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Work-in-Progress: Internet of Things Enabling Remote Student Learning

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Abstract

With advances in sensor, computing and communication technologies, Internet of Things (IoT) enabled devices are becoming more prevalent. COVID-19 forced many educational institutions to move their courses online, at least temporarily. While this rapid shift in teaching formats impacted all courses, it was especially challenging for lab-based courses in which students require physical access to equipment in order to complete their exercises and assignments. As universities transition back to "normal" instruction formats, many have continued to offer an increased amount of online course content, including lab based courses. IoT technologies can be utilized to enable hands-on learning opportunities for students, especially those who are learning remotely.

To support remote student learning, IoT-based labs have been planned as part of the senior capstone design courses in computer science and electrical engineering at Texas A&M University-Kingsville, a Minority Serving Institution. These planned assignments will utilize a basic IoT learning kit comprised of a Raspberry Pi board (or similar basic processor board) along with a collection of sensors. The kits are available to be checked out to students, especially those who are participating in remote learning. The IoT-based lab topics include an introduction to IoT technology, connecting and reading data from sensors and logging it to a website, and remote access/control to an IoT enabled device via the internet. Utilizing the IoT learning kits, these exercises keep students engaged and involved with hands-on learning. Through this introduction to and experience with applications utilizing IoT devices and technology, students will gain a better understanding of and have the opportunity to integrate IoT technology in their senior capstone design projects.

Introduction

Problem based as well as active learning methods both contribute to maintaining student interest in engineering topics; this can be accomplished through design-based projects or simulations [1]-[7]. Prince defines active learning as "any instructional method that engages the students in the learning process." [1] Many educational institutions were forced to conduct their classes online due to COVID-19, at least at the start of the pandemic. This presented a problem for many instructors to maintain student interest in lab based courses for which students were unable to attend in person. As a result many labs were taught virtually or were simulated. For this reason, development of hands-on hardware-based projects or labs that do not require the students to be in the same location as the instructor would continue to aid in student engagements.

Internet of Things (IoT) enabled devices are becoming more prevalent with advances in IoT technologies and IoT-based devices. Examples of IoT-based sensor applications include temperature sensing[8], health monitoring [9] and building automation [10]-[11], to name a few. With the increase in IoT utilization in industrial and consumer applications, students need practice with IoT and to acquire the skills to design IoT-based applications. IoT related course instruction materials covering IoT concepts, background information, theory, cyber security, examples and projects have been introduced at many institutions [12]-[16].

Senior design capstone courses in computer science and electrical engineering at Texas A&M University-Kingsville were impacted by Covid-19. Teams could not meet in-person to work with lab equipment on campus. Teamwork dynamics and meetings were altered. Many teams had to meet online and determine ways to collaborate on and complete their projects. Other universities experienced similar issues. Covid-19 especially impacted project-based courses that involve teamwork as many students could not meet in person due to restrictions. For instance, Magana *et al.* studied different teaching strategies such as scheduling online teamwork meetings, providing instruction on conflict management for teams or teaching the course in a HyFlex mode [17].

Background

Online teaching of lab-based courses has been shown to not be preferred by students [18]. As the shift to online teaching due to Covid-19 impacted most courses at Texas A&M University-Kingsville and Texas A&M University-Corpus Christi, lab-based courses were especially affected since the students in these courses need to be present in-person to utilize equipment to finish their lab-based exercises and assignments. At many universities, students could not attend labs in-person for at least one semester. In some cases at Texas A&M University-Kingsville, the lab instructor would perform the lab, record pertinent lab data and record/stream a video of the lab being performed. The data from the lab would then be available for students to analyze for the experiment. While allowing students to analyze the instructor's lab data, this did not provide the students with hands-on practical lab skills and experience with the associated equipment. We decided to develop a lab kit that students can borrow to work on lab-based assignments off campus to address this issue.

