GNG1103

Technical Report

Deliverable D

[Ella Fossum, 300076269]

[Het Patel, 300143987]

[Hadi Sukkar, 7241905]

[Sandra Michael, 0300142873]

[Bassam Mahdi, 0300041252]

October 8, 2019

University of Ottawa

Introduction

Our team was tasked with creating an automated system to be used in the University of Ottawa's new STEM building using the RossVideo product, Dashboard. The STEM building is host to many different design and entrepreneurial spaces, including MakerSpace. MakerSpace, as well as the other design spaces, are operated by CEED, the Centre for Entrepreneurship and Engineering Design. Based on a meeting and interview with the CEED staff, we determined that they need a system to indicate the availability of 3D printers in MakerSpace.

The automated system would be composed of three main subsystems: the sensor, the microcontroller, and the user interface. After establishing specific design criteria according to the customer's needs, we analyzed and evaluated various types of sensors currently on the market to develop a set of conceptual designs which could be used in our final product. At the very basic level, the user interface would need to be able to clearly indicate whether a 3D printer is in use, idle, or out of order. Our secondary goal is to use the data collected by the sensors to collect data to monitor the machine use over time and help CEED staff keep up with maintenance.

Figure 1: Table of Contents.

1 – The Design

1.1 Subsystem: The Sensor

One of the most integral components of the design will be to determine a method in which a printer can be deemed occupied. Since the printer does not actually need anyone at the station to determine whether the printer is in use or not, it is more sensible to look at the activity of the printer itself to see whether it is in use. The activity of the printer can be tracked using a sensor that can send a signal to a microcontroller which in turn relays the information to a remote user interface to determine whether the printer is in use or not.

1.1.1 Ultrasonic Sensor (Hadi)

To preface this idea, it is important to note how the 3D printer functions when it is and is not printing. When the printer is not doing a job, the arm with the nozzle will not be deployed and the bed upon which the 3D printer creates the 3D object, is lying at the base of the printer. When the printing begins, the bed will move near the top of the printer and the nozzle will begin creating each layer of the 3D object by completing the layer and then moving the bed of the printer down to begin working on the next layer. The 3D printer repeats this process until the job is complete.

One possible design for the sensor is to use an ultrasonic sensor to track the distance from the sensor, which is stationary, to the bed of the printer. The printer that the MakerSpace uses, the Ultimaker 2, has a physical height of 20.5 cm inside the printer. When the printer is not in use, the ultrasonic sensor will detect that an object (the bed) is approximately the full height of the inside of the printer away from the sensor. When the printer is in use, the ultrasonic sensor will be able to detect this as the same object, the bed, will be a shorter distance away from the sensor because the bed will be elevated.

For this design, since the height of the bed is the only variable changing, the sensor would have to be suspended atop the printer. Fortunately, the distance lies within the range of detection of the ultrasonic sensors available to us (which typically go up to half a meter). This solution is also simple and effective. Some sources of interference do exist though, namely if the 3D printer creates enough heat that it changes the temperature of the air in the printer, the speed of sound within the printer can change locally which affects the sensor's mode of detection. Additionally, ultrasonic sensors can accumulate in price since they are $2.00 - 3.00 per sensor. Considering that the MakerSpace has a large number of printers (30+), these sensors will quickly eat up most of our budget.

1.1.2 Contact Sensor (Ella)

The Ultimaker 2 uses a nozzle situated on the top face of the machine to print a project. This nozzle works in conjunction with the bed of the printer; the nozzle moves horizontally on the upper face while the bed moves up and down to create layers. When the printer is idle, the nozzle rests at the rear left corner of the top face. The nozzle is only here when the printer is idle, so determining whether or not the printer is active can be done simply by checking if the nozzle is in the idle position.

A simple solution is to install a small contact sensor to the side of the nozzle on the 3D printer. When the printer is idle, the contact sensor would be touching the side of the printer signaling that the printer is free. When the printer is active, the nozzle moves away from the side of the printer which would cause it to disengage.

This contact sensor could be a simple tact switch, which range from $0.12 - $2.00, or a magnetic reed switch, which range from $4.00 - $7.00. Reed switches are commonly used in home security systems, and notify the homeowner if a door or window is open. These are highly effective devices which are simple to use, but come at a higher price point. Tact switches are much cheaper, but require a greater force on the sensor to cause them to engage or disengage.

