ENSC 405W Grading Rubric for Design Specification

Criteria	Details	Marks
Introduction/Background	Introduces basic purpose of the project.	**/05%**
Content	Document explains the design specifications with appropriate justification for the design approach chosen. Includes descriptions of the physics (or chemistry, biology, geology, meteorology, etc.) underlying the choices.	**/20%**
Technical Correctness	Ideas presented represent design specifications that are expected to be met. Specifications are presented using tables, graphs, and figures where possible (rather than over-reliance upon text). Equations and graphs are used to back up/illustrate the science/engineering underlying the design.	**/25%**
Process Details	Specification distinguishes between design details for present project version and later stages of project (i.e., proof-of-concept, prototype, and production versions). Numbering of design specs matches up with numbering for requirements specs (as necessary and possible).	**/15%**
Test Plan Appendix	Provides a test plan outlining the requirements for the final project version. Project success for ENSC 405W will be measured against this test plan.	**/10%**
User Interface Appendix	Summarizes requirements for the User Interface (based upon the lectures and the concepts outlined in the Donald Norman textbook).	**Graded Separately**
440 Plan Appendix	Analyses progress in 405W and outlines development plans for 440. Includes an updated timeline, budget, market analysis, and changes in scope. Analyses ongoing problems and proposes solutions.	**Graded Separately**
Conclusion/References	Summarizes functionality. Includes references for information sources.	**/05%**
Presentation/Organization	Document looks like a professional specification. Ideas follow logically.	**/05%**
Format/Correctness/Style	Includes letter of transmittal, title page, abstract, table of contents, list of figures and tables, glossary, and references. Pages are numbered, figures and tables are introduced, headings are numbered, etc. References and citations are properly formatted. Correct spelling, grammar, and punctuation. Style is clear, concise, and coherent. Uses passive voice judiciously.	**/15%**
Comments		

March 28, 2018

Dr. Andrew Rawicz

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RE: ENSC405W Design Specifications. – The Ripple Reader: The Affordable Braille Reader of Tomorrow

Dear Dr. Rawicz,

Please find our design specifications for the Ripple Reader, enclosed within. Our mission, at LampLight Labs, is to develop a text to braille reader that is affordable, user friendly, and can be accessed by a wide population. We plan to combine the latest in optical character recognition technology, powerful microprocessors, and cutting-edge hardware design to accomplish our goals. The Ripple Reader takes an innovative spin that is guaranteed to make a splash in the technological industry.

This document will start with an introduction of our product from a high level of design followed by an in-depth analysis of the mechanical, electrical, and mobile components. The document will conclude with a justification of the methods used to implement our end product.

LampLight Labs consists of five passionate and motivated individuals namely Caelan Midwood, Connor Heidema, Randeep Shahi, Amir Hadjifaradji and Abiman Mahendra. Should you have any questions or concerns feel free to contact our COO Connor Heidema at any time. You can reach him at 604-868-9195 or by email at cheidema@sfu.ca.

Best Regards,

Caelan Midwood

Chief Executive Officer

LampLight Labs

Enclosure: Design Specifications for the Ripple Reader

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Issued On: March 28th

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1. Introduction

1.1 Scope

The following document is meant to elaborate on the Ripple Reader and highlight the design specifications, complacent requirements and methods for verification we will comply to, providing a device which is both safe and effective in its intended use. Specifications currently model Proof-of-Concept (POC), prototype (PRT) and production (PRD) designs and discusses which designs easily transfer over to prototype designs. Additionally, an appendix, Appendix B containing the UI design specifications and further planning in Appendix C is included within the document, which discusses key features in determining the usability of the device, assurance of an intuitive design and comfort for the visually impaired.

1.2 Intended Audience

The document is primarily intended to be used by the electrical, mechanical and software engineers at LampLight Labs during the design and verification stages and for any stake holders involved in the project. Verification engineers are to follow this document and the requirements document to ensure that all designs pass the acceptable threshold set by the requirements. Unit and functional testing are key aspect for methods to verify design methods. Engineers should review the document for an up-to-date knowledge of the design specifications.

1.3 Project Background

Over the last 50 years there has been a drastic decrease in the literacy rate of the visually impaired, with many factors attributing to this decline. [1] One of the largest factors is the lack of methods for teaching braille and educational tools [1]. Our product, the Ripple Reader, is an affordable and educational solution to the issue many visually impaired children face. What is the Ripple Reader? It is a refreshable braille display with audio feedback which can take an image or video feed as an input and transform it to braille for users to read.

There are numerous subsystems that work harmoniously to successfully deliver a seamless user experience. This type of experience is especially important because the Ripple Reader has the potential to broaden the everyday lives of 100,000’s of partially, or completely, blind individuals all over world. Our device builds upon current devices. As such, it is important that our functional requirements preserve key features. While keeping this in mind, we also put a large emphasis on user factors included in the device ensuring that the device is safe and simple to use.

LampLight Labs has identified that affordability; ease of use; and educational value will be our three guiding principles for this endeavor.

2. Overall System Design

The Ripple Reader is a product with the intent to teach users braille in a simple and affordable manner. By bridging the gap between braille and everyday text found on posters, papers, books and any median with text, the Ripple Reader will deliver the appropriate braille characters successfully in a seamless user experience.

How will the end-user benefit? The Ripple Reader provides configuration options for an audio feedback system, whereby a user can choose for nothing read back to them, the character they are on read back to them or the word they just read, to be read back to them. This feature is intended to mitigate the learning-curve experienced when initially learning braille, without alienating literate braille readers. How is the Ripple Reader more affordable than other braille devices? LampLight Labs is implementing a multiplexing actuating system whereby fewer actuators can be used to convey the appropriate information. This reduces the cost of the Ripple Reader by a large magnitude when comparing with competitor products.

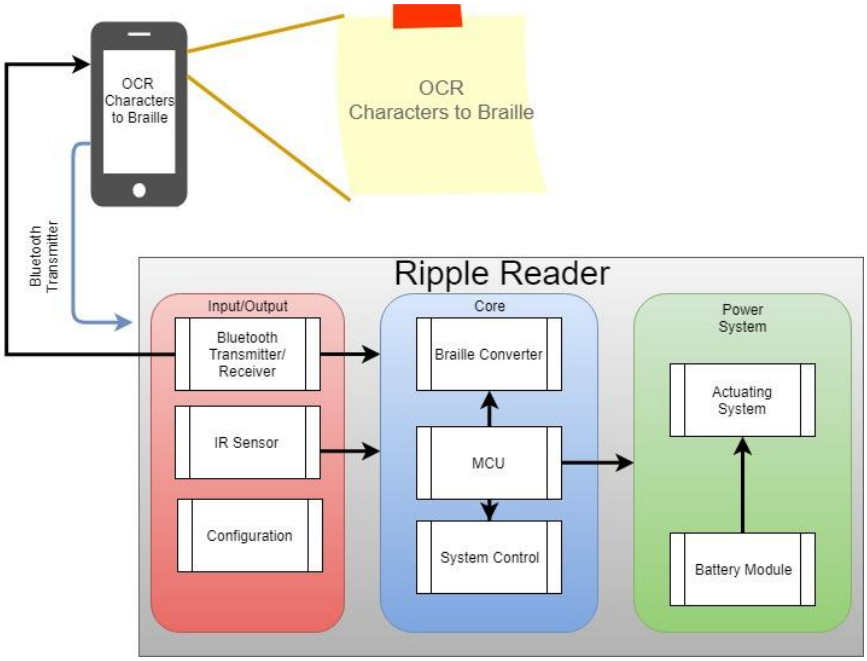

Figure - 1 Higher-level layout of the Ripple Reader system and sub-systems

Figure - 1, demonstrates the various subsystems and their respective interactions. The main subsystems included in the Ripple Reader are: off-boarding Optical Character Recognition (OCR) and audio feedback system via android app, processing core, input/output sensors and configurations and the power system.

The first subsystem, the off-boarding data acquisition system is created with an android app. The OCR content and audio feedback are primarily done through this system. This is because smartphones today possess powerful processors which can off load the “heavy lifting” processing required for OCR. Additionally, there are many accessibility features within smartphones which make it easy to use for the visually impaired.

The second subsystem is the input/output sensors and configuration system. Inputs are received from the off-boarding to the Ripple Reader via Bluetooth. Data received is a serial

stream of characters, which is sent to the microcontroller unit (MCU) to be displayed and stored. Using an infrared sensor, we will measure the time of flight between a user's finger and the sensor. The IR sensor provides a relative spatial location of the finger, and the information is sent to MCU to display the necessary characters. Finally, the configuration of choice is a transmitter via Bluetooth to the phone app, thus initiating the audio feedback.

The third subsystem is the processing core, which encompasses the MCU. Once characters are received by the Bluetooth module, the characters are transferred to the MCU whereby they are converted to braille. The MCU also controls various parts of the systems, mainly the part in which actuators should rise, length of time finger is on a character and proceeding through the text.

Finally, the last subsystem is the power system, which comprises of a battery unit to charge the processing core and provide the proper current to actuate the pins. The multiplexing system found within this system, is what allows the Ripple Reader to display 6-dot braille using less than the typical number of total actuators. This is achieved by an intricate mechanical design of the pins whereby each pin repeats every third character. The current character, previous character and next character is always displayed relative to where the users finger is located. As the user's finger passes through the matrix of characters, the device refreshes to the new characters. The figure to the right of Figure - 2 demonstrates this system.

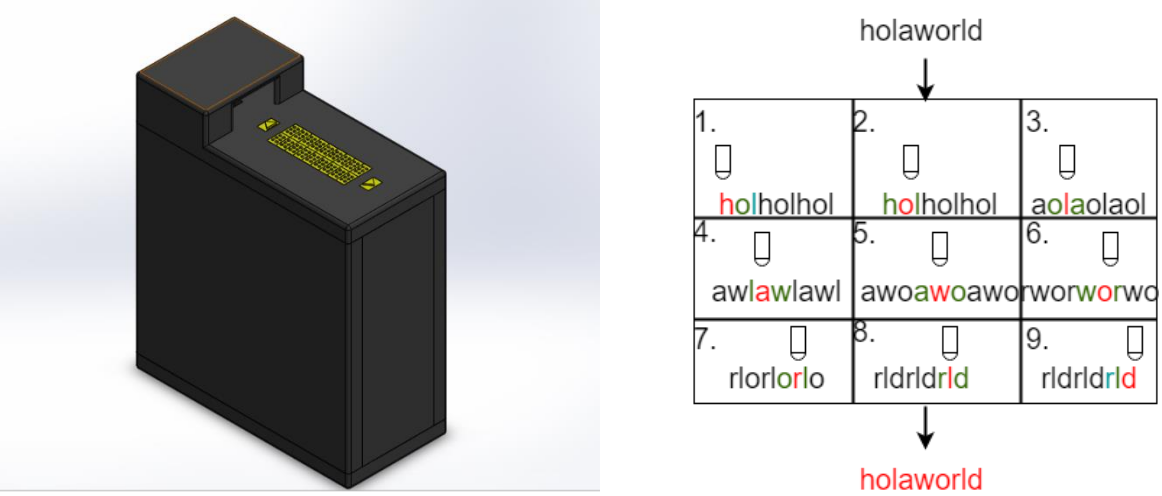

Figure - 2 To the left is our conceptual design, to the right a visualization of the multiplexing

On the left, of Figure - 2 is a Solidwork's conceptual model of the Ripple Reader, it is the production model. A similar model will be achieved in the next 4 months; a key difference between the figure above and the prototype is highlighted in **R5.2** in our requirements document, which states that the production model will have 2 lines, 18 characters, the prototype will have 1 line, 9 characters. Currently, measures are being taking into have the enclosure 3D printed. Key changes between the prototype and proof-of-concept model are the use of LEDs vs actuating pins, an enclosure made of PLA, 5V powered actuating system and battery powered actuating which align to requirements **R1.1**, **R5.4**, **R7.8**, **R6.3**.