Raspberry Pi and IoT Assignments

A basic IoT learning kit that uses a Raspberry Pi board (or similar basic processor board) along with a collection of sensors will be utilized for IoT-based applications and projects as part of the senior design capstone courses in computer science and electrical engineering at Texas A&M University-Kingsville. The initial offering of these assignments will be in two senior design courses with a total enrollment of about 30-40 students depending on the semester. Figure 1 illustrates a basic set-up for an IoT-based application. In the figure, the user I/O represents the keyboard, mouse and display. The application block could be for example a motor, light, or a more complex process or application. The IoT-Based Application block may include applications such as temperature sensors, humidity sensors, lighting, door locks or robotics applications. In the figure, each IoT-Based Application block includes an interface to the cloud.

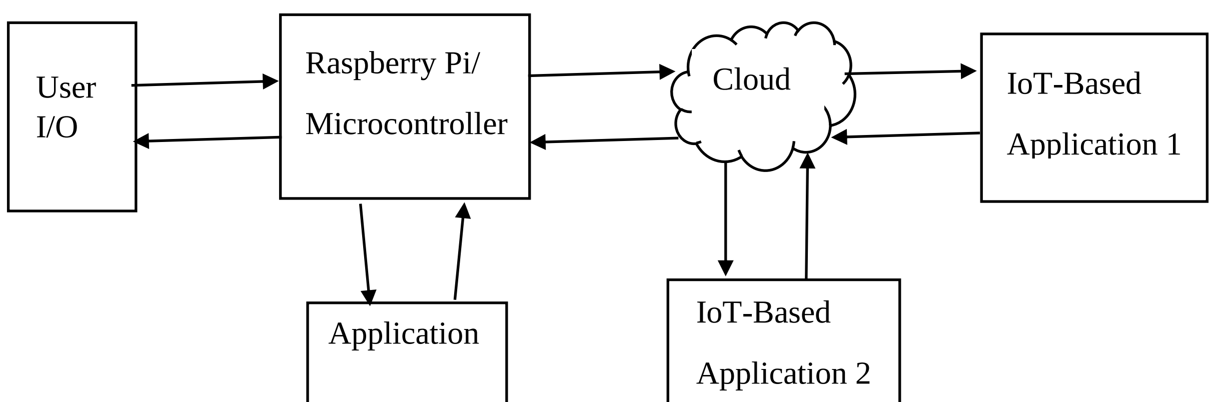


Figure 1 – IoT-Based Applications

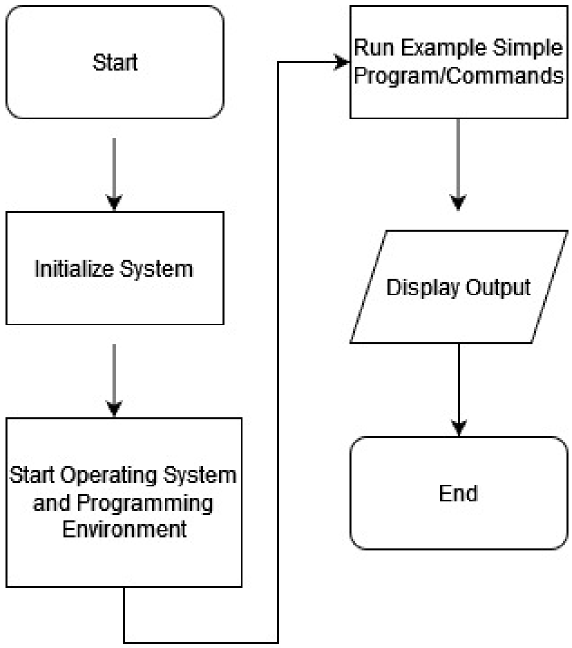
In the past, GEEN 1201 Engineering as a Career class sections offered for freshman students in computer science and electrical engineering at Texas A&M University-Kingsville have included project work with the Raspberry Pi to introduce students to programming using Python for a simple robot guidance system. Course feedback, both formal and anecdotal, indicated that students found the project to be an engaging introduction to programming and the Python language. In this research, IoT instruction materials will be covered in the senior capstone design courses to strengthen the IoT skills and knowledge of the students to facilitate the use of IoT in their senior design capstone projects as part of the funded grant NSF 2044255. In future work, the funded project can also investigate the feasibility of introducing IoT instruction in Sophomore or Junior level courses. As part of the senior design capstone courses in computer science and electrical engineering at Texas A&M University-Kingsville, to introduce students to IoT-based design, the planned Raspberry Pi and IoT-based lab assignments include the following:

1. Introduction to Raspberry Pi,
2. Introduction to IoT technology,
3. Connecting and reading data from sensors,
4. Logging the data to a website, and
5. Remote access/control of an IoT enabled device via the internet.