The main issue with installing contact sensors into the 3D printers is that they could interfere with the mechanics of the printers. Ultimaker 3D printers are expensive pieces of equipment and we wouldn’t want to risk damaging them or altering their processes at all. In order for the contact sensor to be a viable choice, it needs to collect accurate data without interfering with the functionality of the Ultimaker printers.

1.1.3 Photoresistor sensor (Bassam)

The build plate, or bed, of the printer is one of the most important parts of the Ultimaker 2. As described previously, the position of the bed can be used to determine whether or not the printer is in use.

We can use a photoresistor with a bright light to determine the status of the printer. If a photoresistor is placed on one side of the bed with a bright light placed on the other side, we will have created a sensor that detects the position of the bed. When the bed is at rest and the printer is inactive, the bed will block the light from reaching the photoresistor. When the printer is active however, the bed will lift and the light will shine on our receptor. The presence or absence of light on the sensor will send a signal to our microcontroller to update it on the system’s current status.

This solution may not be an ideal solution, because a photoresistor is very sensitive and may detect interference from other lights. Additionally, installing a photoresistor with a light into the Ultimaker 2 printers might interfere with the expensive printers, and we do not want to risk damage. Thotoresistor and lights will also come out to be roughly around $5.00 to $20.00 per duo, which will not be feasible for our budget.

1.2 Subsystem: The Microcontroller

This is a component of the design that serves as the intermediary between the computer and the sensors. The computer provides the programmable instructions for the microcontroller, and the sensor will send a digital or analog signal with the information required to determine occupancy to the microcontroller. This information can either be sent back to the computer as an output or uploaded via wi-fi or an ethernet cable to an IP server directly. Either way the information should eventually be uploaded to an IP to be interpreted by the Ross Video Dashboard. It should be noted that the type of microcontroller can also be relevant. With more complicated designs a Raspberry Pi would be more effective because it is more robust with an actual operating system. Arduinos on the other hand thrive with simpler designs.

1.2.1 Accessing the Microcontroller Remotely with no Display (Hadi)

This idea involves connecting the microcontroller containing the sensor(s) to a wi-fi module which will then connect to a wi-fi router within the MakerSpace. The microcontroller can then be accessed from an outside computer or phone and can be commanded instructions from there. This holds the benefit of requiring no wiring from the microcontrollers to a computer (or display). This makes the design much simpler and inexpensive which is essential since the Wi-fi modules are approximately $3-4 each.

Unfortunately there are also repercussions to this kind of design. Such a design will require port forwarding, which means forwarding all traffic to a certain port on the router to the IP address of the microcontroller. This can be a security vulnerability to the router.

1.2.2 Ethernet Shield and Cable to Create a Web Server (Hadi)

This solution will make use of an Arduino Wiznet Ethernet shield and an ethernet cable to create a web server that will be capable of posting the inputs provided by the sensor (s) into a web server that can then be taken by Ross Video Dashboard to be utilized for the User Interface.

In this set-up the ethernet shield will be connected via an ethernet cable to a router and the microcontroller will be provided instructions that comply with the network settings so as to be capable of generating a web address. This web address can then directly be taken by Ross Video Dashboard.

This solution carries the unfortunate penalty of being fairly expensive. The lowest noted price of the Wiznet Ethernet Shield is $18 and this will be required for each microcontroller. It is also clunky because having a cable originating from each microcontroller can make the microcontrollers difficult to maneuver if the 3D printers are moved around the MakerSpace.

Ethernet however, is generally a better solution than wi-fi in terms of quality because it is typically faster and less prone to interference making it more reliable.

1.2.3 Saving the Sensor Data to a File or Database (Hadi)

This solution involves taking the inputs from the microcontroller, sending them to a display and saving it to a file or database, and then output the data via web server.

This solution is significantly more complex because it involves connecting all the microcontrollers to a processor, storing the information, and then uploading the stored information to a web server. Connecting the microcontrollers to a processor is a difficult task which involves a lot of wiring going from each microcontroller to each processor. Since we want to minimize the number of processors, we will also have to use a port to bring the microcontrollers together before connecting them to the processor.

There is a lot of wiring that has to go from all the microcontrollers to a USB port hub to condense together the number of USBs going to the display. These ports can be expensive, with the cheapest options generally being around $15 for 4 ports. Additionally each USB adapter cable is around $5-10. The wiring also makes this solution fairly clunky and difficult to maneuver.

