GNG2101 Final Report

LUMOS Light Flicker

Submitted by

Team C2B

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Abstract

Simple tasks such as turning on and off the lights can be impossible for the disabled. This is why we created Lumos, a touch activated light flicker. Our approach centered on accessibility and ease of use, with the goal of returning some independence to the user. By employing the iterative engineering design process, we were able to combine our technical skills and original ideas to create a fully functional product. Lumos is an original solution to the problem, and designed specifically for safe use in hospitals and long-term care facilities. This report outlines the design process of the product, as well as economic analysis and business modelling. The report also goes through the process of building and testing three prototypes.

Table of Contents

List of Figures

List of Tables

List of Acronyms

Acronym	Definition
Act.	Actuator
CAD	Computer-Aided Drafting
CB	Circuit board
g	Gram
IDP	Iterative design process
LED	Light-emitting diode
m	Meter
mm	Millimeter
N	Newtons
PLA	Polylactic acid
SM	Switchmate
3D	Three dimensional

1 Introduction

For the disabled, everyday tasks like turning on and off the lights can be impossible. Tools that can give them back their independence can be life changing. Lumos was created to give people with reduced mobility and strength the ability to turn the lights on and off in an accessible manner. Accessibility and ease of use were our top priorities. That is why we decided to make a touch sensor activated light flicker. The sensor is portable, easy to use, durable, and electrically safe. Unlike other available solutions, Lumos doesn’t employ Google Home since many users would be unable to interact with it due to vocal complications. What is more, Lumos is designed for safe and easy use in hospitals and special care home

2 Engineering Design Process

The iterative design process was used to work through the evolution of the design to ensure a final product that works well and meets the customer's needs.

Problem Refinement Loop

To determine if the right problem is being solved, several client meetings were organized at the beginning and throughout the development of prototypes. By presenting the research, analysis, and benchmarking to the client, any changes to the client's needs could be implemented into the problem statement.

Persistence Loop

Prototypes of different fidelities were created and tested to comply with each specific design constraint as well as ensuring each component can be integrated into the system. The lowest fidelity prototype used wires with scrap material to test if the the sensitive touch sensor could be used. The next prototype was used to test the mechanical portion of the devices which evolved from a gearing system to a servo motor. The components were integrated into a working system with first medium, then high quality materials. Tests performed analyses if the final product worked well for the needs of the client.

3 Need Identification and Product Specification Process

Problem Statement

Our client is a long-term patient at the Saint Vincent Hospital, they have very limited mobility and can only use their hands/arms to tap or hit things close to them. They need a device that can turn on and off the lights that they can use from their wheelchair. The resulting product could be accessible by a touch sensor or be voice activated via their Google home.

Prioritized Customer Needs

Using information from deliverable B, the following list of prioritized customer needs was created:

- The light flicker will turn a light on and off without the use of the light switch
- The light flicker is accessible from the seated position in a wheelchair
- The light flicker works with very little mechanical force or range of motion required
- The light flicker operates well after repeated use
- The light flicker does not catch on fire during regular operation

Benchmarking

Switchmate

- Magnetically snaps on top of existing light switches
- Takes voice commands through Google Assistant
- Operates through a mobile device and at the wall switch
- Fits over toggle and rocker switches
- Able to set multiple timers

Issues: could potentially catch on fire

Metrics

Metric	Unit	Need
Dimensions (LxWxH)	mm	
Weight of wheelchair-mounted component	grams	2
Weight of wall-mounted component	grams	1
Quantity	count	1
Battery Life	actuations/battery	4
Mean time between maintenance	weeks	6
Actuation force	N	3
Mean time to mechanical failure	actuations	4

Table 1: Metrics Table

Target Specifications

Performance	Measurable, often conflict between different performance specifications	The product should perform reliably for two years, excepting the necessary replacement of batteries
Service life of the product	Continuous? Intermittent?	Continuous, will be used numerous times per week, likely every day. Less frequent use in the summer. Needs to be functional for a long period of time before repair or replacement needed.
Installation	Delivered and installed; technical assistance.	Bocar available for assistance, we will aid in any way possible. Installation will