These five assignments will support students acquiring the skills and knowledge to utilize IoT technology and devices in their senior design capstone projects. Students will be permitted to borrow the IoT kits for the semester. The students then in groups of normally one to three students will perform each of the assignments. After completing an assignment, students will submit lab assignment reports and demo the assignments, in-person or virtually. Students will be asked to complete a survey about IoT after completion of the five assignments to assess their increased knowledge about IoT.

Assignment 1- The students learn how to set up the processor board and to connect all of the peripherals to interface to the board. Python will be utilized as the programming language. Depending on the students in the course, other programming languages such as C could also be utilized as the Raspberry Pi can support many programming languages. Students will write basic programs to learn how to run a Python program on the processor board and display data. Figure 2 illustrates the steps to accomplish assignment 1.

Assignment 2 - Basic IoT technology and concepts are introduced. Parts of the Raspberry Pi system that will support communication over the internet are identified for the student. A simple program to connect to a WiFi network will be tested. To connect to the WiFi a port will need to be opened. The Raspberry Pi will be programmed to scan for WiFi networks to identify the appropriate WiFi network. Next the Raspberry Pi will need to establish a connection to the WiFi network of interest. Then a command such as Ping can be used to communicate with another local host or computer to verify a properly established network connection. Figure 3 builds upon the steps in Figure 2.



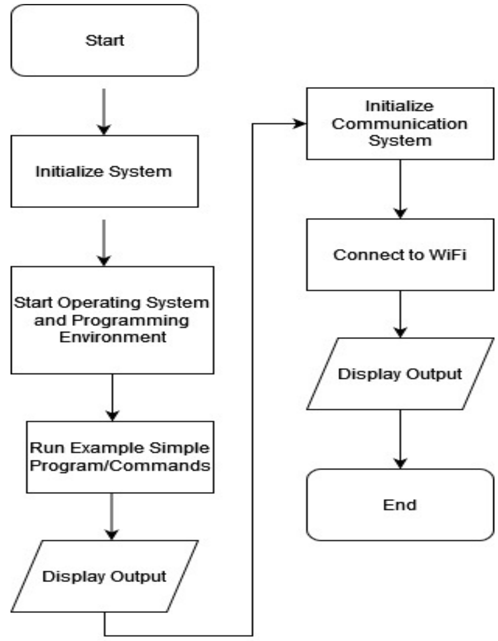


Figure 2 – Flowchart for Assignment 1 - Simple Set Up and Program

Figure 3 – Flowchart for Assignment 2 – Data Display and WiFi Connection

Assignment 3 – A sensor such as a temperature sensor will be connected to the Raspberry Pi. A simple circuit for the sensor will be implemented. An example simple temperature sensor circuit is shown in Figure 4. A DS18B20 could be used as the temperature sensor for this circuit [19]. The Raspberry Pi will take sensor readings over a pin or via a port and store the data locally on the Raspberry Pi. Figure 5 shows the flowchart to complete assignment 3.

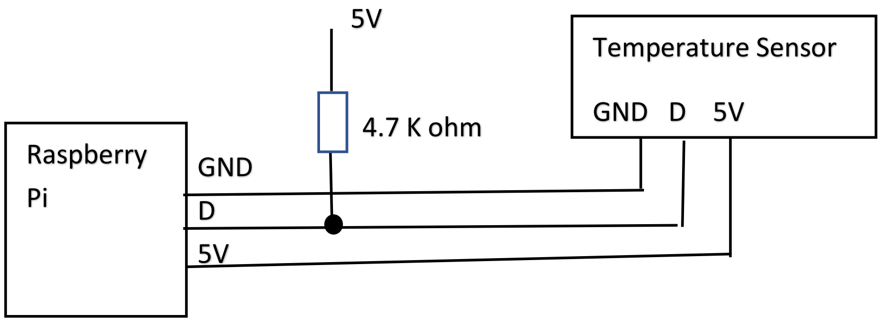


Figure 4 – Simple Temperature Circuit, Based on [19]