3. Mechanical Design

Acronym	Name
POC	Proof of Concept
PRT	Prototype
PRD	Product

Table - 1 Acronyms of stages

Design Specification	Requirement ID	Design Stage	Description
Braille Cell and Layout	R5.1{Both} R5.2{Both}	PRD/PRT/POC	3D printed using **PLA**. 1. Precision Printing 2. Biodegradable
		PRD	2 rows of 9 braille characters each
		PRT/POC	1 row of 9 braille characters
Proximity sensing	R5.3{Both}	PRD/PRT	IR Sensor: **Sharp GP2Y0A51SK0F Analog Distance Sensor** 2-15cm 1. Ideal Range 0 – 10cm 2. Output linearization possible by obtaining Voutput vs (1/distance), 3. Low cost (8CAD per 5 units)
Actuation	R5.4{Both}	PRD/PRT	Solenoid Actuator: **DSTL-0216-05** 1. Compact (0.378" Di x 0.520" L) 2. Short stroke length(2.79mm) 3. Relatively low cost (300CAD for 25 units) 4. Low power(1.1W)
Actuation Translation (Actuation Link Network)	R5.5{Both} R5.6{Both}	PRD/PRT	3D printed using **ABS** 1. Strong, ductile, good flexural strength 2. Heat tolerant (high glass transition temperature) 3. recyclable
Operating Tolerance	R5.8{Both}	PRD/PRT	3D printed using **ABS** to operate between - 5 to 30 Celsius 1. Strong, ductile, good flexural strength 2. Heat tolerant (high glass transition temperature) 3. recyclable
Labelling	R5.10{Both}	PRD	All parts will be labelled on the final production version in text and Braille

Table - 2 Mechanical Specifications

4. Electrical Design

4.1 Proof of Concept

4.1.1 Multiplexing Actuating Systems

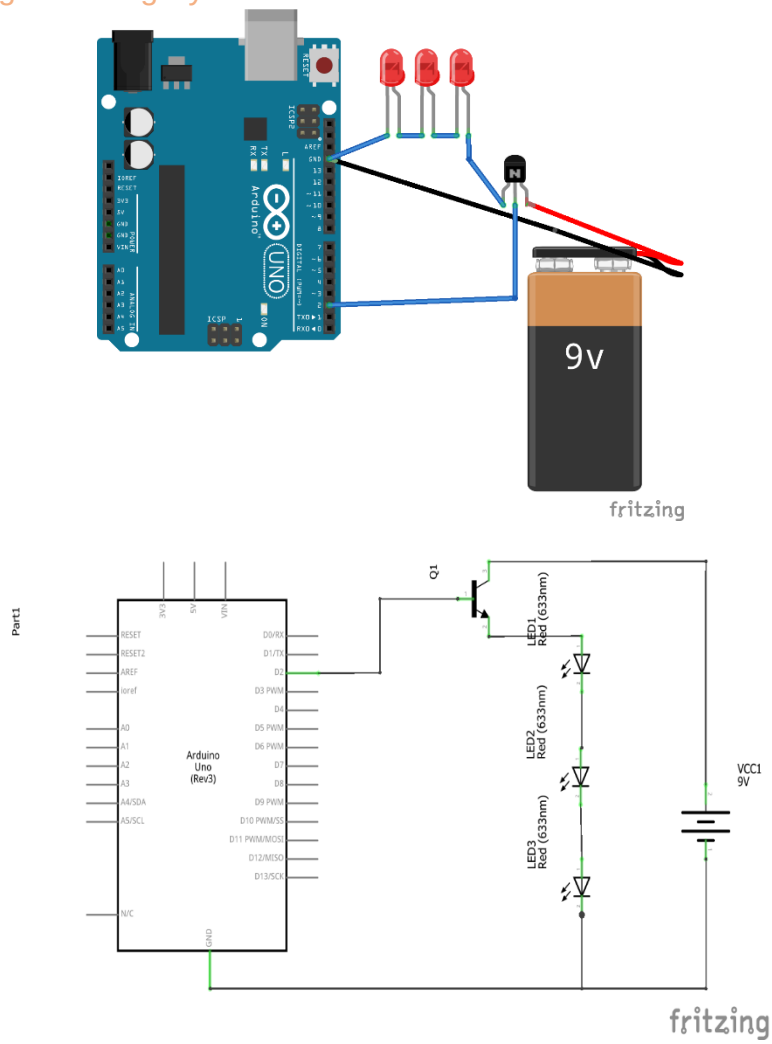

Figure - 3 Simplified circuit diagram and schematic for the POC actuating system

Figure - 3 is a simplified diagram of the multiplexing system for the POC actuating system. LEDs in the POC represent the actuators we will be using. When the light is “ON” this represents the pin in a high state, conversely the light being “OFF” represents a low state. Effectively, 18 pins will be used for the three 6-dot braille characters satisfying **R1.4**. Each LED connects in series with 2 other LEDs providing a total of 54 LED lights, satisfying **R1.1**. This series connection is the simplest solution to a multiplexing system from an electrical point of view, this is because the same current goes through their respective LEDs. Thus every “pin” that is in a high state, has 2 other “pins” each 3 characters away that is also high.

4.1.2 Finger Location

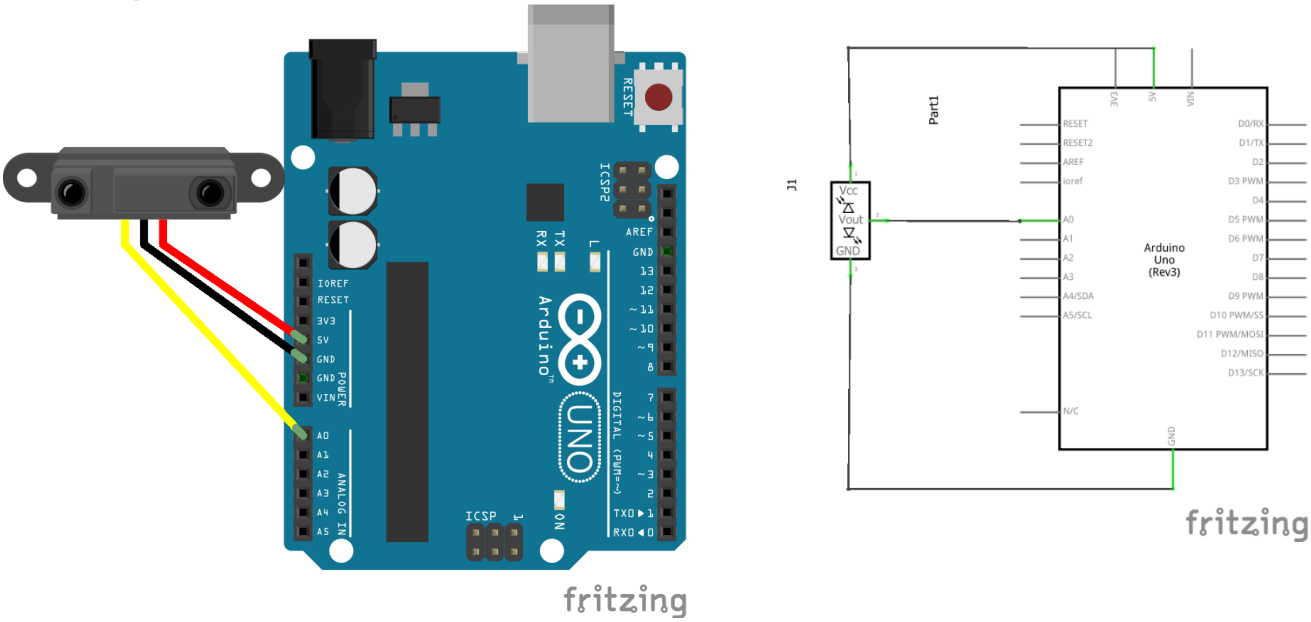

Figure - 4 Circuit diagram and schematic for the IR distance sensor

Figure - 4 demonstrates the finger location circuit with an infrared distance measuring sensor. The Ripple Reader uses the Sharp GP2Y0A51SK0F sensor, which outputs an analog voltage corresponding to distance measurement between 2-15cm. The output voltage is displayed below in Figure - 5, provided by the Sharp datasheet [2]. The sensor has a IR-emitting diode and a position sensitive detector, measurements are based on light propagation and reflecting from an object, the signal returning to the sensor outputs voltage accordingly. It requires ~5V to operate and is easy to connect, the output pin on the sensor goes to the analog pin of MCU.

The arrangement satisfies requirement **R5.3** – “There shall be an IR sensor on each row of braille”. A single sensor is sufficient for the POC because there will only be 1 row of characters.

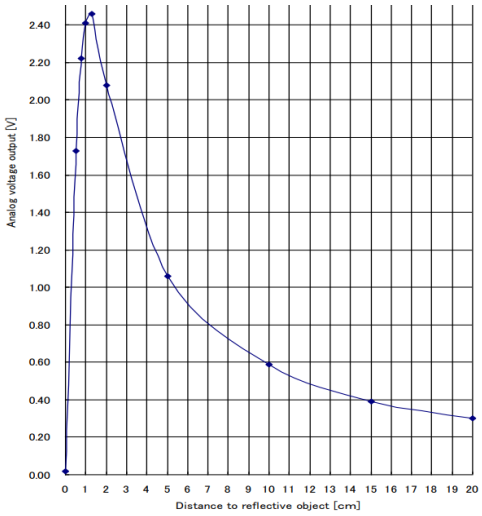

Figure - 5 Graph for the output voltage for IR distance sensor

4.1.3 Bluetooth

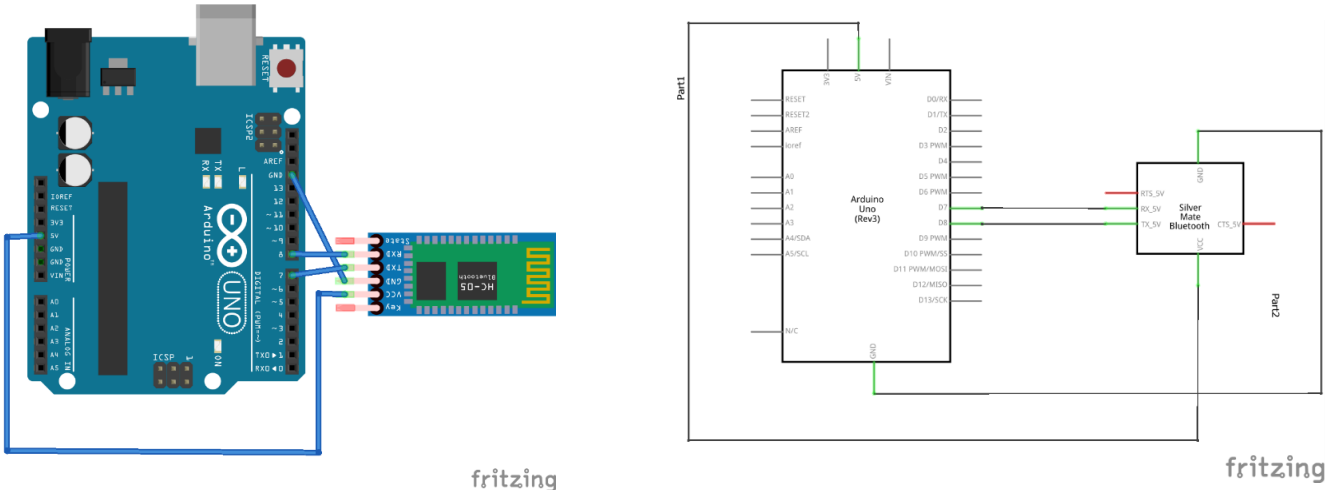

Figure - 6 Bluetooth module diagram

The Ripple Reader uses a Bluetooth module for the serial communication with the companion app. The Bluetooth module is an HM-10 BLE module which provides Bluetooth 4.0 communication as specified by **R4.5.** It is designed to receive the characters sent by the app and to transmit the audio configurations set by the user. These audio configurations are whether the user wants characters, words, or nothing to be read back to them, aligning to **R.1.6**. Two-bits of information is sent to the android application for these configurations, “00” nothing read, “01” for character and “10” for word read back.

