-on practices, especially at the colleges which provide mechanical engineering technology (MET) programs. MET programs mainly focus on hands-on skills instead of theoretical analysis. One of the educational goals in MET is to cultivate future technologists rather than researchers. Unfortunately, the remote classes prevent the students from implementing various experiments. As a result, the remote classes impair the students' deeper understanding of the advanced concepts and theories and make collaborative learning difficult. Therefore, it is necessary to enhance the students' collaboration on the hands-on projects in the remote robotics classes. To do this, the internet of things (IoT) based projects are devised and implemented. These projects are characterized by the usage of the internet, wireless sensor networks, remote control systems, remote collaboration among group members, modular design (modularity), and remote data exchanging protocols. The structures of the robots are designed by computer-aided design software based on modularity, and the designed modules are shared in class among different groups. The remote communication software and apps are provided to the students to facilitate their collaborations. The robots are equipped with sensors that are integrated into the wireless network to enable remote data exchanging. To introduce the proposed practice in detail, a project of a smart robot car based on IoT is taken as an instance. The project used the IoT-ready wireless sensor and actuator framework to enable remote collaboration. After the implementation of the projects, the students can increase the immersive feeling in the remote classes, and then, help them to master the theories, know the usage of the hardware and software, and gain rich experience in robotics.

Keywords: IoT, Robotics, Mechanical Engineering Technology, Framework

1. Introduction

Distance/online learning [1] is becoming an important form at academic institutions, and the growth in distance/online learning has been outpacing the growth of enrollment [2,3,4]. At present, the pandemic has been even further pushing distance/online learning to the peak based on the census from the United States Census Bureau[5]. According to the data of EducationData.org, 98% of the institutions have moved most of the in-person classes to the online sections[6]. From the same source, the parents have many concerns including poor content, little collaborative learning, inconsistent instruction, little to no access to professors and teaching assistants, poor instructor preparation, and limited technical knowledge by professors. As the result, some of the students even decided not to go to the colleges, and the enrollment of the colleges declined significantly, especially, the enrollment of engineering and engineering technology was impacted seriously[7,8].

As one of the important programs, robotics in mechanical engineering technology (MET) mainly focuses on hands-on skills instead of theoretical analysis. One of the educational goals of robotics in MET is to cultivate future technologists rather than researchers. The remote classes prevent the students from implementing various in-person experiments, even though the virtual laboratories[9] have been widely employed. As a result, the remote classes impair the students' deeper understanding of the advanced concepts and theories required by robotics. Besides, as one of the important aspects of robotics class, collaboration on hands-on projects is extremely difficult for the students.

To enable the online learning of robotics classes, there are several types of practices at present. One is to use online learning to teach the coding skill as introduced in reference [10]. The second is to implement the simulation as discussed in reference [11, 12]. The third is to employ the videos to demonstrate the construction of the robots as shown in reference [13]. Certainly, other implementations cannot be covered here. Although all the solutions are contributing to the development of online robotics learning, there is one capability that should be enhanced furtherly: collaborative learning in remote robotics classes. To enhance this capability, a framework of the internet of things (IoT) [14] is employed while using an online learning management system (OLMS) in the following discussion.

2. IoT Framework and Learning Management System to Enable Remote Collaboration

2.1. Practical IoT framework for remote robotics classes

The IoT framework is used in a junior-level robotics class named "Actuators and Sensors Application in Robotics" in the department of MET at the New York City College of Technology in which there are three levels of robotics classes [15,16]. In this class, the students are assumed to learn the applications of popular sensors and actuators and study wireless communication devices and protocols. Then, they can synthesize the knowledge of fundamental STEM, the introduction level of robotics, and design to develop a complicated project. As discussed above, the class mainly focuses on how to understand the theories through practical applications indirectly instead of how to deliver the theories directly. The educational aim specializes in robotics technology to prepare for career-based classes and laboratories. Therefore, the concerns of the class will be the devices and the corresponding applications.

Although there is not a standard definition for IoT, IoT is usually defined as an information architecture to exchange goods and services (things) via the internet. It bridges the gap between the things in the physical world and their corresponding informational representation in the digital world [14]. There are two methods to describe the architecture of the IoT including IoT device architecture that focuses on the hardware and setup of the IoT structure[17], and IoT reference architecture that is used to describe the informational structure [18]. For the robotics classes in MET, the main concern is to learn and practice the usage of sensors and actuators. Therefore, the hardware-based IoT architecture is discussed here. There are four layers in the IoT device architecture [19,20] as shown in Figure 1:

(1) IoT devices. They form the base layer and include any devices that can exchange information via the internet and various protocols, for example, smart sensors, smart actuators, and other smart devices.

