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Electronic Office Signage Device

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Student Paper: Electronic Office Signage Device

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Introduction

The objective of this capstone is to communicate a professor's status outside of their office to students and other faculty members. Students will arrive at a professor's office to find that professor missing or busy for an unknown reason and an unknown amount of time. Our design will allow for a professor to display their whereabouts, thus alleviating the issue. The display must be readable and fit within the constraining area of their office window. Other portions of product design such as charge frequency and energy requirements were also factored into the decision matrix.

Competitors to this product include what is currently being used by our clients: sticky notes, whiteboards, and papers to convey messages about the professor's whereabouts. Other competition includes existing electronic signage and streaming devices such as Chromeboxes and Extron devices. This product will comply with wireless and electrical safety standards, varying based on the solution. Stakeholders in this project include the professors at the university, students or other persons wishing to seek a professor in their office, and the Information Technology (IT) department for integration with existing infrastructure.

The proposed solution for our project is Solution B consisting of a E-paper 6-inch display with Multi-color performance. The main power source for this prototype is the Mini Solar Panels attached to the exterior connecting to the Arduino Nano 33 IoT Microprocessor to control the display. The device will pull updates from a web server that are set and configured by the user through a website and/or a mobile app.

Our device would be usable in any space that has a window by or in the door that the device fits in. Source code for our device and hardware design files will be made available upon the completion of the project. Initial development will involve prototyping materials, such as development boards and 3D printed enclosures. The inclusion of all these components will lead to better manufacturability.

Objective and Motivation

This project is intended to create an innovative electronic medium for use by university faculty members to communicate their current task or advertise their location to students seeking to visit the faculty member outside of office hours. Our project will provide a way for Professors to reduce student interruptions during online meetings and help students by letting them know why their professor is not currently in their office during a time they may normally be in their office.

Our project will improve communication between professors and students wishing to visit them. The project deliverable will allow professors to more easily inform students of their schedule, if they are out of their office, and when they will be available. This will allow professors to more easily help their students with classes or with questions, and the students will have an easier time having access to their professor. But why a sign at all? Why not an application that can be hosted on a mobile device? Students may not check an app if they are conveniently nearby to the faculty member's office. Additionally, faculty members often leave phones in their offices, preventing them from setting their status or checking the status of other faculty members they may be trying to meet with.

We performed a survey to gather information relating to features the system would require for faculty members to utilize the system. We have summarized the results of this survey in figure 1. From these survey results, we derived the customer requirements that were used to detail our constraints, generate our assumptions, and detail our designs.

Customer Requirement	Description
1	Faculty members need a device to display their location and status to students that can be updated easily. This device needs to have a readable display, be electronic, and must be easy to configure and use.
2	Faculty members need a way to remotely update the displayed messages on the device for situations where they cannot physically interact with the device. This can mean updating the display through a mobile app, or through a web interface.
3	Faculty members prefer a wireless device, meaning no external wires can be exiting the device as they may pose safety risks.
4	Of the faculty members surveyed, 74% said they would be more likely than not to configure the device using a touch screen. This touch screen may include a mobile app to configure the device or a touch screen mechanism on the device itself.
5	66% of our survey respondents said that they would prefer a color display over a black and white display. This would allow for more customizability options to place in the hands of the users.
6	Our survey revealed that 58% of respondents felt that a display size of 6 inches was necessary for the device. This means customers would like a reasonable large enough viewing area to be able to see from a reasonable distance.
7	75% of our respondents felt that an E-Paper display would be the best fit for this device. The epaper display is designed to appear like a piece of paper. It does not have a backlight, reducing the power consumption when compared to an LCD display.
8	Our survey showed that 75% of faculty members would be willing to change batteries on the device at a rate greater than once per month. This indicates that if a device needed to be changed any more frequently than a month, the value of that device to clients would be greatly reduced.
9	When given the option to select multiple choices, 58% of our surveyed faculty wanted to configure the device using a website. Additionally, 50% of those surveyed said they would want to configure the device using a mobile app.
10	Faculty want to be able to display custom messages regarding assignments, current status and location, and their next availability. Additionally, faculty members want the ability to utilize preset messages.
11	For customizability, 63% of survey participants wanted some form of basic image support and 54% of respondents wants the ability to alter the layout of the displayed messages.
12	Faculty would like an option to have the board automatically display a set schedule, such as when professors are teaching semester classes.
13	Device needs to be affordable for the university.