4.2 Prototype

4.2.1 Power system

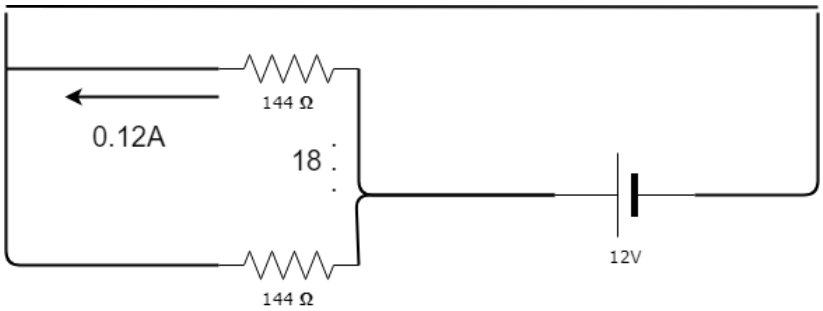

Figure - 7 Simplified Solenoid Circuit

The system will be powered with the ABENIC DC 12V 1800mAh Super Rechargeable Portable Li-ion Battery. The batteries are DC sources which satisfies **R6.11**. These batteries are rechargeable thus satisfying **R6.9**. With 18 push 5.4V Delta Electronics solenoid actuators each with a resistance of 144 ohms (displayed in Figure - 7) at 12V we can determine the total current of the system:

$$I = \frac{12}{144} * 18 = 1.5A$$

Equation - 1 Current needed by power unit

5. Firmware Design

Figure - 8 Single-Board microcontroller Arduino Uno

5.1 Microcontroller unit

The microcontroller used for the POC is the Arduino Uno with a 32-pin I/O extension. The choice of microcontroller for the POC was selected for a variety of factors, primarily the ease of development. Engineers at LampLight Labs are well versed and familiar with C/C++, which are both compiled on the ARM processor found in the Arduino. Other factors included pin count, clock speed, cost, memory, output voltage and ADC component. The Arduino Uno provides 2 interrupt pins, which is sufficient for the buttons for moving to different lines, 18 pins are required for the actuating system, 1 analog pin for the proximity sensor and 4 pins for the Bluetooth module. With the 32-pin extension there should enough pins to operate the system sufficiently. The specification for the Arduino are listed below.

Parameter	Value
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328P) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz
Length	68.6 mm
Width	53.4 mm
Weight	25 g

Table - 3 Arduino Specs provided by the Arduino Website [3]

Despite requirement **R5.7** being a prototype requirement, it can be satisfied in the POC as the clock speed is fast enough in the POC to actuate pins at 5kHz and typically 16MHz is on the lower end of the spectrum for speeds.

5.1.1 Prototype

For the prototype we were considering various other microcontrollers for improved memory, voltage output, clock speed and more pins while keeping cost considerations in mind. Ideally, we would want to satisfy requirement **R2.4**, which states the Ripple Reader will be no more than $200. One of such microcontrollers we found were UDOO NEO, which offers 1GHz of processing speed, 512MB of RAM and memory, 36pins and operates between -40 - 105°C. These features all correspond to **R2.6**, **R5.7**, **R5.8** and **R6.3**.

The speed of the Arduino would suffice to satisfy the time requirements for reading a file and displaying the character; however, to fully implement requirement **R2.6** more memory would be required as text files of novels exceeds the memory capacity of the Arduino. Modules can be bought to increase the non-volatile memory, such as adding an external I2C EEPROM to the Arduino. However, the UDOO NEO's memory storage should suffice.

5.2 Text to Braille Conversion

The text to braille conversion is done through the on-board processor, this has been found to be the most efficient method for translations as it only requires characters to be sent over. Each character read is mapped to the appropriate braille character thus the speed at which it can convert characters is very fast. Braille characters represented within the code are a string of 6-bits of data "0" represents low state of pin, "1" represents high state, for instance "b" translates to "110000" which means pin 1 and 2 are in a high state. This can all be done sufficiently quickly and should satisfy **R2.7** with the appropriate clock speed.

5.3 Interrupt Handling

Requirements **R1.16** and **R1.17** state there shall be a next and previous button for scrolling through the braille text, this has been implemented via interrupts on the on-board processor. Pins 2 and 3 are interrupt pins in the Arduino, and effectively when a button is pressed a connection is made between the voltage terminal and the pin, this elicits a state change observed in the pin which triggers the interrupt. The interrupt handler proceeds to iterate through the text 9 characters which is then displayed by the device. Note that the interrupt handlers on the Arduino cannot perform other interrupts or delays.

5.4 Miscellaneous

Other requirements which will can be handled by the microcontroller unit are listed below. Effectively, with push solenoid actuators, if no current is supplied to the system, the pins are all down by default, thus satisfying **R7.1**. As for **R1.5** – depressing all pins when no finger is present and **R3.15** - shall be polled every 0.01 seconds for IR sensor data; the MCU is programmed to poll from the pin of the IR data and to provide no power to the system if no finger is detected. Finally, for the POC no configuration option is available currently for contracted or regular braille; however, for the prototype a flag will be created whereby the MCU will translate based on user configurations.

6. Application Design

The Ripple Reader application will provide users additional access to documents and books from a picture format. As so much text today is still not digitized it is imperative the Reader incorporates a camera with OCR to capture the full range of documents the visually impaired may read. Figure - 9 below illustrates the kind of image expected to be taken by a camera using our application. Additionally, by utilizing a phone, a less expensive processor may be used to do image processing and a less expensive audio feedback mechanism can also be employed.

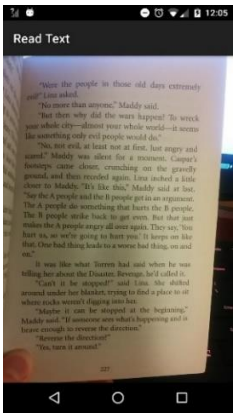

Figure - 9 Sample image of p case of the Ripple Reader

6.1 Picture Acquisition

When the application is opened for the first time the user may take a picture by tapping the screen to collect the content on the screen for OCR to process it. As per **R3.10** and **R3.11** the phone will vibrate twice if the picture is captured successfully and three times if it is not captured successfully. If the user instead swipes the screen, the reader will be set to automatic mode. In this mode the user will again aim the camera at the text. This time a picture will automatically be taken when certain criteria are met. Criteria include seeing if the most text letters have been seen over a threshold letter count for a certain timeframe. This ensures auto mode will not take arbitrary pictures. This mode is meant to help the visually impaired take pictures if they have difficulties with the camera. **R3.9** means the camera also determines the brightness of the room and sets its flash accordingly. Finally autofocusing is done on the image, aiding the user in taking a quality picture for OCR to be performed. The processed ascii to braille processed file will finally be sent to the device for user reading. Most of the OCR implementation has already been finished utilizing a Google library. Since it is functional, not much research into the OCR was necessary.

6.2 Audio Feedback

On top of OCR, the Ripple Reader will provide audio feedback as per **R3.8** to the user when they reach a certain letter or word and is stuck. To do this the phone and the reader will both store the last picture taken in a braille format. When the user doesn't understand a letter, an event will trigger to send the index of the letter in the braille file to the phone via Bluetooth. The event will be caught by the application and either the corresponding letter or word may be read out depending on the user configuration.

7. Conclusion

The Design Documentation details how the desired requirements covered in the Requirements Document will be met. The Requirements specifications are translated to design components that will be implemented in three different versions of the Ripple Reader, namely, the Proof of Concept, the Prototype and the Production versions.

The Design Documentation aims to address safety, usability, efficacy and efficiency of the Ripple Reader through sound and robust design. The design is broken down from top level overall system design to low-level subsystem design of the mechanical, electrical, firmware, and application subsystems.

Although the design documentation explicitly details and justifies the components that will be used, LampLight Labs understands requirements specifications and design specifications might change when unforeseen design issues or optimisation methods come to light.

Ultimately the design documentation will provide clarity and serve as a reference to the construction and assembly of the Ripple Reader. We hope to provide the end users a safe, reliable, and a practical system that will help them become literate in Braille based on the design documentation.

Appendix A

Test Plan

The Ripple Reader and its corresponding application must adhere to its prescribed requirements to guarantee customer satisfaction. Since our reader may be used to read anything from textbooks to vital information, we must also ensure it works for the customers own safety. As such we have created a set of test cases seen in Table A - 1 all-encompassing of our requirements.

Table of Tests

Test Case	Req ID(s)	Expected Results	P/F (Comments)
1. Inspect the Ripple Reader and the phone application while the device is off	R1.1 R1.6 R1.10 R2.2 R2.5 R3.14 R4.5 R4.6 R4.7 R4.8 R4.9 R5.1 R5.2 R5.3 R5.4 R5.6 R5.7 R5.10 R6.10 R7.1 R7.7 R7.8 R7.9 R8.5 R8.6 R8.7	The Ripple Reader has 2x9 cells, a shield to its left containing 2 IR sensors, a back and forward button, an audio button with 3 configurations associated to it, a contracted braille button, and a power button. The device weighs no more than 2.5kg The device is made entirely of recyclable 3d printed plastic or steel There are no sharp edges and all electrical wiring is contained within the device. An emblem is on the side of the device signifying it passed tests before being sent out. All the pins are depressed All labels and buttons are embossed along with written in letters There are no logging devices or other signaling devices to capture data to sell The reader should fit within the dimensions 10x10x15cm give or take half a centimeter If the Reader is the onboard configuration, the camera on the board is at least 8 mega-pixels in resolution and a speaker capable of 20 to 60 decibel output The reader has a Bluetooth transceiver inside to send and receive data from a smartphone There is an outlet to charge the phone from	