(2) IoT gateway. This is the second layer, and also called the aggregation layer that is a device to collect and pass the data between the devices layer and processing engine layer. It defines the rules to aggregate the data. A wireless router can be taken as a simple gateway device.

(3) Processing engine. The most common form of this layer is the IoT cloud that processes the data passed by the aggregation layer, for example, the Arduino IoT cloud [21].

(4) Application layer. The terminal devices include the desktop, laptop, tablet, smartphones, and other consoles that can identify, manage and control the IoT devices via the application interfaces.

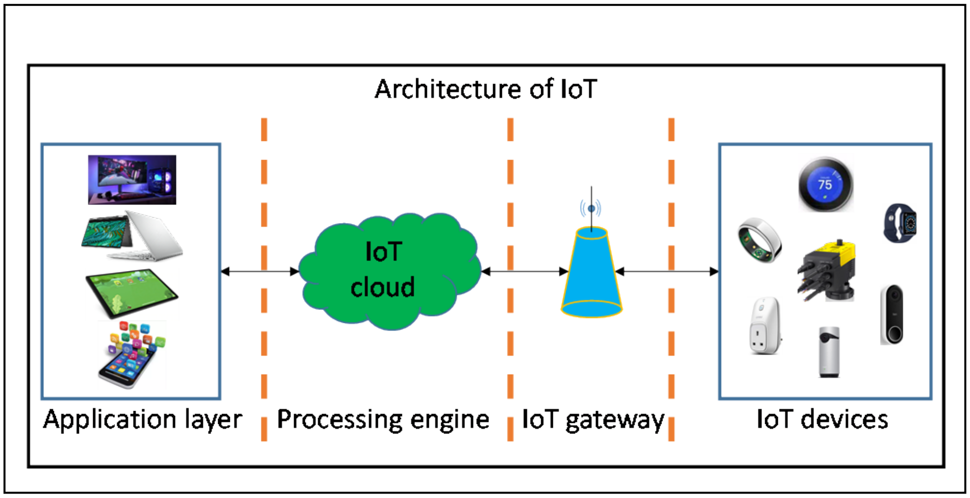

Figure 1: IoT Device Architecture

In an online robotics class, the IoT framework will enable the student to implement their group project collaboratively. Besides, the cost of the materials is one more important concern because the students cannot use the laboratory resources, and the hardware must be prepared by themselves. At the same time, the Arduino sensor development kit has been used in this class for several years[22,23], but the sensors are not smart for the IoT application. So, it is a better way to select a compatible device to convert the sensors into IoT devices. Moreover, most of the cloud for the developers are not free, so, it is necessary to select an IoT could that is free bundled with their products. The Arduino IoT cloud is free if the Arduino IoT devices are employed, so it is selected as the processing engine layer [24]. The selected Arduino IoT device to make the sensors smart is "Arduino Nano 33 IoT"[25]. The wireless router is taken as the IoT gateway to connect the IoT devices and the processing engine. Up to the application layer, the students are required to use the desktop or laptop even though they are also encouraged to use the tablet and smartphone. The IoT framework for the robotics class can be found in Figure 2.

2.2. Usage of an online learning management system

OLMS is commonly referred to as a software application that deals with the administration, tracking, and reporting of training events in an automatic or semiautomatic way [26]. Many LMSs can promote online education, and a list of most of LMSs can be found in reference [27]. The priority of the selection depends on the availability of the LMS. The most common practice is to employ the LMS provided by the colleges or institutions. For the online robotics class, the ideal LMS should enable students to have a virtual meeting, share the videos, initiate group discussions, and deliver the learning contents in real-time. Here, the Blackboard LMS is used in the online robotics class. The Students are allocated into several small groups, and 3 members are in each group. Each group has its discussion board, and they can implement the above activities via the function of collaborating ultra. The arrangement of the group discussion board in one session is shown in Figure 3. When the students work on the group projects, they can communicate and exchange ideas while fabricating the prototype with an IoT framework.