FIGURE 1. SURVEY RESULTS FOR CUSTOMER REQUIREMENTS

Constraints and Evaluation Metrics

In order to finalize the proper solution, a list of constraints was created to gauge the solutions against one another. These constraints will be used in a decision matrix to decide the most effective solution that aligns with the customers' requirements.

The first constraint is the device must have a display that is readable from at least a 3-foot viewing distance. This will allow the display to be readable from a reasonable distance, while being large enough to display appropriate information. This addresses the first customer requirement of needing to have a readable display, which we have interpreted as having a sufficiently large display, explained in another identified constraint. The second constraint is the user must be able to make changes to display from an external device anywhere on campus. If a faculty member is away from their office, this allows them to let students know why without having to physically visit their office first. This constraint addresses other details from the first customer requirement, namely the need to be able to configure and change the device remotely. This also addresses the second requirement, allowing faculty to modify the device when they cannot physically interact with it.

The third constraint is the device must not have any hanging wires. If outlets or ethernet ports are far from the window, wires could make it difficult to navigate and create possible safety risks. This directly addresses the third customer requirement, putting the safety of users first. The fourth constraint is the display does not have to be touch enabled. Because the device can be configured remotely through a web or mobile interface, a touch screen display on the device itself is not necessary. This constraint touches on the remote configurability of the device shown in the second customer requirement, by highlighting that as a priority over local configuration of the device through a touch screen on the device itself. Additionally, the fourth customer requirement is addressed, as our survey results revealed that 74% of those surveyed would want to be able to configure the device using a touch screen. Our constraint derived from the fourth customer requirement that the remote configurability option with the desire to use a touch screen would dictate development of an application for mobile devices.

The fifth constraint is the display should have at least one color (in addition to black and white). Extra color allows for more customizability and readability. This constraint derived from the fifth customer requirement, in which 66% of our survey respondents indicated that they would prefer multiple colors, or at least more than just monochrome colors, when using this device. The sixth constraint is that the diagonal length of the display must be at least 6 inches. This will allow the display to be viewed from a reasonable distance. Students should be able to glance at the message from a few feet away given the building environment. In addition to the first constraint, this constraint addresses the first customer requirement relating to readability. We identified the need for a larger display for the device based on this first customer requirement. This was supported by our survey results which indicated that 58% of those surveyed would require a display size of at least 6 inches.

The seventh constraint is that the device must utilize an epaper display. An e-paper design avoids glare from the building, is extremely low power, and is incredibly readable. From the survey, 75% of our respondents indicated that an e-paper display would be preferred over an LCD display. This constraint addresses that identified customer requirement, in addition to addressing readability from the first customer requirement through reduced glare. The eighth constraint is the period between maintenance must be a minimum of one month. The device should keep usability in mind. Needing to change a battery or charge the device at a high frequency will result in a poor user experience for both faculty and students. This constraint was identified from several customer requirements, in addition to the eighth customer requirement. From the survey, 75% of respondents did not want to change the batteries on the device more frequently than a month. Additionally, the need for an e-paper display that is sufficiently visible indicated the need for a low power consumption design.

The ninth constraint is to have at least one method to configure the display, either through a mobile application or web application. This will allow the faculty member to let students know of status while outside of the office. Either a mobile application or web application would achieve this task. This was derived from the first and second customer requirement, indicating the need for remote configuration options. Additionally, this constraint addresses the ninth constraint, as the survey showed that 58% of those surveyed would want to configure the device through a website and 50% of those respondents would want to configure the device using a mobile app. The tenth constraint is that the software needs to display custom messages set by the user, with preset messages also being an option. This offers more customizability allowing a faculty member to give specific reasons for their absence, including their class schedule. This constraint resonates with the first customer requirement in regards to the ease of use for the faculty member. This also addresses the survey result showing that faculty members want to be able to set custom messages addressing various possible conditions, which may exceed a set of preset messages.