		The application will allow the user to change the volume of the audio feedback The braille cells each conform to the UK guidelines for braille characters Inside the device are vertical rods that extend the actuators to multiple places The processor runs at a frequency greater than 5 MHz The parts should all be labelled with a unique identifier The reader has an external power block it can charge with	
2. Press the power button twice	R1.2	The Ripple Reader turns on and off	
3. Leave the Reader with test.txt (see Appendix D) for 3 months while off	R1.3	The data of test.txt persists	
4. Move your finger over the devices characters	R1.4 R5.5	The correct previous current and next characters are always seen on the device with a ripple effect of the 3 characters appearing over the other characters	
5. Inspect the device while it is on and you are not interacting with it	R1.5	All the pins should be depressed	
6. With the letter-audio configured, put your finger over any character for over a second. Change the configuration to word mode and no-audio mode	R1.7 R3.8	The letter word, or nothing should be read out to the user through the Ripple Reader application	
7. Move your finger over an unknown character or word	R1.8	An error should be read to the user, signifying the Reader does not understand the letter or word	
8. Take pictures using the Ripple Reader Application of a book page	R1.9 R3.2 R3.3 R3.10 R4.3	The picture is converted to braille and transferred to the Ripple Reader. The phone should vibrate twice. The camera will autofocus within 2 seconds The optimal picture is taken compared to other pictures taken of	

		the book when the words are 50 pixels in height	
9. Use the contracted and regular braille configurations while reading	R1.10 R1.11	The reader should show the correct contracted or uncontracted braille	
10. Get the device to be in the data capture mode without taking a picture	R1.12	The user will hear an error message indicating the illegal state	
11. Let the battery drop to a low level and trigger other errors on the Ripple Reader	R1.13 R1.14	The Reader should read errors to the user	
12. Upload a file to the Reader	R1.15	The Reader should show the file starting at the first index	
13. Press the next button of the device with a file loaded in while you are not at the last index of the file	R1.16 R2.6	The reader displays up to the next 18 characters within a second when the user puts their finger over the cells	
14. Press the previous button on the device when you are not at the first index of the file that is read in	R1.17	The Reader displays up to the previous 18 characters	
15. Press the next button when no file is loaded into the reader	R1.18	An error should be read to the user indicating the scroll function cannot be performed at the time	
16. Run the reader through audio modes and contracted braille mode	R1.19	The reader should always be able to actuate the proper characters so long as the device is on	
17. Take the battery out of the Ripple Reader	R1.20	The Ripple Reader should lose all memory as though a soft reset has occurred	
18. The reader comes with a user manual and repair manual	R2.1 R7.11	The user manual and repair manual are packaged with the reader	
19. Perform the usability test with several participants	R2.3	The usability test passes the requirement value of 80/100	
20. Go to a store to purchase the product	R2.4	It costs less than $200	
21. Move your fingers over the reader while a file is loaded	R2.7 R3.15	The next characters are displayed as fast as 0.02 seconds. The IR values are polled every .01 seconds	

22. Acquire the contents of the image file	R3.1	The image should be readable in a .png format	
23. Inspect the data transferred to the device	R3.4 R3.5	6-bit braille characters should be sent to the device for the content of the data Check the cells embossed on the reader correlate with the logical '1's in the file	
24. Hover the camera over text	R3.6	OCR shall be attempted to be performed in 0.1 seconds	
25. Take a picture of a page with letters 24 pixels large written in times new roman	R3.7	99% of the words are properly extracted	
26. Take a picture with a camera in a dark room	R3.9	Flash is activated on the camera	
27. Take a picture using the Ripple Reader Application of illegible text	R3.11 R3.12	The Reader should vibrate 2 times indicating an error during OCR. An audio error can be heard	
28. Use the Ripple Reader for an extended period	R3.13	No advertisements should be sent through the actuators to the user	
29. Use the Ripple Reader application with multiple kinds of android phones	R3.16	The application should be fully functional	
30. Use the Ripple Reader for 2 hours straight.	R4.2 R6.5	The Reader is still functional after this time. It remains below 45 degrees Celsius,	
31. Leave the Reader on for 15 hours while not actuating any pins	R4.2 R6.6	The Reader is still functional after this time. It remains below 45 degrees Celsius	
32. Upload a test file to the reader via USB	R4.4	The reader successfully saves the file to persistent memory	
33. Leave the Reader in the rain for 10 minutes	R4.10	The Reader is functional after this time	
34. Use the reader in conditions of humidity of 60%	R4.11	The reader should operate normally	
35. Run the reader at 30 degrees Celsius and -5 degrees Celsius	R5.8	The reader should operate normally	
36. Turn on the reader and try to use it right away	R5.9	The reader should operate normally in less than 5 seconds	

37. Take 100 photos with the onboard camera	R6.1	The camera successfully saves each concurrent picture	
38. Insert a DMM to the input and output ports of the actuators	R6.2	A voltage of 50 volts is seen consuming 0.5 Watts across the aggregated circuit	
39. Insert a DMM to the input and output ports of the device	R6.3 R6.12	A voltage of 3.3 volts is read, DC power should be observed	
40. Check the electrical wiring	R6.4, R6.5	The wiring should all follow the appropriate standards listed in the requirements	
41. Leave the Ripple Reader on for 10 minutes	R6.8 R6.9	The Reader goes into power saving mode after 5 minutes and off mode after 10 minutes	
42. Plug in your phone to a wall with a micro-USB adapter	R6.11	The phone should charge normally	
43. See the public git repo of our software code	R7.2	The code is written to standard	
44. Call our support line	R7.3	A person familiar with our device should answer the phone to aid you in using the equipment	
45. Take apart the device	R7.4	The device should be easy to take apart and put back together	
46. Drop the Reader from a height of 1 meter	R7.5	The Reader sustains no damage	
47. Check the general sustainability of the device	R7.6	Sustainability should run in accordance to the standards outlined in the requirement	
48. Check the internal layout of the device with the public documentation	R7.10	Everything about how the device works should be public and match our implementation	
49. Check the original labelling of the parts	R8.1 R8.2	The materials should show they have been bought by respected manufacturers who abide by the Medical device regulations	
50. Apply a surge of energy to the Ripple Readers power port	R8.3	The fuse to the reader should blow and the reader should be turned off if it is not already off	
51. Make the Reader heat up above 45 degrees Celsius	R8.4	The reader should turn off	
52. Check the circuit conforms to RoHS guidelines	R8.8	It should follow these guidelines	

Table A - 1 Test Requirements

ENSC 405W Grading Rubric for User Interface Design
(5-10 Page Appendix in Design Specifications)

Criteria	Details	Marks
Introduction/Background	Appendix introduces the purpose and scope of the User Interface Design.	**/05%**
User Analysis	Outlines the required user knowledge and restrictions with respect to the users' prior experience with similar systems or devices and with their physical abilities to use the proposed system or device.	**/10%**
Technical Analysis	Analysis in the appendix takes into account the "Seven Elements of UI Interaction" (discoverability, feedback, conceptual models, affordances, signifiers, mappings, constraints) outlined in the ENSC 405W lectures and Don Norman's text (*The Design of Everyday Things*). Analysis encompasses both hardware interfaces and software interfaces.	**/20%**
Engineering Standards	Appendix outlines specific engineering standards that apply to the proposed user interfaces for the device or system.	**/10%**
Analytical Usability Testing	Appendix details the analytical usability testing undertaken by the designers.	**/10%**
Empirical Usability Testing	Appendix details completed empirical usability testing with users and/or outlines the methods of testing required for future implementations. Addresses safe and reliable use of the device or system by eliminating or minimizing potential error (slips and mistakes) and enabling error recovery.	**/20%**
Graphical Presentation	Appendix illustrates concepts and proposed designs using graphics.	**/10%**
Correctness/Style	Correct spelling, grammar, and punctuation. Style is clear concise, and coherent. Uses passive voice judiciously.	**/05%**
Conclusion/References	Appendix conclusion succinctly summarizes the current state of the user interfaces and notes what work remains to be undertaken for the prototype. References are provided with respect to standards and other sources of information.	**/10%**
CEAB Outcomes: Below Standards, Marginal, Meets, Exceeds	1.3 Engineering Science Knowledge: 4.1 Requirement and Constraint Identification: 5.4 Documents and Graphic Generation: 8.2 Responsibilities of an Engineer:	

Appendix B

User Interface

Table Of Contents

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Tables

1. Introduction

The Ripple Reader is a modern refreshable braille display which incorporates the use of a smartphone app. Both the Ripple Reader and its companion smartphone will need to have their User Interfaces be as clear and intuitive as possible for an enhanced User Experience as well as the successfully adoption of the Ripple Reader into the market.

1.1 Purpose

The purpose of this document is to analyse the User Interface needs of the visually impaired and design according to these needs. LampLight Labs needs to be very diligent in designing the User Interface and the User Experience.

1.2 Scope

The focus of this document is on all three stages of the Ripple Reader. The document contains the analysis of the product's target consumer and solutions their specific needs in terms of User Interface and User Experience.

2. Product Analysis

2.1 User Analysis

The end users of the Ripple Reader can be divided into categories as provided in Figure B - 1 below.

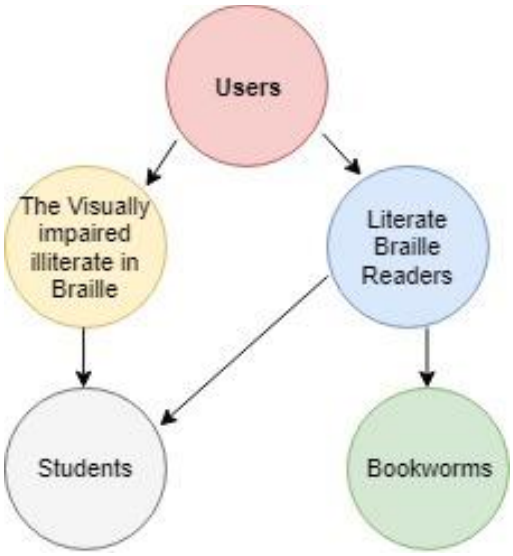

Figure B - 1 Typical users of the Ripple Reader

Our primary user for this device is anyone who wishes to learn the language. This is, in particular because of the niche our product can serve for users attempting to learn Figure B - 2 depicts the simplicity of learning to read braille using the Ripple Reader vs traditional means. Combining the audio feedback with the feel of the language, users have a single solution to learning as opposed to needing the feel or braille along with some form of teacher or computer for guidance. This simple option in learning attracts people to get the product, ultimately to afford the ability to read braille, whether it be at school, or even on the go.

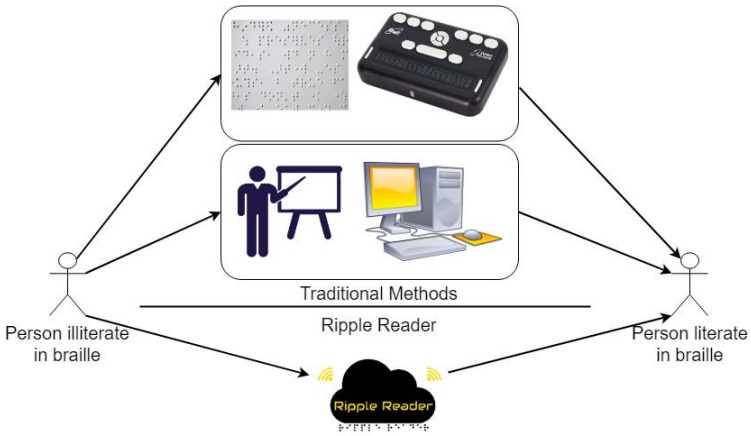

Figure B - 2 Paths a person may take to learn to read braille

The next users of the device include people who are students wishing to acquire general knowledge not specific to braille. Analogous to people who are sighted who judiciously learn content through textbooks or lectures, the visually impaired also have much to gain through a tactile method of learning on top of audiobooks. One visually impaired man supports this claim stating the following, “I prefer Braille books in key information and outline, and then listen to audio books to enrich and clarify the information much more.” [4] From this one can surmise that learning braille can augment students learning capabilities.

2.2 Technical Analysis

According to Donald A Norman’s The Design of Everyday things text on UI design [5], there are 7 pillars of ideologies that must be considered when created a new technology. In the next 7 sections, drawing direct parallelism to Norman’s book, we will describe our solutions for each of these ideologies.

2.2.1 Discoverability

By interacting with the device, the user should be able to discover all the important features about the device for the most optimal user experience. LampLight Labs has decided for some design choices which will help the user become familiar with the device as soon as they interact with it and increase overall user experience which will be crucial to the Ripple Reader’s success and adoption within the visual impaired community.