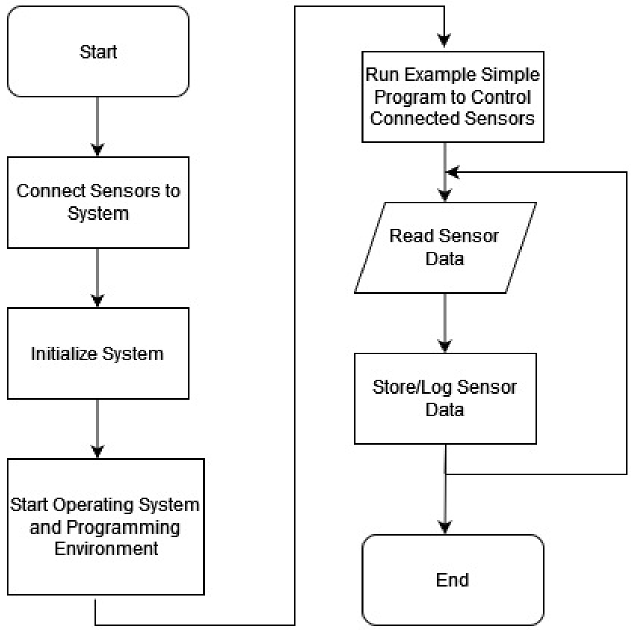


Figure 5 – Flowchart for Assignment 3 – Storing Sensor Data Locally

Assignment 4 – In this assignment, students will connect the processor board to the internet, to the cloud. Students will connect the processor board to a WiFi network. The data obtained from a sensor will be posted to a website and will then be able to be accessed from the cloud. Figure 6 shows the flowchart to complete assignment 4. The sensor data will be stored on the processor board before it is uploaded to a website.