The eleventh constraint is that the software allows for the display of a basic pixel image. An image can act as a helpful visual aid for the faculty member's status. This addresses the survey result showing that 63% of those that were surveyed wanted a method to display basic images with the device. This feature may also grab the attention of students passing by, addressing the readability from the first customer requirement. The twelfth constraint is that the software must allow for display layout customization. Altering the layout of the messages displayed will offer more customizability and could possibly improve readability. This addresses the first customer requirement, as well as giving the 54% of those that were surveyed the ability to customize the layout of the display.

The thirteenth constraint is to allow for simple automation. Simple automation will allow the faculty member to display where they are and their availability without them needing to change the sign's message by hand. The faculty member will do this by queuing up messages to display on a schedule. This will improve ease of use and improve quality of life for the users. The fourteenth constraint that was identified was price. When compared to our competition, the goal is to have a cheaper product without sacrificing quality.

Our evaluation metrics were derived from how well our alternative solutions met the constraints. A solution may have a display that is less readable from a distance than other displays, indicating that it would not be a successful solution in that measure. Because of the number of our constraints, a solution may redeem itself when other constraints are considered. While we did consider price in our constraints, the weight for that constraint was less due to the importance of the other constraints in regard to the number of customer requirements that were met.

Tools and Stakeholders

The tools that we have used to begin solutions for this product have come from a majority of our classes. Examples of this span from knowledge of circuit diagrams to applying the methods learned from user interface design, and even to some of the general education classes like cost benefit analysis from accounting. Outside of our classes, however, there are various tools that will also be leveraged to assist with the completion of this project. For example, utilization of Hypervisor tools, such as VMWare Workstation, will be necessary when developing the backend environment for the system. This would allow us to create images that can be distributed to clients of our system.

The stakeholders for this project would mostly be the professors of the university. The professors will be the main users of the device seeing that they will be placed inside the professors' offices. Another stakeholder of the device would be the students/visitors to the office as the sign is designed to communicate if the professor is available or not and where to find them. The visitors should be able to read and understand from this sign how to contact the professor. Additional stakeholders include the university IT department should our users want us to integrate certain functions of the box with existing IT infrastructure. Our metrics for IT will be substantially different from those for students, as IT will need metrics relating to network and compute resources while students and visitors will be more interested in visual aesthetic and appearance.

Potential Solutions

Solution A:
Solution A consists of a E-paper 6-inch display with monotone colors. The main power source for this prototype is the Mini Solar Panels attached to the exterior with rechargeable batteries as a backup supply. The ESP32 microcontroller will control the display. The device will pull updates from a web server that are set and configured by the user through a website and/or a mobile app.

Solution B:
Solution B consists of a E-paper 6-inch display with Multi-color performance. The main power source for this prototype is the Mini Solar Panels attached to the exterior connecting to the Arduino Nano 33 IoT Microprocessor to control the display. The device will pull updates from a web server that are set and configured by the user through a website and/or a mobile app.

Solution C:
Solution C consists of a LCD 6-inch display with Multi-color performance. The main power source for this prototype is the Mini Solar Panels attached to the exterior connecting to the Raspberry Pi 4 Microprocessor to control the display. The solar panels will be split between 3 to power the processor, and 2 to charge the batteries. The device will pull updates from a web server that are set and configured by the user through a website and/or a mobile ap.

Solution D:
Solution D is a paper sign with the indications of locations and a pointer to locations to inform students where the professor is. This is the current solution to the problem and is not electronic at all.