To design for discoverability, below, LampLight Labs has listed a couple of the most important design elements that will adhere to the discoverability ideology in the format of a table

Concern for Discoverability	Solution
The User will need to power on the Ripple Reader	We have decided to place the power button at the top right of the device and have made it a switch with either size of the switch having the braille word on or off.
The User will need to be able to determine the remaining battery life of the Ripple Reader	We have decided to have the user’s smartphone read out the remaining battery life. This can be discovered by pressing a button beside the power switch.
The User will need to pair their Ripple Reader with their Smartphone	When the device turns on for the first time, the Ripple Reader will beep every 10 seconds to let the user know that the Ripple Reader is in pairing mode. When the device has already been paired to a Smartphone, if the user would like to re-pair the Ripple Reader to a different device, there will be a button on the face of the Ripple Reader which can be user to pair a second device.
The User will need to determine if the Ripple Reader has successfully connected with their Smartphone	When the User opens the complementary app for the Ripple Reader, the app will automatically turn on the Bluetooth and attempt to connect to the ripple reader. As soon as the Smartphone can connect to the Ripple Reader, the Smartphone will tell the

	user that the Smartphone was connected to the Ripple Reader.

Table B - 1 Discoverability solutions

2.2.2 Feedback

The general purpose of feedback is to convey information to the user about the current state of the device in an intuitive way. Because of our demographic of potential consumers, LampLight Labs will need to be extra diligent in determining the most natural form of feedback that the user can easily understand. Below are some examples of feedback that the group may pursue in the development of the prototype in Table B - 2.

Stimulus	Feedback	Meaning
Taking a picture with the App	Smartphone vibrates for 2 x 0.3 second pulses	The smartphone app was able to successfully capture the text with the camera
Taking a picture with the App	Smartphone vibrates for 1 x 1.0 second pulse	The smartphone app was unable to successfully capture the text with the camera
Device is powered off and is plugged in for charging	Ripple Reader displays a number from 0 to 100 in braille using the first 3 braille cells	The Ripple Reader is currently displaying its current charge level
Braille words for "on" and "off" can be felt on each side of the Ripple Reader's power switch	Each of these words dictates the power state of the Ripple Reader depending on which side the switch is positioned	The user can derived the power state of the Ripple Reader by simply feeling for the braille word to the side of the switch
Ripple Reader's battery has dropped below 15%	An auditory message will be sent from the Ripple Reader or companion smartphone app that says "15% battery is remaining"	This lets the user know that the Ripple Reader is running low on battery power and will need to be charged soon.
The User's Smartphone has paired with the Ripple Reader via Bluetooth	The smartphone will vibrate or play a message notifying the user than the Ripple Reader has been paired with the smartphone successfully	This notifies the user that the smartphone and the Ripple Reader were able to successfully connect.

Table B - 2 Feedback Systems

2.2.3 Conceptual models

A good design should help portray all the information required to create an reasonable and understandable conceptual model of the Ripple Reader, leading into a strong understanding and confident feeling of control towards the Ripple Reader.

From LampLight Labs first meeting with CNIB, we have learned that the younger generations of the visual impaired have been increasing become familiar with smartphones. Because our solution has a smartphone component associated with it, prior experience with a smartphone

will be highly advantageous in familiarization with the smartphone component of the Ripple Reader.

2.2.4 Affordances

At the highest level, an affordance is an attribute of a system than enables a User to preform a desired action or ability. For the Ripple Reader, the affordances that are provided to the User are listed below.

Smartphone:
The smartphone will provide the user will the ability to take a picture of a text and convert it into braille. Another affordance that a smartphone will provide is auditory feedback that the user can use to help them learn braille.

Ripple Reader:
The Ripple Reader will allow the User to read the translated braille using the refreshable display that is on the face of the device. The underlying components for this affordance are actuators and a complex mechanical multiplexing system.

2.2.5 Signifiers

The signifiers that will be used for the Ripple Reader need to be well thought out to ensure that the User will be able to discover aspects about the device and to properly receive feedback with minimal lose of communication and meaning. The following signifiers can be found within out design

- the power switch will be in the top right with braille world for power below it
- the previous key will be located on the left side of the face of the device whereas the next key will be located on the right side of the face of the device. These keys will also have signifiers denoting their intended use in braille below them

2.2.6 Mappings

Efficient mapping of important controls will allow the user intuitive control mappings by following the principles of good mapping enhanced as much as possible though spatial layout and temporal contiguity.

For the Ripple Reader we have thought in detail about where to place each of the controls following the ideas of good mapping. Below we have listed a couple examples of where we will be mapping the controls for the ripple reader.

- There will be no buttons that will be placed below the refreshable braille display. This is to ensure that we can provide with user with a wrist rest.
- All the controls will be located above the refreshable braille display or to the sides of the braille display
- More specifically, the “previous line” and “next line” buttons will be placed on the left and right of the refreshable braille display respectively. This mapping will be intuitive for the user as spatially when the user reaches the end of a line they will already be near the “next line” button. If they would like to go to the previous line, they will need to reread the previous line started from the left side of the refreshable braille display which is where the “previous line” button is located near.

2.2.7 Constraints

Adding constraints to our design will limit the number of actions that the user can preform with the device. The actions that will be removed are such that they offer no utilization towards the Ripple Reader. A major constraint that is being applied to the deign of the Ripple Reader is the quality that all of the controls for the standalone Ripple Reader will be on the face of the device.

A major constraint that is available to LampLight Labs is our product's integration with smartphones. Because half of our entire system is based around a smartphone app, we are already able to limit the amount of actions that a user performs with the smartphone app. By programming the app in a very intuitive format and adhere to quality of good user experience, we can help cut down on any unnecessary actions that the user might make.

Some other smaller constraints are listed below:

- The device will be physical constrained such that it will be small enough to be portable yet large enough to be useable.
- The power button location will be where most laptops have their power button which is on the top right of the keyboard. Our design draws parallel from this as we have done the same.

3. Engineering Standards

Here at LampLights Labs were adamant, and stringent, in the application of engineering standards that effects not only user experience (UX) for clients just using Ripple Reader as an accessibility tool but any other individuals interacting with our products. As such, the following UX related engineering standards can be broadly broken down to into two main, not necessarily mutually exclusive, subsection: standards that directly correspond to the unique needs of a braille reader and standards associated with R&D, production, maintenance, user safety, etc.

As with any great product, the entire development and life-cycle most meet industry standards because the UX begins not with the intended market's end user but when the very first part is designed for production and it ends when the very last part is dismantled. The continuity of following industry standards throughout the entire life of Ripple Reader is not only crucial to the delivery of market competitive product but guarantee that any individual handling Ripple Reader has the upmost confidence that their safety is our number one concern.

As such, is vitally important that Ripple Reader meets the following standards because they guarantee that explicit needs of Unified English Braille (UEB) users are meet.

Standard Name	Issuer
Accessible Signage Guidelines, 2016	Braille Literacy Canada
Braille Formats: Principles of Print-to-Braille Transcription, 2016	Braille Authority of North America
Guidelines to produce Automated Braille Transaction Documents. 2016	Braille Literacy Canada
Guidelines and Standards for Tactile Graphics, 2010	Braille Authority of North American & Canadian Braille Authority
Rules of Unified English Braille, Second Edition, 2013	International Council on English Braille (ICEB)

Table B - 3 Braille standards

By following the above standards, we signal to visually impaired community that Ripple Reader is fully compliant with their existing knowledge of UEB and adopters will quickly become comfortable with our product with minimal adaption. Furthermore, by following these standards we guarantee that individuals learning braille through Ripple Reader have the assurance that their knowledge of UEB is transferable to other mediums (such as printed books) or other UEB compliant devices.

Though UEB compliance is the top of the priority list for standards that must be met to deliver a superb end-user UX. Ripple Reader utilizes numerous input/output subsystems, besides braille, to deliver a fully function product; most notably Bluetooth Core Version 4,0 and Universal Serial Bus Revision 2.0 Specifications. By following these standards, LampLight Labs guarantees a

high degree of interoperability with current generation hardware (such as various model of Samsung S series of smart phones) to maximize both the potential size of our intended market and the future market of Ripple Reader through backwards compatibility built into the above standards.

Lastly, Ripple Reader will follow several standards relating to the internal electro mechanical subsystems that enable Ripple Reader to deliver unmatched user value. Furthermore, by following these standards Lamplights Labs will be to more effectively communicate with future innovation or manufacturing partners by using standards as knowledge bridge to expedite the consolidation of conversation without being bogged down in Ripple Reader unique jargon. Please refer to Table B - 4 for full awareness of the standards that Ripple Reader will follow.

Standard Code	Standard Name	Issuer
CAN/CSA-C22.2 NO. 61508-1:17	Functional safety of electrical/electronic/programmable electronic safety-related systems	CSA Group
CAN/CSA-C22.2 NO. 0-10 (R2015)	General requirements - Canadian electrical code, part II	CSA Group
C22.2 NO. 0.15-15	Adhesive labels	CSA Group
CAN/CSA-CEI/IEC 62304:14	Medical device software - Software life cycle processes	CSA Group
ISO 13854:1996	Safety of machinery -- Minimum gaps to avoid crushing of parts of the human body	International Organization for Standardization
ISO 9241-920:2009	Ergonomics of human-system interaction - Part 920: Guidance on tactile and haptic interactions	International Organization for Standardization
C22.2 NO. 0.23-15	General requirements for battery-powered appliances	CSA Group
CAN/CSA-C22.2 NO. 107.2-01 (R2016)	Battery Chargers	CSA Group
CAN/CSA-C22.2 NO. 0.17-00 (R2013)	Evaluation of Properties of Polymeric Materials	CSA Group
ISO / ASTM52915 - 16	Standard Specification for Additive Manufacturing File Format (AMF) Version 1.2	International Organization for Standardization

Table B - 4 Other Standards

4. Usability Testing

4.1 Analytical Usability

4.1.1 Heuristic evaluations

The following heuristics taken were based on Nielsen's heuristics in his book *Usability Engineering.* [6]

Heuristic	Implementations
1. Visibility of System Status	The Ripple Reader can use a voice to tell the user when they are switching modes. The application can further be used to poll the system for its current status of operation.
2. Match between system and real world	The reader uses the same braille standards several other Reader employ to match with real world standards of the language After discussing with the CNIB it was revealed that reading braille is more about sliding fingers over the character rather than statically placing a character under a user's finger. As such the previous current and next characters are always actuated for the user so they always have a sliding feel over the characters The buttons have shapes that will end up being familiar to a user. A play shaped triangle button will end up powering the system on and off. Another button will have a speaker on it to signal to the user that it is for the audio portion
3. User Control and Freedom	The user can nearly at any time switch from any state of the device to another state. As the master thread of the device will always be dedicated to actuating cells the user should never be blocked while running another thread even if it was unintended
4. Consistency and Standards	Our product will follow a single set of standards in different area's. If standards are conflicting the standard we apply will be explicitly written in the user guide
5. Error Prevention	Error prevention is most important when a user is going to overwrite data on the reader. As such before a phone or computer sends data to the reader the corresponding device will ask the user if they really want the data to overwrite existing content
6. Recognition rather than Recall	As all buttons will be embossed, the user will not necessarily need to remember the position of the buttons
7. Flexibility and Efficiency of Use	The phone application will be able to be set into an automatic or manual mode as specified by a less novice user of the device. This will allow experienced users to tailor their experience of the Reader to their own needs making it simpler to use and match their skill level with a camera
8. Aesthetic and Minimalist Design	The reader will be designed to be as small as possible to be convenient for the user to use. Further it will be designed to

9. Help users recognise, diagnose, and recover from errors	When a user enters an error state, the reader will notify the user of the error and attempt to go back to the basic actuation state
10. Help and documentation	The Reader will come with a phone number in the package along with a user manual and repair manual, so users don't get discouraged in case something is not clear to them or the product breaks

Table B - 5 Table of Heuristics

4.1.2 Cognitive walkthroughs

4.1.2.1 Tasks and Action Sequence

Task Description	Action Sequence
Switch on the Reader	Press On button
Switch off the Reader	Press Off button
Find charge level of Reader	Listen to the phone audio
Recharge the Reader	Plug charging cable to USB port
Connect Reader to computer via USB cable	Plug USB cable to computer and Reader
Pair Reader to phone via Bluetooth	Enable Bluetooth on Reader -> Pair with phone
Take a picture using the Reader	Place Reader over text -> press capture button
Locate Braille characters	Feel the top of Braille reader and locate Characters
Switch to next set of characters after reading the first set	Press next button
Go back to previous set of characters	Press prev button