Aesthetics	Appearance	Ideally, it would be professional looking At the least it should have a good finish
Ergonomics	Man-machine interface	Needs to be attached to a desk or wheelchair and touch sensitive. Flicker device needs to be easily switched manually by any individuals trying to turn on the light normally.
Materials	Readily available, durable, cost	Needs to be constructed from durable materials such as metal, plexiglass and plastic
Production Life Span	Two years or two decades	Upwards of 3000 clicks
Quantity	One of a kind or 20 million?	One of a kind (two if time allows)
Documentation/Training	Ease of use of the product	Function needs to be easily understood and use needs to be easily repeated. Client is tech-savvy so this should not be a major concern.
Legal	Liabilities	Ensure we are not at fault for any malfunctions resulting in injury or damage of property or to life, etc.
Testing	Protocol to ensure that product meets specifications, required test equipment, facilities, time.	Repeated use testing implemented, product will be left to run for an extended time to simulate heavy wear on internal parts and on sensors to determine product life

Environment	Temperature, pressure, noise level during manufacturing, storage, use.	Will make limited to no noise, save for the clicking of the light switch which is unavoidable
Patents	Literature, product data – Do you have to license someone else's patent?	N/A we are making one product not to be sold, but for the clients personal use.
Quality/Reliability	Mean Time Before Failure (MTBF), Mean Time to Repair (MTTR)?	3000 clicks should last the client around 2 years, will need to replace the batteries every couple months
Competition	What similar products will be the competition?	The Switchmate and Hue by Philips will be competing products. Switchmate does not agree with client however.
Maintenance and repair	Frequency and type, ease of access, special tools material Needed	Need to replace batteries can be done with screwdriver
Weight	Easily handled by proposed users?	Light enough to be held onto the wall by two magnets
Size	Small enough, convenient for handling during shipping and use?	Product should be large enough that it can be touched easily but small enough to fit on the side of a wheelchair
Disposal	Green engineering, toxic, standards.	Batteries and motor need to be safely recycled after part life has ended.
Company constraints	Competing products, limits on funds, facilities, personnel	Limited budget of 100$

Customer	Familiar with this type of product, will need training for its use?	Very familiar with type of product as she has attempted a similar version
Time-scales	Three months or three years to get product to market?	3 months or less
Product Cost	How much can we manufacture it for? Target cost?	The target cost is $20 because that is the cost of the competing brand. However, a maximum of $40 is acceptable
Safety	Testing, warning labels, built-in safety switches/over-rides.	The product will be tested to ensure that it does not overheat or break. Since the product will not use a large amount of energy, over-rides will not be necessary.

Table 2: Target Specifications Table

4 Conceptual Designs

Actuator

1. Lamp-style clamp wireless design: Button on a portable desk clamp that communicates wirelessly to the light flicker
2. Wheelchair run over pad: A pressure sensitive pad on the ground that can be run over for actuation
3. Clamp-device with a large pressure sensor: A sensitive touchpad that would require little force or motor skills to use

Light flicker

1. Wheel with a motor: Motor spins wheel and flicks switch
    a. This is an improvement of what last year's project group attempted
    b. This design would make it harder to find space for any other hardware in the box, for example an Arduino or the batteries
    c. This design would require lots of specific prototyping

2. Linear actuator: Moves back and forth to turn the lights on and off with a gearing system
    a. The linear actuator seems perfectly suited for this use and would be very easy to install onto the current light switch
    b. The use of the linear actuator would leave a lot more room in the box than the wheel and motor design, would make it alot easier to fit in batteries, Arduino etc.

3. Open-faced case with moving mallets: The mallets would be moved with the use of a linear actuator or servo motor
    a. A secondary user could interact directly with the light switch
    b. Safety concerns may arise due to the open faced concept since the moving parts wouldn't be encased
    c. It would be difficult to code a motor to move one mallet at a time

4. Rotating cylindrical bit with two mallets and a push button: Closed casing with a button for manual use. A rotating, thin cylindrical bit with two mallets move the light switch would be used inside the casing.
    a. This design would be more mechanically difficult to configure and build than the others
    b. This design would also require a lot of prototyping and testing to ensure the rotation was exact and that enough force was applied