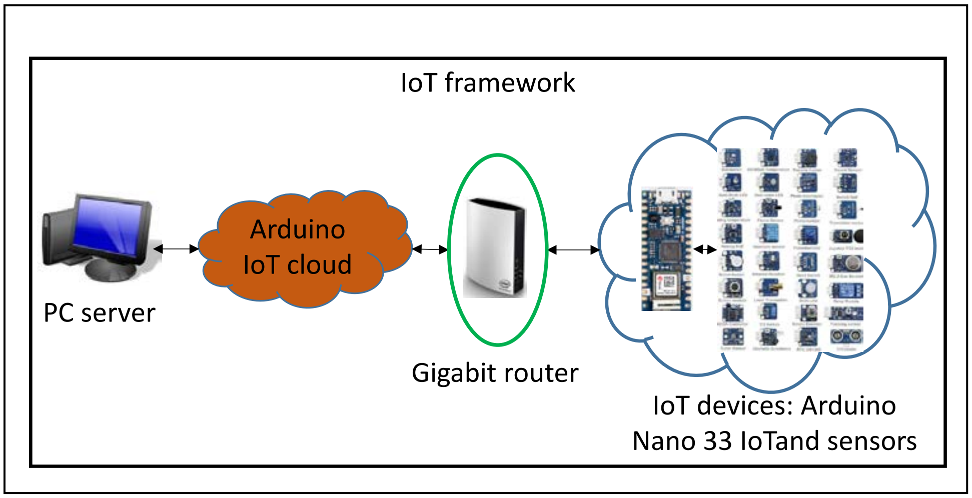

Figure 2: IoT framework for an online robotics class

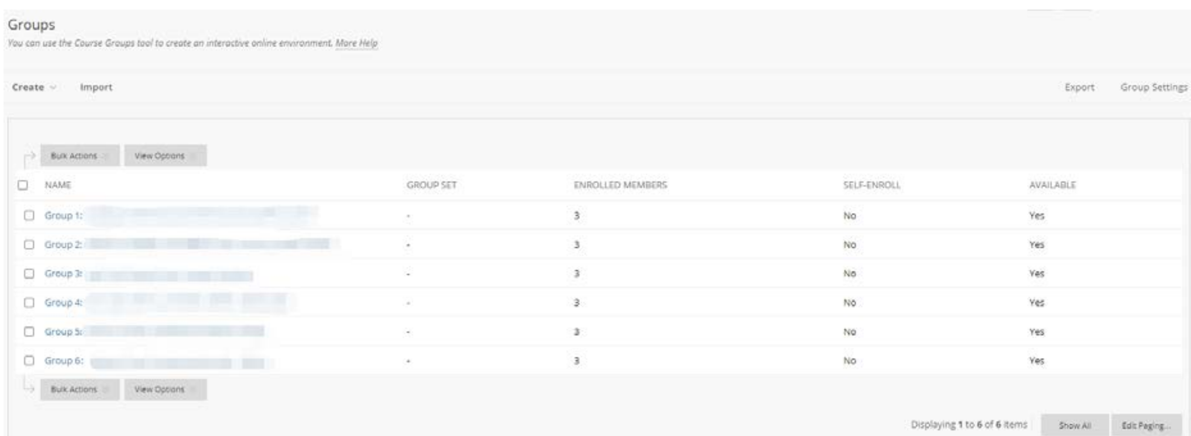

Figure 3: Group discussion board in Blackboard LMS

3. Collaborate on Design of IoT-based Robot Car

3.1. Modular design

Modular design (modularity) is a design principle. The system or product is decomposed into subsystems or parts (modules) that are standard or can be created, modified, manufactured, and replaced in bulk [28]. For the robotics project, a design based on modularity has the potential to increase the efficiency of fabrication, and decrease the cost of manufacturing and assembly. Besides, the modern computer simulation [29, 30] will be helpful to analyze and fabricate the prototype of the project. In the robot car project, the robot can use the ready-to-use models available online including chassis, wheels, joints, and power unit. To furtherly simplify the fabrication of the robot car, a smart robot car kit that includes an Arduino UNO R3 single-board microcontroller and motor shield is selected as the basic prototype of the car (refer to Figure 4)[31].

3.2 Collaborate via IoT framework and OLMS

To use the Arduino IoT cloud, the students are directed to sign up to create since the Arduino IoT cloud is part of the created environment. Then, they need to log in to the Arduino IoT cloud to create a thing (register an Arduino device) in which Arduino Nano 33 IoT is specified and configured. After that, variables can be created for the sensors and events, for example, temperature, luminance, and humidity. Then, the Arduino Nano 33 IoT is connected to the Internet via the wireless router. Finally, they can edit the sketches and create the dashboard for the console of the robot (refer to Figure 5)[32].