Proposed Solution:

Based on our decision matrix, as shown in figure 5, solution B best fits our constraints. Solution B consists of a 6-inch, multi-color epaper display and an Arduino Nano 33 IoT microprocessor. The power for the device will come from both a solar panel, as well as a rechargeable battery as a power backup. The user of the device will use either a mobile or web app to enter the desired message to be displayed. that information will then be sent to a web server. From the web server, the device will pull updates at a regular interval, and be in a low power state when in between the interval triggers. The detailed functional decomposition of our design can be found in figure 2.

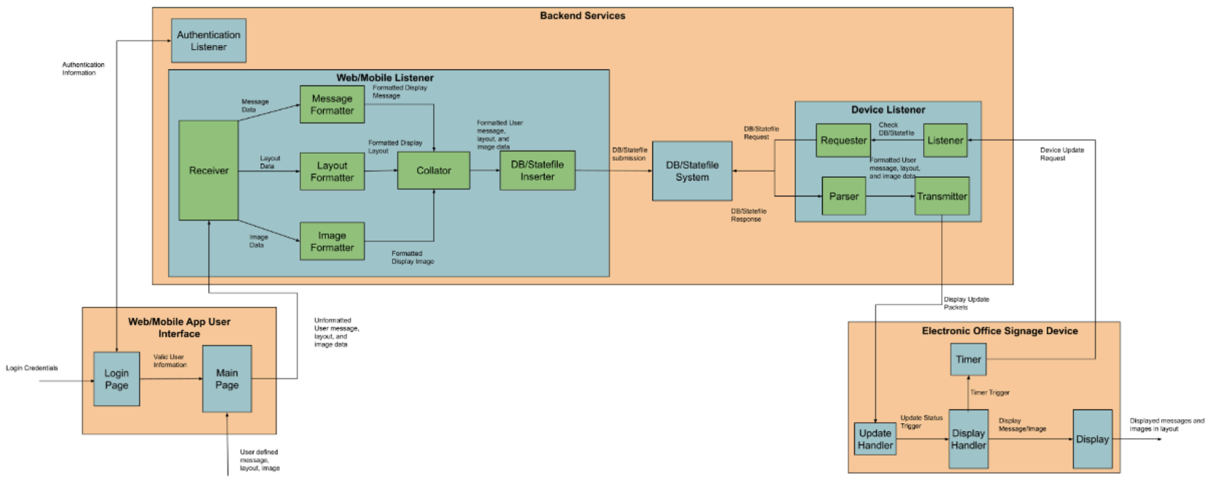

FIGURE 2. FUNCTIONAL DECOMPOSITION

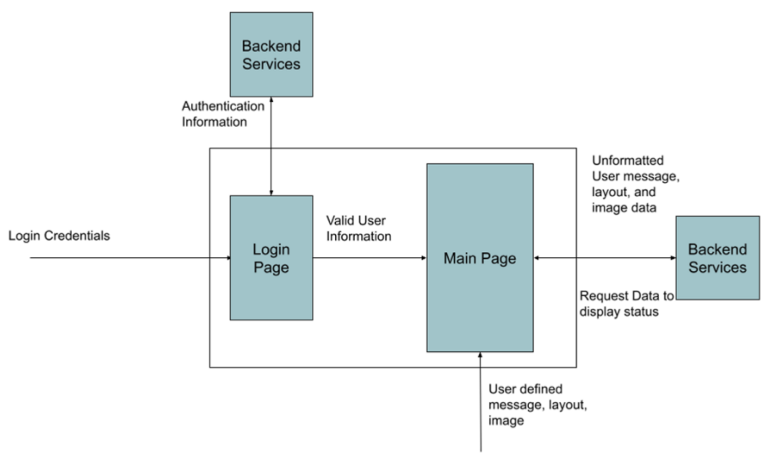

FIGURE 3. WEB/MOBILE APP USER INTERFACE

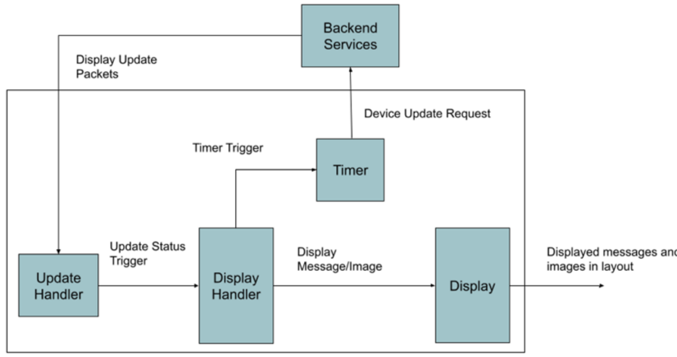

FIGURE 4. ELECTRONIC OFFICE SIGNAGE DEVICE

Criteria	Weighing Factor	Solution A (Low Power)		Solution B (Mid Tier MultiColor)		Solution C (High Power/Performance)		Solution D (No Solution)	
		Rating	Score	Rating	Score	Rating	Score	Rating	Score
Constraint 1	9	1	9	1	9	1	9	1	9
Constraint 2	9	1	9	1	9	1	9	0	0
Constraint 3	9	1	9	1	9	1	9	1	9
Constraint 4	4	1	4	1	4	1	4	0	0
Constraint 5	7	0	0	0.8	5.6	1	7	1	7
Constraint 6	9	1	9	1	9	1	9	0	0
Constraint 7	7	1	7	1	7	0	0	0	0
Constraint 8	9	1	9	0.5	4.5	0	0	0	0
Constraint 9	7	1	7	1	7	1	7	0	0
Constraint 10	7	1	7	1	7	1	7	0	0
Constraint 11	7	0.5	3.5	0.8	5.6	1	7	1	7
Constraint 12	4	1	4	1	4	1	4	1	4
Constraint 13	4	0.5	2	0.5	2	1	4	0	0
Constraint 14	8	0.6	4.8	0.4	3.2	0.5	4	1	8
Totals:	100		84.3		85.9		80		44

FIGURE 5. DECISION MATRIX

Budget

Based on figure 5, the price for a singular unit of our accepted unit is roughly $132 (breakdown in figure 6). Based on our client base and the ability to change our product based on their feedback, the group has decided to make 5 units for this project. These predictions mean that the final budget for all five units will be $725 to allow a little bit of wiggle room to allow for any unpredicted outcomes.

Single Unit Solution BoM		
Component	**Quantity**	**Price per unit (Price estimates)**