Actuator Platform

1. Google home
2. Android/ iPhone app
3. Manual actuation

Device	1	2	3	4	5	6	7			8	9	10	11	12	13
Performance	4	5	2	3	4	3	3			5	4	2	4	3	5
Service life	5	5	2	3	5	4	3			4	3	2	4	4	5
Ease of manufacturing	4	3	3	4	3	4	4			4	3	3	5	3	4
Complexity	5	3	3	4	3	4	4			3	2	2	5	3	4
Installation	5	5	3	5	5	5	5			4	3	2	5	3	3
Aesthetics	4	5	2	4	5	4	4			4	4	2	5	5	4
Ergonomics	5	5	2	4	5	3	3			-	-	-	-	-	-
Materials	4	5	1	3	5	3	3			4	4	2	5	3	5
Product life	3	5	1	2	4	3	3			5	2	2	4	3	4
Training	5	5	5	5	5	5	5			-	-	-	-	-	-
testing	4	3	2	4	5	3	4			4	2	2	4	3	4
environment	4	5	2	3	5	3	4			3	4	1	2	2	4
reliability	5	5	2	4	5	4	3			2	1	1	3	3	5
repair	4	5	2	3	3	4	3			3	1	3	2	2	4
weight	3	5	1	3	5	4	4			3	3	2	4	4	3
size	3	5	1	3	5	4	4			3	3	2	4	4	3
time scale	5	3	3	4	3	5	5			3	1	4	4	4	3
cost	4	2	2	4	5	2	3			2	1	4	3	3	4
safety	4	5	1	4	5	4	4			3	3	3	3	3	3
Total	80	84	40	69	85	71	71			59	44	39	66	55	67

Where:
1.Lamp clamp touch sensor pad
2.Fully google home solution
3.Wheelchair drive over pad
4.Spring loaded clamp touch sensor pad
5.App for tablet
6.Velcro strap attachment
7.Magnetic touchpad
8.Case with circular rotating actuator
9.Rubber belt with actuating rod
10.wheel with motor
12. Linear actuator
13.servo motor with linear motion gearing

5 Project Planning and Feasibility Study

Project Plan

Task List

Task	Task Owner	Required Resources	Completion Deadline
Client meeting	All members	N/A	Feb, 4, 2019
3D print parts			
Linear motion gears	Lucas	Makerspace	Feb 10, 2019
Desk clamp	Jamie	Makerspace	Feb 10, 2019
Button	Paul	Makerspace	Feb 10, 2019
Order parts			
Amazon	Eric	Money	Feb 10, 2019
Digikey	Paul	Money	Feb 10, 2019
Prototype circuit on breadboard	Paul	Circuit Components	Feb 8, 2019
Draw preliminary solution	Petra	Prototype components complete	Feb 9, 2019
Basic prototype assembly	Petra	3D parts	Feb 10, 2019
Gather research on design	Eric		Feb 13, 2019
Create powerpoint	Jamie	Research, prototypes	Feb 14, 2019
Practice Speech	All members	Finished presentation	Feb 14, 2019
Finalize changes for prototype 2	All members	Prototype feedback	Feb 15, 2019
Software flow chart	Paul, Lucas		March 5, 2019
Write code			
Button	Petra, Eric	Button	Feb 17, 2019
Radio	Paul	Arduino radio	Feb 17, 2019

Servo	Lucas	Arduino, motor	Feb 17, 2019
Touch Sensor	Paul, Lucas	Touch sensor circuit board	Feb 17, 2019
Tune touch sensor	Eric, Paul	Touch sensor, code for touch sensor	Feb 18, 2019
Test touch sensor	Jamie, Peta	Touch sensor, code for touch sensor	Feb 19, 2019
Finalize costs	Jamie	All parts ordered	Feb 28, 2019
Target Audience	Lucas		Feb 28, 2019
Compare to market	Eric	Prototype 1	Feb 28, 2019
Write up for report	Petra	Final design	March 3, 2019
3D print remaining parts	Eric	Makerspace	March 7, 2019
Laser cut casing	Petra	Makerspace	March 7, 2019
Compile code	Paul		March 7, 2019
Assemble prototype 2	Jamie	3D printed parts, code, motor, battery pack, laser cut case, arduino radio, arduino and wires, (all materials)	March 8, 2019
Test prototype	Lucas	Finished prototype 2	March 9, 2019
Video tests	Eric	Camera	March 9, 2019
Present progress to client	All members	Prototype 2	March 10, 2019
Research economics information	Lucas		March 12, 2019
Write report	Jamie		March 17, 2019
Create video plan	Petra		March 12 2019
Edit video	Paul	Video of tests, prototype design	March 17, 2019
Organize work done	Paul, Eric	All notes and ideas taken	March 23, 2019