Despite all the complexity and cost in this solution, it will be the most powerful, reliable, and secure option. A web server generated from a computer will have more capabilities in terms of how we can manipulate it and how many users can access the server at once.

1.3 Subsystem: The User Interface

One of the main design criteria is that our team must develop a system that uses the RossVideo product Dashboard. Dashboard will be a useful tool to create a visually pleasing, easy to navigate user interface to display the data collected by our sensors. Our user interface will include the following features: a visual system to indicate the status of each printer in the MakerLab, a tally indicating the total number of printers currently available and in use, an indication of which printers may be out of order, a refresh button to allow users to see the most recent updates, timers to indicate the length of time that each active printer has been in use, and a timer to indicate the time remaining in the day.

1.3.1 Interactive Map (Het)

The client meeting made it evident that CEED staff often encounter users who are unaware of the hours of operation of MakerSpace or who are unable to locate the specific machine they want to use. This problem could be solved by an interactive map which can give out information to 3D printer users.

The goal is to make the user’s interaction with the space and our product as simple and as efficient as possible. An interactive map will help users seek necessary information about which 3D printers are in use or available, and how much time is left in the day for them to access the 3D printer library. This information will help students make quick educated decisions without any confusion or need to ask CEED staff.

Since the interactive map would be a stationary screen positioned in the lobby of STEM, it is cannot be accessed remotely. This problem means that the map is not a feasible solution; the map would be positioned in the STEM building already, so it does not save time for the users, who could take a few extra steps to look inside the MakerSpace themselves.

1.3.2 Mobile App (Ella & Het)

An app is a simple interface that displays data in a user-friendly way. This UI is extremely convenient since it can be accessed using one's mobile phone. If we were able to upload the data to an app, this would provide a simple solution which effectively displays the necessary information.

Mobile apps do however present their own set of problems which make them attractive as possible UI solutions. Apps are more difficult to develop, and getting information from our microcontroller to the app would be a challenge as well. We are also required to use Dashboard, which would not lend itself well to a mobile app.

Ultimately, we want to create a product which is accessible to all users of the MakerSpace and we have determined that a mobile app will not suffice. The app would need to work on a variety of mobile phones, including iOS and android, and this would be a challenge to develop. We also need to consider that all MakerSpace users may not have access to a mobile device, which would inhibit them from making use of our product

1.3.3 Website (Sandra)

A common inconvenience that users often encounter is physically getting themselves to CEED in order to work on their project, but not finding any available 3D printers. One possible user interface that would help reduce this inconvenience is having a website which could indicate which printers are being used, how long they have been active, and which printers are idle.

The ideal user interface that addresses all these issues is a website. In fact, a website is clear, efficient, and easy to access remotely. If students or other users of Makerspace want to verify which 3D printer in Makerspace is currently being used before leaving their residence, they could look at the website and get informed. This method of interface could be convenient for them since it would prevent unnecessary traveling and help them better manage their time. It would also be very compatible with Dashboard and would be able to support a multitude of features.

Conclusion

Our goal is to create an automated system which can be used in Makerspace to remotely inform 3D printer users whether a printer is available for them to use or not.

Our final product will consist of three main components: the sensor, the microcontroller, and the user interface. We analyzed many designs for each of these subsystems and weighed them on their cost and functionality.

We determined that the contact sensor would be the best option for the first subsection since it is easy to install, simple to troubleshoot with, and cheap enough to be installed into every printer in the MakerSpace. For the microcontroller, we have chosen to use Wifi to relay the information since it is the cheapest option which also takes up less room in the MakerSpace. The website was the clear winner when it came to choosing a platform for our user interface. The simplicity, accessibility and strong capability to connect to our microcontroller set it apart from the more flashy mobile app.

We have ultimately determined that the combination of these three subsystems will provide us with a product that answers our customers needs and that will greatly improve the MakerSpace as a whole.

References

- “IP Address.” *IP Address - Raspberry Pi Documentation*, Raspberry Pi, www.raspberrypi.org/documentation/remote-access/ip-address.md.
- M., S. “WebServer.” *Arduino*, Arduino, 7 Sept. 2018, www.arduino.cc/en/Tutorial/WebServer.
- “Ultimaker 2 User Manual.” Ultimaker, 7 Nov. 2015.
- “3D Printer Bed – How to Choose the Right Build Plate.” *All3DP*, 14 Jan. 2019, all3dp.com/2/3d-printer-bed-how-to-choose-the-right-build-plate/.