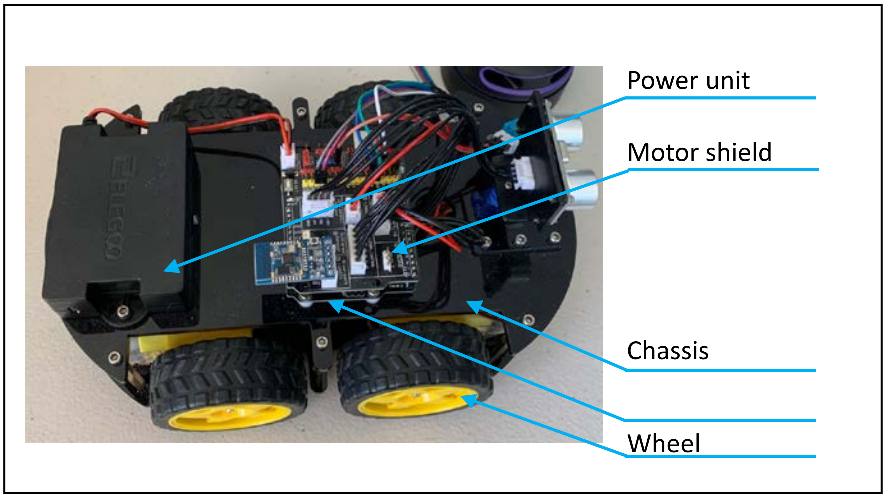

Figure 4: Basic prototype of smart car

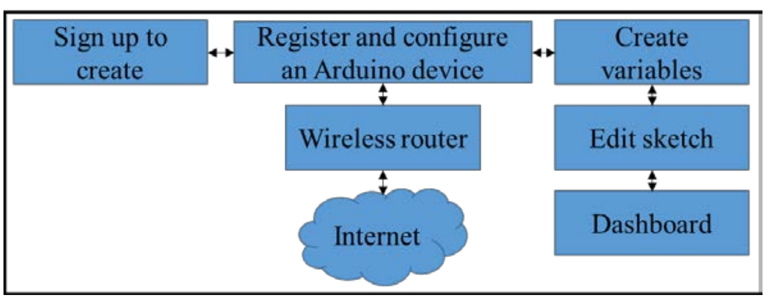

Figure 5: Start with Arduino IoT for robot car

During the implementation, the humidity sensor is connected to the IoT cloud via Arduino Nano 33 IoT. The car is kept by the team leader of a group, and the other two members of the group can edit the sketch via the over-the-air with the Arduino IoT cloud [33]. The leader of the group will share the dashboard in real-time via the collaborate ultra in the blackboard. Then, all group members can practice the usage of the sensors and control the smart car (the design of the smart car be found elsewhere).

3.3 Sample application of project

The humidity in the basement has the potential to endanger the electrical lines and electrical appliances. Hence, one of the groups uses the smart car to make daily patrol around the basement. The car is controlled via the dashboard. The value of humility will be shown in the dashboard and stored. Once the value of the humidity exceeds 70%, the car stops to give a warning sign. The scenes for normal status and abnormal status can be found in Figure 6. The more complicated application of this project is to locate the leaking location by drawing a humidity map.

Figure 6: Scenes of patrol

4. Evaluation and Discussion

This is the first time to open the full online robotics classes at the college. Hitherto, 2 sessions have employed the proposed method. There are 18 students and 20 students in the sessions separately. During the implementation, all the students make every effort to stay in class even though 3 of them were infected by the virus. All the courses are administrated by the instructors who take the responsibility of preparing the experiments. Moreover, a peer assessment mechanism is established to evaluate the performance of the students. This mechanism combines the instructors' evaluation (70%) and the evaluation from other students in the class (30%) to decide the final individual grade.

It is very important to take the students' performances as the standard to evaluate the efficiency of a teaching method. The common students' performances can be divided into two catalogs (1) the improvements in respect to the knowledge and the skills, (2) the students' career prospects. In the project-based courses, the students gradually increase their capabilities by the implementation of group projects. The overall performance of the students is evaluated in five aspects: (1) combine knowledge and information to identify problems, (2) demonstrate an understanding of all the pieces of the problem, (3) formulate strategies to solve narrowly defined problems, (4) find the correct and detailed solutions to the problems, and (5) solve the problems in the midterm and final. 88% of the students can combine knowledge and information to identify problems, 91% of them demonstrate an understanding of all the pieces of the problem, 84% of them can formulate strategies to solve narrowly defined problems, 86% of them can find the correct and detailed solutions to the problems, and 81% of them can solve the problems in the midterm and final (refer to Figure 7).