Microcontroller	1	$19
Display	1	$63
3D Printer Filament (Kilograms)	1	$25
Solar Panels	5	$8
Batteries	4	$17
Total	12	$132

FIGURE 6. BUDGET FOR A SINGLE UNIT

The microprocessor, display, solar panels, and batteries are currently pre-manufactured. The outer enclosure of the device will be modeled, and 3D printed in-house to increase manufacturability and to provide the client with a means of replacing cracked or broken enclosures. Well documented assembly instructions will be provided with the prototype on the basis that any student worker or faculty member should be able to duplicate our prototype implementation with the components outlined in our bill of materials.

Conclusions

Our project to this point has been reasonably straightforward with limited issues in terms of information gathering. We have been fortunate enough to benefit from a simple concept in terms of customer need and have been given significant creative control in terms of the direction of the project. The largest issues we encountered were with some research concepts, such as the possibility of utilizing radio frequency energy harvesting, and with our system integration. The different systems for the project were developed in parallel, with the integration details being worked on sequentially to prevent interfacing issues. Our solution meets most of our constraints and customer requirements, while still offering flexibility to pivot the function of the software to match whatever a customer may need, such as office reservation signage. This expands our potential customer base to include office environments, reservable public spaces, as well as retail stores.

For mass production, our design will require several alterations, namely the changing of the enclosure from 3D printed material to molded plastic or formed metal. Additionally, changing the electronics design to a custom designed printed circuit board will improve the reliability and quality of the system. If we set our product price to be approximately $150-$175, based on our Budget of Materials in figure 6 we would recoup losses based on material cost and design time investment to all for a modest profit margin.