Summarize project plan	Petra	Research used, prototypes	March 23, 2019
Analyse final design	Lucas	Finished prototype 2	March 23, 2019
Create presentation board	Jamie	Design ideas, research, final conclusion	March 28, 2019
Practice presentation	All members		March 28, 2019

Table 3: Task List

Feasibility Study

Technical: The team has had basic training in all technical aspects of the course, and is competent with coding. Paul is a fifth year student in electrical engineering, and has specialized knowledge and expertise with arduinos and circuits. The group will have to to self-learning on the subject of 3D modelling to make the 3D printed parts required.

Economic: The materials required are inexpensive and are needed in low quantities. We will leverage our access to 3D printing for free at the university to minimize costs by 3D printing as many components as is reasonable. The cost is expected to be under $100, the budget of the project, with room for unexpected expenses.

Legal: The materials required are inexpensive and are needed in low quantities. We will leverage our access to 3D printing for free at the university to minimize costs by 3D printing as many components as is reasonable. The cost is expected to be under $100, the budget of the project, with room for unexpected expenses.

Operational:There are no time delays in obtaining materials, and no required training to begin prototyping making. There no organizational constraints preventing the team's success. We are expecting to have sufficient time to create the product.

Scheduling: The product must be completed and functional by the end of the semester. Our design is straightforward yet effective Our plan has reasonable expectation for progres. There should be no issues with our milestones being met by the deadline.

6 Analysis:

Force analysis to move light switch

	Test 1	Test 2
Rocker Switch 1 (stiff)	0.18 N	0.19 N
Rocker Switch 2 (medium)	0.15 N	0.16 N
Rocker Switch 3 (soft)	0.12 N	0.135 N

Table 4: Force analysis data table

Average force required to actuate light switch

$$\underline{Force\ }(stiff) = \frac{0.18 + 0.19}{2} = 0.185\ N$$

$$\underline{Force\ }(medium) = \frac{0.15 + 0.16}{2} = 0.155\ N$$

$$\underline{Force\ }(soft) = \frac{0.12 + 0.135}{2} = 0.1275\ N$$

assume force is applied at a 90 degree angle

Arm length = 0.03m

Force provided by 9g servo motor (533g force)

$$Force\ =\ 0.533\ g * 9.8m^2/s\ \ = 5.22N$$

$$Torque = force * radius$$

$$Torque = 5.22N * 0.03m$$

$$Torque = 0.1566N.m$$

Force provided by 25g servo motor (700g force)

$$Force = 0.700g * 9.8m^2/s\ = 6.86N$$

$$Torque = 6.86N * 0.03m$$

$$Torque = 0.2058N.m$$

Based on the available torque provided by servo motors, the 25g was chosen so device could be implemented and used with all switches with ease.

7 Prototyping, Testing and Customer Validation.

We performed four main tests: sensor testing, radio range testing, motor testing, and integration testing with a light switch. The goal of our testing was to make sure that the individual components of the device met the requirements.

As more prototypes were created for specific testing purposes, regression testing was performed to make sure new prototypes performed as well as old prototypes. Sensor testing began with prototype one, motor and range testing began with prototype two. Integration testing began with prototype three.