Table B - 6 Task and Action List

4.1.2.2 Cognitive Questions

Task	Cognitive Questions	Results
Switch On Reader	Will the user be trying to switch on Ripple Reader?	
	Will the user be able to notice the Ripple Reader Switch On button?	
	Once the user finds the button, will they know that it is the right one for the switching On the Reader?	
	After the Ripple Reader is switched on, will the user understand the feedback given?	
Switch Off Reader	Will the user be trying to switch Off the Ripple Reader?	
	Will the user be able to notice the Ripple Reader Switch Off button?	
	Once the user finds the button, will they know that it is the right one for the switching Off the Reader?	
	After the Ripple Reader is switched Off, will the user understand the feedback given?	
Find charge	Will the user be trying to find the charge level of the Ripple Reader?	

level of Reader	Will the user be able to notice the Ripple Reader charge level through the phone?	
	Once the user finds the charge level option, will they know that it is the right one to check the charge?	
	After the charge level button is selected, will the user understand the feedback given?	
Recharge the Reader	Will the user be trying to recharge the Ripple Reader?	
	Will the user be able to notice the Ripple Reader USB port?	
	Once the user finds the port, will they know that it is the right one for charging the Reader?	
	After the Ripple Reader is plugged in to charge, will the user understand the feedback given?	
Connect Reader to computer via USB cable	Will the user be trying to connect Ripple Reader to the phone?	
	Will the user be able to notice the Ripple Reader USB port?	
	Once the user finds the USB port, will they know that it is the right one for connecting Reader to computer?	
	After the Ripple Reader is connected to the computer, will the user understand the feedback given?	
Pair Reader to phone via Bluetooth	Will the user be trying to pair Reader to phone via Bluetooth?	
	Will the user be able to notice the Ripple Reader Bluetooth pairing button?	
	Once the user finds the button, will they know that it is the right one for pairing the Reader?	
	After the Ripple Reader is paired, will the user understand the feedback given?	
Take a picture using Ripple Reader	Will the user be trying to take a picture with the Ripple Reader?	
	Will the user be able to notice the Ripple Reader camera button?	
	Once the user finds the button, will they know that it is the right one for taking a picture?	
	After the picture is taken, will the user understand the feedback given?	
Locate Braille characters	Will the user be trying to locate Braille characters layout on Ripple Reader?	
	Will the user be able to locate the Braille layout?	
Switch to next set of characters after the first set	Will the user be trying to switch to the next set of characters?	
	Will the user be able to notice the next character set button?	
	Once the user finds the button, will they know that it is the right one for the switching to the next set of characters?	
	After the next character set button is pressed, will the user understand the feedback given?	
Go back to previous set of characters	Will the user be trying to switch to the previous set of characters?	
	Will the user be able to notice the previous character set button?	
	Once the user finds the button, will they know that it is the right one for the switching to the previous set of characters?	
	After the previous character set button is pressed, will the user understand the feedback given?	

Table B - 7 Cognitive Question Sequence

4.2 Empirical Usability

4.2.1 User Testing

4.2.1.1 User profile

The following table describes the participants who will be recruited to conduct the usability testing.

Variables	Distribution
Number of Participants	20 - 30
Age Groups	(10 -15) 25%,
	(16 – 25) 25%,
	(26 – 50) 25%
	(>50) 25%
Gender	50% Men
	50% Women
Visual Acuity	50% Legally Blind
	25% Severely Visually Impaired
	25% Moderately Visually Impaired
Technical Skills	50% Daily use of Smart Phone
	50% Unfamiliar with Smart Phones
Braille Literacy	25% Not Familiar
	25% Somewhat Familiar
	25% Familiar
	25% Expert

Table B - 8 Groups invited to be part of usability testing

4.2.1.2 Method

The following checklist is used to conduct the user testing

Itinerary Checklist	Done / Not Done
Product description of the Ripple Reader to participants	
Briefing on the safe operation of the Ripple Reader to participants	
Description of objectives to participants	
Description of List of Tests	
Readthrough and clarifying consent form	
Obtain participant consent	
Conduct usability tests	
Conclude test and debrief	
Obtain feedback	
Compensate participants	

Table B - 9 Usability Testing Methodology

4.2.1.3 Objectives

The following are the list objectives to be tested.

Objectives	Results *Ex: 18/20*
Can the user switch on the Reader	
Can the user switch off the Reader	
Can the user find charge level of Reader	
Can the user recharge the Reader	

Can the user connect Reader to the computer via USB cable	
Can the user pair the Reader to phone via Bluetooth	
Can the user take a picture using the Reader	
Can the user locate Braille characters	
Can the user switch to next set of characters after reading the first set	
Can the user go back to previous set of characters	

Table B - 10 Test Objectives

4.2.1.4 Task list

The following is the layout of the list of tasks and variables introduced in the experiment.

Description	Machine state	Success / Failure	Time Taken
Switch on the Reader	1. Reader switched On/Off 2. Full Charge		
Switch off the Reader	1. Reader switched On/Off 2. Full Charge		
Can the user find charge level of Reader	1. Reader switched On/Off 2. Half/Full/Empty Charge		
Can the user recharge the Reader	1. Reader switched On/Off		
Can the user connect Reader to phone via USB cable	1. Reader switched On/Off		
Can the user pair the Reader to phone via Bluetooth	1. Reader switched On/Off 2. Reader App Open/Closed		
Can the user take a picture using the Reader	1. Reader switched On/Off		
Can the user start reading the characters	1. Reader switched On/Off 2. Reader App Open/Closed		
Can the user switch to next set of characters after reading the first set	1. Reader switched On 2. Reader App Open/Closed		
Can the user go back to previous set of characters	1. Reader switched On 2. Reader App Open/Closed		

Table B - 11 List of Tasks

4.2.1.5 Quantitative Data

The following data describes the quantitative data that will be collected from the testing session.

Task	Error Count	Error Description
Ex: Switch on the Reader	*Ex: 5*	*Ex: Failed to find On button*
Switch off the Reader		
Switch on the Reader		
Find charge level of Reader		
Recharge the Reader		

Connect Reader to computer via USB cable		
Pair Reader to phone via Bluetooth		
Take a picture using the Reader		
Locate Braille characters		
Switch to next set of characters after reading the first set		
Go back to previous set of characters		

Table B - 12 Quantitative Data Collection

4.2.1.6 Observations

The following tables describes the verbose observations made from the testing session, especially any safety issues.

Task	Observations	Reason
Switch on the Reader	*Ex: Majority of elderly users (>50) confused On button with Off*	*Ex: On and Off buttons located too close to each other*
Switch off the Reader		
Find charge level of Reader		
Recharge the Reader		
Connect Reader to computer via USB cable		
Pair Reader to phone via Bluetooth		
Take a picture using the Reader		
Locate Braille characters		
Switch to next set of characters after reading the first set		
Go back to previous set of characters		

Table B - 13 Observation

4.2.1.7 Feedback and Debrief

The participants will be debriefed on the observations made by the observers, and the participants' feedback will be obtained via questionnaires as listed in the table below.

Questions	Responses
What do you like about the device?	
What don't you like about the device?	
Would you consider using this device daily?	
What would you change about the device?	
What features would you want to see in future versions of the device?	
What features would you do not want to see in the device?	
What retail price would you set for this type of device?	

Table B - 14 Feedback Questionnaire

4.2.2 Field studies

Field studies will be conducted by providing potential users with a fully functional version of the Ripple Reader and letting them use the device for themselves for a set period. The user feed back will be obtained using mid study interviews, logging user data on the Ripple Reader automatically and by observations logged by the user after each use.

Criteria	Description
Participants	10 – 20 participants within the same demographic constraints as Usability Tests
Duration	2 – 3 months
Recruitment	Via CNIB or advertisement in media sources
Reimbursement	Will be discussed and agreed upon with participants
Data Collection	Mid study interviews, automatically logged user data, manually logged user observations after each use

Table B - 15 Field Studies

5. Conclusion

Having a strong UI and UX for our project lays a foundation onto how many users will adopt the product. Several of them will be adamant about the language not changing in any form, much in the same way that spoken languages do not change grammar rules once they have been placed. As such we have made it our top priority to make the user experience of our Reader, as similar for them as reading book in braille as possible.

Several design choices were implemented to make the user feel as comfortable using our device as possible all the way to actuating 3 cells at a time with the proper letters, so the user can have a feeling of sliding their finger over the cells rather than only actuating a single cell at a time with the proper letter. Other important features we put in the device include using multiple cells up to 18 so the user doesn't need to keep pressing the next button on the cells.

As we continue to develop the device we aim to keep in contact with the CNIB to ensure our incremental devices are seamless to use by the visually impaired. In an industry such as this, we need to make sure we stay in contact with people who are visually impaired, so we don't make improper decisions on the device.

ENSC 405W Grading Rubric for ENSC 440 Planning Appendix

(5-10 Page Appendix in Design Specifications)

Criteria	Details	Marks
Introduction/Background	Introduces basic purpose of the project. Includes clear project background.	**/05%**
Scope/Risks/Benefits	Clearly outlines 440 project scope. Details both potential risks involved in project and potential benefits flowing from it.	**/10%**
Market/Competition/ Research Rationale	Describes the market for the proposed commercial project and details the current competition. For a research project, the need for the proposed system or device is outlined and current solutions are detailed.	**/10%**
Personnel Management	Details which team members will be assigned to the various tasks in ENSC 440. Also specifically details external resources who will be consulted.	**/15%**
Time Management	Details major processes and milestones of the project. Includes both Gantt and Milestone charts and/or PERT charts as necessary for ENSC 440 (MS Project). Includes contingency planning.	**/15%**
Budgetary Management	Includes a realistic estimate of project costs for ENSC 440. Includes potential funding sources. Allows for contingencies.	**/15%**
Conclusion/References	Summarizes project and motivates readers. Includes references for information from other sources.	**/10%**
Rhetorical Issues	Document is persuasive and demonstrates that the project will be on time and within budget. Clearly considers audience expertise and interests.	**/10%**
Format/Correctness/Style	Pages are numbered, figures and tables are introduced, headings are numbered, etc. References and citations are properly formatted. Correct spelling, grammar, and punctuation. Style is clear, concise, and coherent.	**/10%**
Comments:		

Appendix C

ENSC 440 Planning

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Figures

Tables

1. Introduction

1.1 Intended Audience

The intended audience are the engineers at LampLight labs and the project mentors and supervisors we will be working with over the next few months. This documentation will serve as both a reference material as well as a design guidance document that will help the project meet its functional, safety and affordability goals and deadlines.

At LampLight Labs we are aware that none of the planning is set in stone and will undergo many changes as we continuously verify and iterate our design and requirement specification. However, the general structure of the project plan will remain the same.

In the ENSC 440 planning appendix we have attempted our best to foresee probable issues and conflicts that might arise as well as other general contingencies. We have also laid out plans for personal management and financial plans that will help us go about our tasks in an orderly organised fashion.

1.2 Project Background

The main purpose of the Ripple Reader project is to provide an affordable, easy to use educational tool that will help visually impaired persons gain literacy in Braille and in the process gain independence and get access to opportunities and employment.

The Ripple Reader will be affordable by using fewer actuators and by utilising the processing power of ubiquitous smart phones. The Ripple Reader can employ fewer actuators thanks to a unique actuation system that multiplexes single characters to multiple braille cells by identifying where the user's finger is positioned.