If we had to repeat this project and had to do something differently, we would have added more detailed questions in the survey we sent to faculty members to better define the need for the project. Additionally, we would perform more detailed research on competition, possible technology to leverage, and perform a broader search on components to source. We would also have designed a custom printed circuit board for our selected design.

Bibliography

1. "Arduino Nano 33 IoT," Arduino. [Online]. Available: https://store-usa.arduino.cc/products/arduino-nano-33-iot?selectedStore=us. [Accessed: 17-Nov-2021].
2. "5.65inch ACeP 7-Color E-Paper E-Ink Display Module, 600×448 Pixels," Waveshare. [Online]. Available: https://www.waveshare.com/5.65inch-e-paper-module-f.htm. [Accessed: 17-Nov-2021].
3. "Energizer Recharge® Rechargeable batteries," Energizer. [Online]. Available: https://www.energizer.com/batteries/energizer-rechargeable-batteries. [Accessed: 06-Oct-2021].
4. "AOSHIKE 10Pcs 5V 30mA Mini Solar Panels for Solar Power Mini Solar Cells DIY Electric Toy Materials Photovoltaic Cells Solar DIY System Kits 2.08"x1.18"(5V 30mA 53mmx30mm)", Amazon.com, 2021. [Online]. Available: https://www.amazon.com/AOSHIKE-Electric-Materials-photovoltaic-53x30MM/dp/B07BMMHMSJ/ref=sr_1_6?dchild=1&keywords=solar+panels&qid=1632491747&refinements=p_36%3A-2500&rnid=2661611011&sr=8-6. [Accessed: 06- Oct- 2021].
5. "Amazon.com: Waveshare 4.2Inch E-Ink Display Module ..." [Online]. Available: https://www.amazon.com/4-2inch-Module-Communicating-Resolution-Controller/dp/B074NR1SW2. [Accessed: 06-Oct-2021].
6. "Arduino Uno R3" [Online]. Available: https://upload.wikimedia.org/wikipedia/commons/3/38/Arduino_Uno_-_R3.jpg. [Accessed: 07-Oct-2021]
7. "Raspberry Pi 4 Model B" [Online]. Available: https://upload.wikimedia.org/wikipedia/commons/thumb/f/f1/Raspberry_Pi_4_Model_B_-_Side.jpg/1280px-Raspberry_Pi_4_Model_B_-_Side.jpg. [Accessed: 07-Oct-2021]
8. "Raspberry Pi Pico" [Online]. Available: https://external-content.duckduckgo.com/iu/?u=https%3A%2F%2Fwiki.52pi.com%2Fimages%2Fthumb%2F3%2F3b%2FRaspberry_Pi_Pico_2.jpg%2F640px-Raspberry_Pi_Pico_2.jpg&f=1&nofb=1. [Accessed: 07-Oct-2021]
9. "Amazon.com: Energizer rechargeable AA and AAA battery ...," *Amazon*. [Online]. Available: https://www.amazon.com/Energizer-Rechargeable-Auto-Safety-Over-charge-Protection/dp/B00IM3P8GS. [Accessed: 07-Oct-2021].
10. "Home," Best Online Shopping Store for Electronics, Fashion, Home Improvement & More in Indonesia. [Online]. Available: https://www.ubuy.co.id/en/product/MAB9YXIU-new-5-options-home-office-privacy-sign-do-not-disturb-door-hanger-in-a-meeting-in-a-session-be-right#gallery-4. [Accessed: 07-Oct-2021].
11. "Arduino Uno R3," Arduino CC [Online]. Available: https://store-usa.arduino.cc/products/arduino-uno-rev3?selectedStore=us. [Accessed: 07-Oct-2021].
12. "Raspberry Pi 4 Model B," The Pi Hut [Online]. Available: https://thepihut.com/products/raspberry-pi-4-model-b?variant=20064052740158&src=raspberrypi. [Accessed: 07-Oct-2021].
13. "Raspberry Pi Pico RP2040 With Loose Unsoldered Headers," Adafruit [Online]. Available: https://www.adafruit.com/pico?src=raspberrypi. [Accessed:07-Oct-2021]