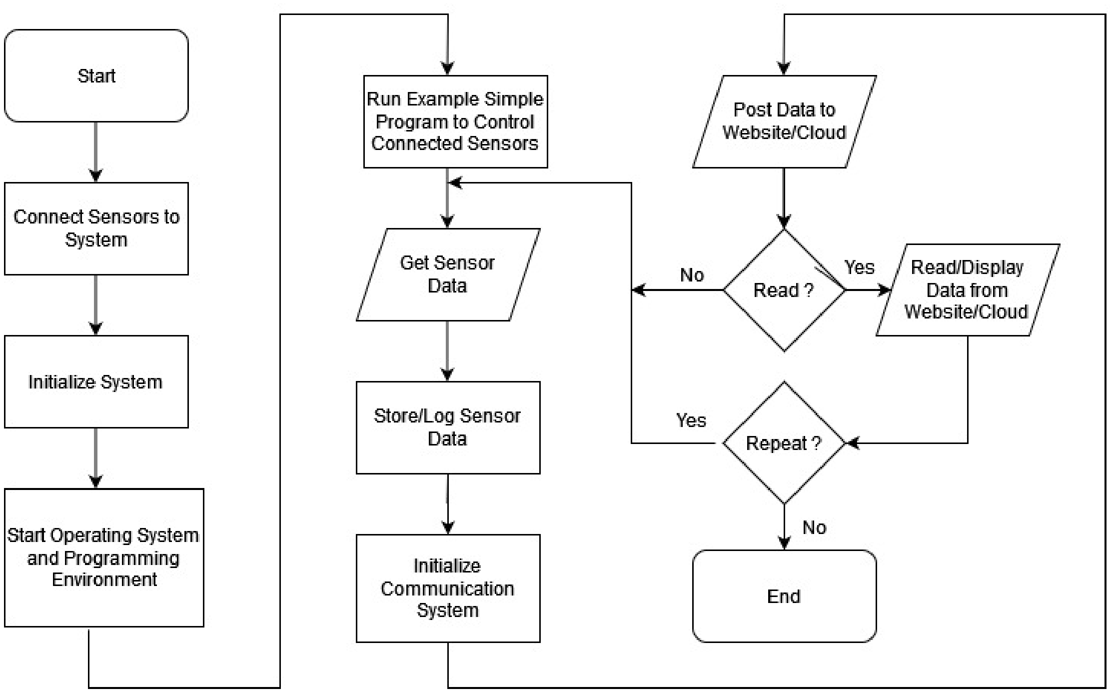


Figure 6 – Flowchart for Assignment 4 – Posting Sensor Data to Cloud

Assignment 5 – Building on the prior assignment and using the obtained sensor data to determine the device control or function, students will control a camera, motor, light or other similar application. The application will be connected to the processor board and the board will be accessed via another processor board or PC over the internet. Figure 7 illustrates the various steps to complete assignment 5. The stored sensor data will be used to determine the control or function to be performed on the IoT-based device or application.

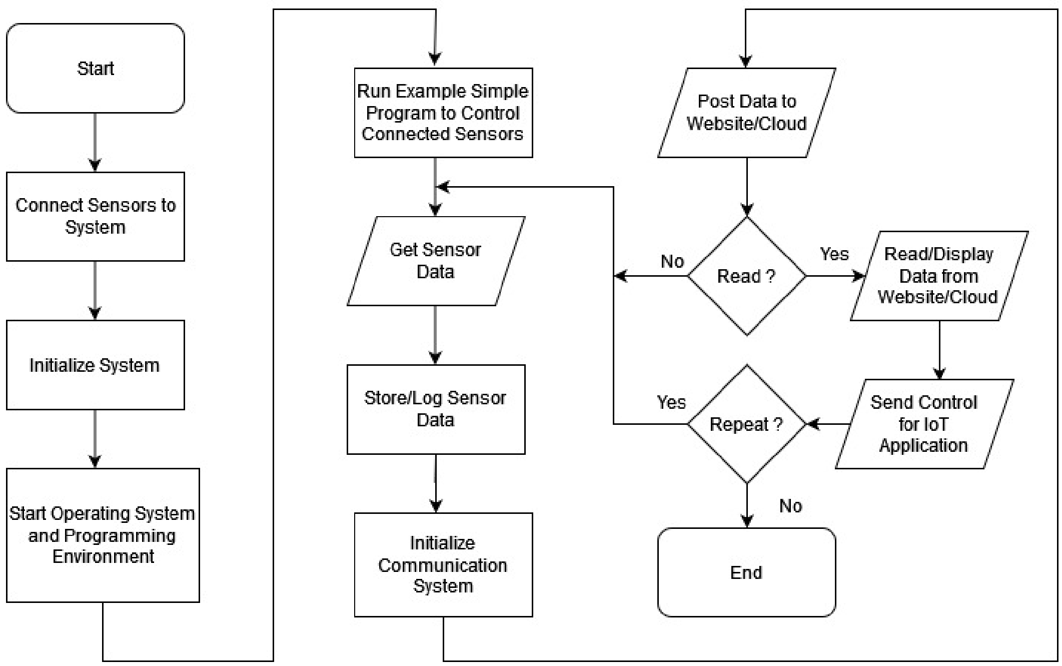


Figure 7 – Flowchart for Assignment 5 – Posting Sensor Data to be Used to Determine Control for IoT-Based Application

With the assignments outlined in Figures 2-7, students can acquire the practice and skills needed to build upon the hands-on lab experience to incorporate the acquired knowledge into their senior design projects or other class projects.

Conclusions

Utilizing the IoT learning kits, will keep students engaged and involved with hands-on learning, especially in cases where the student cannot attend or participate in person in a lab-based course. The planned assignments will aid students with learning the basic knowledge and the steps required to use IoT devices and technology; students will gain a better understanding of and have the opportunity to integrate IoT technology in their senior design capstone projects. Example senior design capstone projects currently using IoT technology at Texas A&M University-Kingsville include a smart irrigation system and a robotic arm application. These projects both build upon the experience and skills one would develop by completing these five assignments. Actively engaging students in the design and testing of IoT-based applications and devices during their courses will further their skill sets and better equip them for working on IoT-based industrial and consumer applications. The assignments can readily be extended to other processor boards and to other courses.

Acknowledgements
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