The Ripple Reader also provides audio feedback to the user which enables the user to actually identify and, in the process, learn Braille characters. We at LampLight Labs hope that this will enable young, middle aged as well as elderly people easily learn Braille.

In addition to being a learning tool the Ripple Reader also will be able to act as an accessibility device whereby visually impaired people will be easily be able to take pictures of text and read it through the Braille display.

Hence, at LampLight labs we hope that we will be able to successfully conceive a device that grants visually impaired people literacy in Braille and the ability to go about their day to day needs with ease.

2. Scope

The scope of our project has been decreased in some respects from our original proposal. One major descope that was done is that LampLight Labs has agreed as a group to pursue the off-board configuration. This has allowed the group to descope the uncertainty and ultimately reduce the amount of risks as will be shown in Table C - 1 heading into ENSC 440. The scope remains mostly unchanged and these sections will reflect it as such.

2.1 Risks

The following table, Table C - 1, details the risks of the project. The Risks table from the Proposal has been borrowed here and modified accordingly. Details may be found in Appendix E

for understanding the table below.

Risks	Severity	Likelihood	Impact Area	Mitigation Strategy
Team members may become ill	Minimal	Medium	Any part of the project can be affected depending on who gets sick and when	Our team has multiple members in each domain of expertise so that if one person becomes ill, another member can take over the ill members duties
Feature Creeping inflates the scope of the project	Significant	Medium	The project will have constant delays which may prevent the product from achieving fruition within the launch window.	Project members must all agree on the scope of the product and not add features without further analysis being performed on the viability and rate of return of the feature
Project timeline is miscalculated	Severe	Low	The entire project could be affected as an unforeseen critical path could block development	The timeline will be reviewed and revised multiple times throughout the project launch window
Stakeholders disagree on what the product should be or what it should be capable of	Minor	Medium	Stakeholders may request changes to the product that could have a sizable impact on the products original timeline and purpose	We will frequently communicate with Stakeholders to update them with our design implementations. Concerns from the stakeholder will be taken into consideration during planned review sessions
Stakeholders become disengaged with the product and	Moderate	Low	If stakeholders become disinterested, we will lose our ability	We will keep the stakeholders informed about the progress of the

stop communication			to ask our target audience for feedback	project to remedy any concerns they may have
Project is not communicated coherently with the stakeholders	Significant	Low	The product may lack significance for the stakeholders	The Group will be concise when communicating with any of the shareholders to avoid mistranslated ideas
Team misinterprets the projects requirements	Severe	Low	The entire project will be affected as the final product would not match the requirements specifications	The requirements will be strictly typed so that misinterpretations of the requirements can be minimized
Incorrect phrase read to user	Severe	Low	Reading an incorrect phrase could be dangerous to the user	The team will ensure the most high end OCR is done to make sure proper characters are read into the Ripple Readere
The target audience may not find the product easy to use	Severe	Low	The product will not sell well and be a commercial failure	Constant communication with stakeholders and the target audience will mitigate this
Team may be unable to agree on a solution to the problem	Minimal	Medium	May cause the timeline of the project to be changed negatively	Every member will have the opportunity to voice their opinions and concerns about anything that pertains to the project during meetings
Failure to acquire financial support for the product	Minor	Medium	Project may not have sufficient funding to do everything that is proposed	The product will have requirements that are necessary different levels of requirements based on the funding we receive
Product may be too expensive that Consumers may buy the competition	Severe	Low	The product may become a commercial failure	The market price of the of the product will be compared with the competitor's products that are already in the market
Another company may come out with a similar product and beat us to the market first	Severe	Low	The product will be overshadowed by the first product to market and may not sell as well	Active research will be done to see what the market trends are, and we will adapt accordingly with changes being made to the schedule or requirements as needed.
The mechanical multiplexing system that is	Severe	Low	The product will not work without	LampLight Labs will constantly be testing the integrity of the current

the sole of the project may not be finished in time			this critical component	mechanical solution being as critical as possible in any possible flaws

Table C - 1 Table of Risks

2.2 Benefits

2.2.1 Affordability

To meet the stated goal of affordability from the eyes of the customer. Extensive measures have been made to optimize existing mechanisms for dynamically altering braille character arrays using a highly experimental analogue multiplexing system to reduce the overall size, weight, and power requirements when compared to our competitors.

Furthermore, special attention has, and will continue to, be given to the development of an overall systems architecture geared towards the ease of maintenance and repair through the appropriate choice of mechanical assembly designs; materials; and compartmentalization of subsystems.

2.2.2 Ease of Use

Since Ripple Reader most meet the exacting standards of braille both, standard and contracted versions, in terms of both translation and tactile feel. This project has a near clinical level of specificity for product to successful in its intended purpose. This specificity will be discussed in later documentation.

Assuming the dimensional requirements of braille are met, the final idealized product will take cues from ergonomic handheld devices, such as video game console remotes, and the unique needs of the partially sighted to develop a portable device with the snap-and-view properties of a digital camera and usability of an e-book. Thus, maximizing the practicality of any solution while simultaneously minimizing the stigmatization associated with using a device of assistance.

Finally, depending on the loaded software and braille library conversion tables. Ripple Reader is theoretically print language agnostic. Thus, opening the doors hundreds of thousands non-English speakers.

2.2.3 Educational Value

The final guiding principle is to maximize the educational value to students of all ages and experience through the proposed, but not guaranteed, incorporation of basic and advanced braille learning features such as contracted braille language and auditory feedback of current character (or word) being read.

Furthermore, the guiding principles of affordability amplifies the educational value of this device because a non-visually impaired individual will be, ideally, able to repair basic mechanical functionality of the device. While simultaneously exposing a greater number of individuals to socializing with those that are visually impairment.

3. The Market

3.1 Competitors

Some of the fundamental systems that compete with our product in our market today in order of increasing complexities are transcription programs, braille embossers, braille readers, reader-Apps, and advanced technologies.

Transcription programs allow teachers to quickly transform students work into a text file they can read to give auditory feedback on the work. This greatly reduces the teachers need to excel at reading braille. Some software's that exists today in this category include the 'Braille Blaster' [7].

Braille embossers are analogous to how printers work for text. They can take digital braille formatted files and emboss pages with their content. While you can export files to have them processed at a relatively affordable price, there are not too many embossers available and it can be difficult to get embossed materials promptly. The most affordable version of an embosser to buy from Braillo costs upwards of $23000 [8].

Braille Readers are machines which can read text from a computer and transcribe the text onto a set of actuators to give quick access to digital content in braille. The most affordable versions cost between $450 and $1200 being the Orbit Reader 20 [9] and the Canute braille reader [10]. The steep price difference is due to the Orbit only having a 20-character display while the Canute can provide a much more satisfactory 360 characters at a time. This allows any user or student to read braille without the need of switching the page of braille they are reading constantly.

Reader apps are mobile applications which can give the visually impaired the ability to experience the world. Two such applications are the free Seeing AI provided by Microsoft [11] and the KNFB reader [12]. Seeing AI can tell the user about the world around them and read physical text using OCR. KNFB on the other hand can do everything that Seeing AI can and be integrated with a braille reader to read the text taken in the picture through a braille reader. Unfortunately, KNFB costs upwards of $100 and having this along with a braille reader is quite expensive.

Finally, there are newer technologies being developed today such as notetakers, the tactile display provided by Team Tactile [13] and the BLITAB [14]. Notetakers are devices that are built into a tablet like device and often only have a few characters to work with. They allow users to interact online and do things one could usually do with a tablet. The most notable of these is the BrailleNote Touch [15]. These cost nearly $7000 but are incredibly useful for learning things straight off the internet. The tactile display is a braille display which can take a picture of any page of text and near instantly convert it into braille. This eliminates the need for a separate application to do the OCR. Finally, the BLITAB [14] is like a notetaker except rather than only providing the 18 characters provided by the BrailleNote, an entire screen provides the output. The Tactile display and BLITAB are still in early stages of development and have yet to make it to the market.

3.2 Our product

Our product fits in the middle of all these products greatest relative values as shown in the Figure C - 1 below. It is more affordable than most hardware because of its design to conserve on the number of actuators used. It is also able to connect to a camera which allows pictures and OCR to be done on images and be displayed to the screen much like the Tactile display and a KNFB linked braille reader. Further is can act as a regular reader by plugging into a computer. Finally, it has educational abilities as when the user is stuck at any point in the braille reading, audio feedback may be provided assisting the user to learn the language.

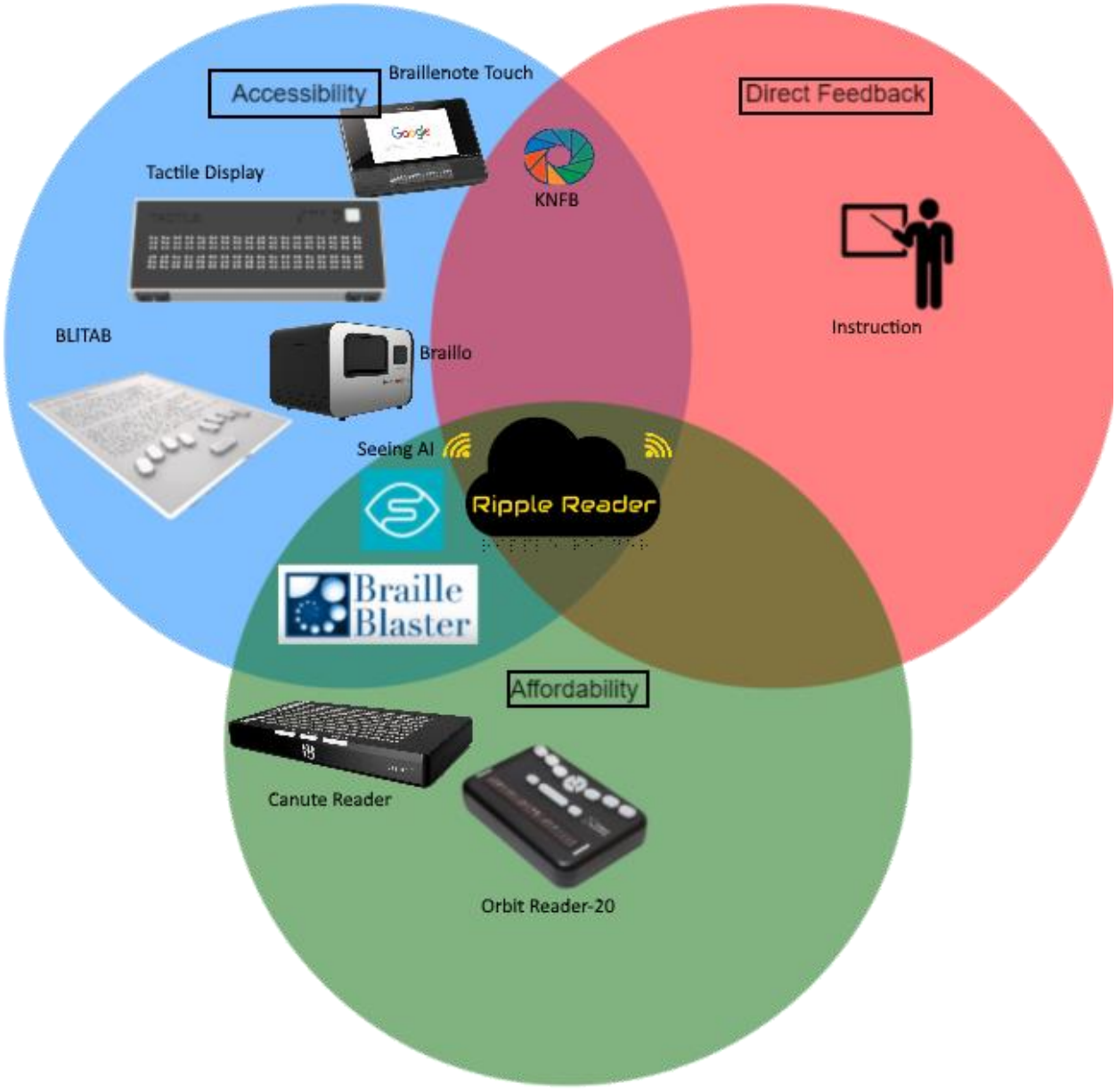

Figure C - 1 Competitors in the market of assisting the visually impaired in learning braille

4. Management

By leveraging the fundamental work already performed to deliver a proof of concept (POC) for its early April deadline. The transition from POC to prototype (PRT) development is expected to be relatively seamless since we have always planned on delivering a full optional prototype in early August. Furthermore, there has been no last-minute shake-ups in which aspects of Ripple Reader's prototype development that individuals team members are willing and able to perform. Thus, allowing any lead (of a task) to continue to apply their specialized knowledge without excess time spent transferring knowledge to a new lead. Specifics of whom will lead, and be seconded, to each task will be addressed after an overview of the project management methodologies and aids that will be used to manage development.