Besides, a post-class survey (refer to Table 1)was administrated to find out concerns to the poor content, little collaborative learning, inconsistent instruction, little to no access to professors, poor instructor preparation, and limited technical knowledge by professors. The result shows that 11% think that the content is poor, 13% think that the collaborative learning is not enough, 6% think that the instruction is not consistent, 4% think that it is not easy to catch the professors, 3% think that the instructor's preparation is limited, and only 1% think that the professor has limited technical knowledge. This result is extremely brilliant when being compared with the data provided by reference [6] in which "Parents ranked quality of remote instruction students were presently receiving as 5.6 out of 10".

Therefore, the IoT platform combined with the OLMS is helpful for online robotics classes. The students in these classes have demonstrated a similar performance as the ones in the in-person classes. Furthermore, the students can also be well-prepared for the advanced robotics classes and focus on the more sophisticated projects15,16,[34].

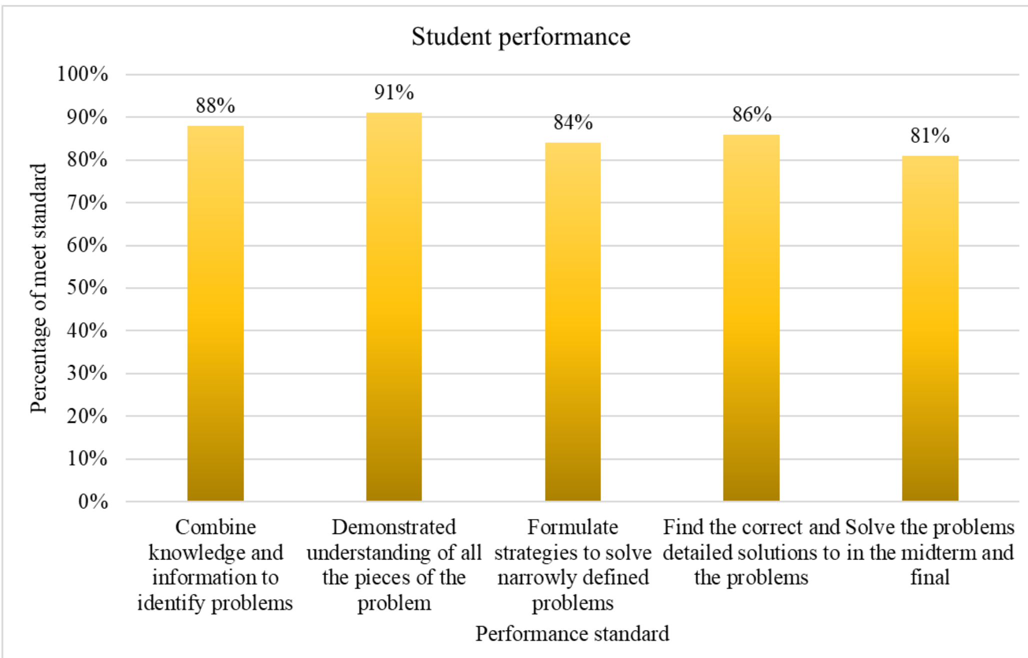

Figure 7: Student performance statistics

Table 1: Post-class survey results

Questions (Answer No or Yes)	Percentage of Yes
Poor content	11%
Limited collaborative learning	13%
Inconsistent instruction	6%
Instructors not available after class	4%
Limited instructor's preparation	3%
Instructor's limited technical knowledge	4.0

5. Conclusions and Future Work

In this paper, how to employ the IoT platform and OLMS to promote the online robotics classes is introduced. This work is a tentative practice for a full online engineering class that is characterized by intensive hands-on projects. To demonstrate the implementation, the usage of IoT platforms and OLMS is discussed firstly. Following that, the collaboration among the members of the project group is narrated. Then, a sample of the projects is demonstrated. Based on the evaluation of the students' performance and the post-class survey, it has been proved that the combination of IoT platforms and OLMS can improve the students' performance in online robotics classes.

In the future, the IoT platform will be furtherly developed by adding other third-party devices, for example, ESP8266, to increase the flexibility of the platform. The cloud can be furtherly developed with the SDK provided by Arduino IoT cloud. The modular used to fabricate the robots will be distributed to the students from the campus uniformly. The sensors and actuators connected to the IoT cloud will be increased. Besides, the IoT cloud usage is still limited due to the limitation of the account type. Hence, it is necessary to upgrade the account to enable more complicated projects and applications.

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