4.1 Project Management

As with any project that deals with multiple disciplines, it is fundamentally crucial to incorporate a certain degree of task parallelization to guarantee that progress is constantly being made and that all team members are engaged through the entire development cycle. Hence, Ripple Reader's prototype development can be split into four main domains: software/firmware; mechanical systems; electrical systems; coordination & logistics. These four domains correspond to Section 3 – 5 of the main text but in the context of revamping the POC into the outlined PRT in previous documentation. Please refer Gantt chart excerpt below to for a more in-depth breakdown of Ripple Reader's prototype development. Note that the end of each Phase is a milestone.

ENSC 440 (Summer 2018) - Ripple Reader Prototype

LampLight Labs
Caelan Midwood

Project Start: Mon, 5/7/2018
Display Week: 1

May 7, 2018

TASK	PROGRESS	START	END	7 M	8 T	9 W	10 T	11 F	12 S	13 S
Phase 1 Mechanical Design & Rev. Eng. of Electrical Systems										
Research Equivalent IRL System	0%	7-May	13-May							
Design Mech. Assembly	0%	14-May	20-May							
Consult with Ext. Refence/Redesigr	0%	20-May	31-May							
RE MCU's Neccesary Components	0%	7-May	16-May							
Determine PCB Requirements	0%	16-May	31-May							
Phase 2 Manufacturing & Testing of Mech. System & PCB Design										
Order Parts for Mech. Assembly	0%	1-Jun	7-Jun							
Assemble Mech. Assembly	0%	8-Jun	16-Jun							
Test Mech. Assembly & Tweak	0%	16-Jun	30-Jun							
Design PCB & Simulate (if possible)	0%	1-Jun	15-Jun							
Consultation for PCB & Optimize	0%	10-Jun	30-Jun							
Phase 3 Integration & Testing + Design & Print Enclosure										
Submit PCB Design 4 Manufacturin	0%	1-Jul	14-Jul							
Order aux. parts (batteries, etc.)	0%	1-Jul	10-Jul							
Design & Print Enclosure	0%	1-Jul	10-Jul							
Integrate Subsystems	0%	10-Jul	31-Jul							
Final Test & Presentation Prep.	0%	15-Jul	31-Jul							
Phase 4 Presenation & Buffer										
Estimated Completion Date		1-Aug	16-Aug							
Buffer		1-Aug	16-Aug							

Figure C - 2 Gantt Chart

Though the Gantt Chart outlines the chronology of the prototype's development, it does not address who will be leading each task as this will be laid out in the next section. Lastly, our team

at LampLight Labs have been utilizing a suite of digital tools to coordinate and communicate among ourselves with great success over the last four months and will be continue these practices over the next four as well. Additionally, weekly meetings will continue to be held throughout the entire semester with at least one in-person being meeting every fortnight.

4.2 Personnel Management

As mentioned in the previous section, each task will be assigned a "lead" based upon their interests and abilities with additional members "seconded" to aid them in completing the task. The position of 'lead' is merely a title bestowed upon the individual whom is documenting and coordinating the completion of the task, while working on it themselves, to ensure completion. Furthermore, just because someone is "seconded" to task doesn't mean that they subservient to the lead and retain full autonomy to suggest, raise, and question directives. Finally, the position of lead was created to allow all group members to have an opportunity to experience a certain degree of management authority (even if its minor and short lived) and isn't fixed. Please see Table C - 2 below for the, tentatively, assignments using individual's initials.

Task	Lead	Seconded
Research Related Mech. Designs	AM	AH, CM, RS, AM
Design Mech. Assembly	AM	AH, CM, RS, AM
Consult with Ext. Refence & Redesign	CM	AH, RS,
RE MCU's Necessary Components	AH	CH, AM,
Determine PCB Requirements	AH	AH, CM, RS, AM
Order Parts for Mech. Assembly	CM	CH
Assemble Mech. Assembly	AM	AH, CM
Test Mech. Assembly & Tweak	RS	AM, CM
Design PCB & Simulate (if possible)	CH	AH, CM, RS, AM
Consultation for PCB & Optimize	CM	AH, CM, RS, AM
Submit PCB Design 4 Manufacturing	All	
Order aux. parts (batteries, etc.)	CM	CH
Design & Print Enclosure	AM	CM, RS, CH
Integrate Subsystems	All	
Final Test & Presentation Prep.	All	

Table C - 2 Assigned tasks for 440

As mentioned in both Table C - 2 and Figure C - 2 above, there are two main consultation sessions that will, ideally, take place during the prototype development. The first will be with Rainhouse Canada (formerly Prototype Equipment Design) a Victoria based ISO-registered design and manufacturing company specializing in bespoke mechanical systems and the second will be with Creative Microsystems in Vermont, USA. Creative Microsystems is an American based microchip manufacture specializing in rapid small batch semiconductor manufacturing and optical holography. Both of these companies will be approached through a mutual contact, Dr. James Plant, whom served as Caelan Midwood's supervisor/mentor at Swiftsure Spatial System Inc. It should be reiterated that meeting with these two companies is tentative at best due to their extremely busy schedules and that fact that will be effectively providing pro bono consultation.

5. Cost Considerations

The cost considerations have been broken down into the following sub categories,

1. Research and Development

2. Procurement and Assembly

5.1 Research and Development Costs

Research and development costs in Table C - 3 below take into consideration all possibilities in terms of equipment and assembly that will be investigated for optimizing our product to adhere to the design standards. If a method or technology is found that satisfies our needs, any further research or development will be done in that category.

Subsystem	Components	Cost
Linear Motion Generation per braille pin	Linear Actuators	$40
	Piezoelectric Actuators	$40
	Solenoid Actuators	$30
	Novel Motion Link System	$100
Power	Battery	$30
	Motor Control Board	$100
	Power System	$50
Image Capture & Manipulation Board	Micro FPV Camera	$20
	Processing Board	$30
	Artificial Lighting	$10
	Ambient Light Control System	$10
Central Control Board	Interconnection Cables	$10
	Board	$25
	Buttons	$5
	Audio	$10
	User Feedback System	$30
Enclosures	Main Enclosure	$50
	Linear Motion Mounts	$20
Misc	Miscellaneous	$30
	Duct Tape & WD40	$20
	Reverse Engineering	$80
Buffer (20%)		$77
Total		$607
Total w/ Linear Motion		$820

Table C - 3 Research and Development Costs

5.2 Procurement and Assembly

The procurement and assembly cost in Table C - 4 below reflect the capital required to purchase all the parts, integrate them and assemble them according to the finalized product design.

Item	Units Estimate	Unit Cost Estimate	Description	Total Cost
Primary PCB	1	$25	For image processing, and converting text to both Braille and audio	$25
Secondary PCB	1	$25	For operating actuators and locating finger position through tactile sensing	$25
Camera	1	$15	For capturing text images	$15
Bluetooth Transmitter/ Receiver	1	$15	For transmitting and receiving data from smartphone	$15
3.5mm audio jack	1	$2	For audio output	$2
Actuators	18	$5	One for each Braille pin constituted within 3 Braille characters (3*6)	$120
Braille Character Assembly Units	9-18	$0.50	For Braille output	$10
Directional Buttons	4-5	$0.60	For navigating along a line of text and/or accessing the preceding or succeeding line	$3
3D printed actuating link network	1	$15	Since only 3 characters (previous, current, next) are actuated the link network will duplicate the characters to the rest of the Braille character assembly units	$15
Product Housing	1	$10	Housing for the entire assembly	$10
IR proximity sensors	1	$20	To keep track of where the finger is, an infrared sensor will be used to measure the distance, another option will be to complete a conductive circuit by having thin strips of copper throughout the outside of the device.	$20
Total cost of procurement, production, and assembly per unit				$260
Total cost of procurement, and assembly per unit with 20% buffer				$312

Table C - 4 Procurement and Assembly Costs

5.3 Funding

One of the main sources of funding for our project will be the Whighton Fund, for which we will send an application next semester.

Besides the Whighton funding, we are also negotiating with the CNIB for funds and they seemed interested in the design and affordability of our final product. We are expecting a positive response within the next few months.

Further, we have received a positive response from the IEEE SFU student branch for our funding request, and they are willing to provide us 100 CAD.
The final source of funding we are looking into is crowdfunding. We intend to produce a video of our product and hope to present it to the public along with our design specs. We hope this will encourage people to fund our project via a start-up page such as "*kickstarter.com*".

Currently we are unaware about the exact amount that will bestowed from each source to our project. It is hoped that all the sources will cover the majority, if not, all the cost. If there are any outstanding expenditures to be met, they will be covered through personal contributions.

6. Conclusion

The goal of the project is provide the visual impaired with a better solutions for both casually reading braille and learning how to read braille. With our product, we, LampLight Labs hope to bridge the gap between unaffordable refreshable braille displays and ways to learn braille with the Ripple Reader. The Ripple Reader will be the modern refreshable braille display that will be both affordable and a great teaching aid.

Over the duration of the past months we have come to realize how many other people have been seeking to make this work out and we believe that the 5 of us have the necessary skills to make this ground-breaking device. Hopefully sooner than later this product will reach the market and more people can finally have access to literacy in a more equal way to the average person.

Appendix D

Test Files

The following paragraph should be copied into a .txt file.

File name	Instructions	Contents of file
test.txt	Insert the 'Contents of file' into a .txt file on your computer. With the Ripple Reader connected delete all other files on the device and upload this file to the device.	This isds £ test file. It contains 28 words and 20 different words. It also contains 168 characters. It also contains 1 line. It is also self-referential. Wow!

Table D – 1 Test file contents

Appendix E

MITRE Guidelines for risk evaluation

Following are guidelines the group MITRE use to analyze risks brought forth from a project [16].

Severity	Description
Severe	A risk event that, if it occurs, will have a severe impact on achieving the desired results, to the extent that one or more of its critical outcome objectives will not be achieved
Significant	A risk even that, if it occurs, will have a significant impact on achieving desired results, to the extent that one or more stated outcome objectives will fall below acceptable levels
Moderate	A risk even that, if it occurs, will have a moderate impact on achieving desired results, to the extent that one or more stated outcomes objectives will fall well below goals but above minimum acceptable levels.
Minor	A risk event that, if it occurs, will have a minor impact on achieving desired results, to the extent that one or more stated outcome objectives will fall below goals but well above minimum acceptable levels
Minimal	A risk that, if it occurs, will have little or no impact on achieving outcome objectives

Table E – 1 Table of Severity [17]

Risk	Probability of Occurrence
High	65% - 100%
Medium	35% - 65%
Low	0% - 35%

Table E – 2 Table of Probability [17]

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