Sensor Testing

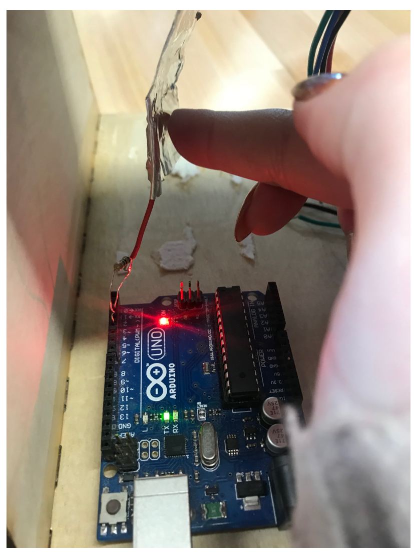


Figure 1: Image of sensor testing for prototype one

To test the prototype, the metal surface was touched with various forces and durations to ensure that it is sensitive enough to meet the specifications from deliverable B. This testing also ensured that there is no jitter (false detection of button pressing) in the system. The table below details the results of the testing. Taps are short touches, while holds are prolonged touches. The Arduino consistently detected the touch inputs and turned on and off the LED built into the Arduino.

Touch Type	Pressure Applied	Touch Detected
Tap	light	yes
Tap	medium	yes
Tap	high	yes
Hold	light	yes
Hold	medium	yes
Hold	high	yes

Table 5: Sensor testing table for prototype one

Motor testing

The main purpose of testing the motor was to determine whether the motor had enough power to actuate the light switch. Initial testing using the open source actuator only moved the switch up, and not down. After using a power supply that could supply more current, our prototype was able to actuate the switch in both directions with ease. In order to be able to use the more standard power supply, we adjusted the position of the motor on the actuator, raising it slightly. This also allowed our prototype was to actuate the switch in both directions with ease.

Originally, the USB power supply from microcontroller did not provide sufficient power to the motor. After increasing the distance normal to the switch cover the motor was able to provide additional torque and move the switch. Doing this makes the prototype closer to the final product, as it will have the light switch cover and our device casing separating it from the switch. The test results are summarized in the table (Table X) below.

Power Supply	**Motor placement**	**Successful Actuation Up**	**Successful Actuation Down**
Standard 1A USB supply	Low	Yes	No
Standard 1A USB supply	High	Yes	Yes
2A Bench Supply	Low	Yes	Yes
2A Bench Supply	High	Yes	Yes

Table 6: Motor testing table

Range testing

To test the range of our radios, we simulated the level of radio frequency interference that would be found in the hospital by performing the testing in the Makerspace during peak hours. The device was tested by actuating the switch on and off twice at varying distances. We began with a distance of 1m, and increased by 2m intervals until we reached a distance of 15m, or triple the maximum distance found in the hospital. There were no missed radio signals. The results of the testing are summarized in the table below.

Distance (m)	**First Actuation Detected**	**Second Actuation Detected**
1	yes	yes
3	yes	yes
5	yes	yes
7	yes	yes

9	yes	yes
11	yes	yes
13	yes	yes
15	yes	yes

Table 7: Range testing table

Integration Testing

When the final prototype was assembled, tests were performed to verify that all of the individual subsystems worked with one another. This included verifying that the housing of the device did not physically interfere with the moving parts of the device, that the housing did not physically interfere with the power cable connecting to the device, and performing the other prototype tests again to make sure the device functioned as required.

Summary of Client Feedback

At the third client meeting we presented our thoughts on the size of the device, and the placement of the device around the room. We had originally talked with the client about the touchpad device having a clamp. We had made the assumption that we could clamp it onto either her desk or her wheelchair tray. At this client meeting she suggested it be stuck onto the wall somehow as opposed to on her wheelchair or desk. We came to the conclusion that we will use command strips to stick the touchpad to the wall. Not only will this work better for Molly, but it also opens the door to making the device battery free, as it can be stuck on the wall close to an outlet. Although we had originally planned for a clamp-on design, this change is minor and can be implemented into the final design.

Detailed Design of Prototype Two

The objective of prototype two was to create a functional prototype of the final solution. The prototype had to be able to detect touch, transmit the detection to the wall mounted device, and actuate the light switch. To achieve this as simply as possible, the second prototype is a complete circuit on a breadboard. The only mechanical components present are those necessary to detect touch or actuate the light switch. We used 3D printed materials to save on cost.

The circuit diagram for this prototype is identical to the one designed for the first prototype, but the power supply of the sensor circuit is a wall power supply instead of three AA batteries. This was for simplicity and testing reasons. The circuit diagram in the figure below accurately represents that which will be implemented in our final product.

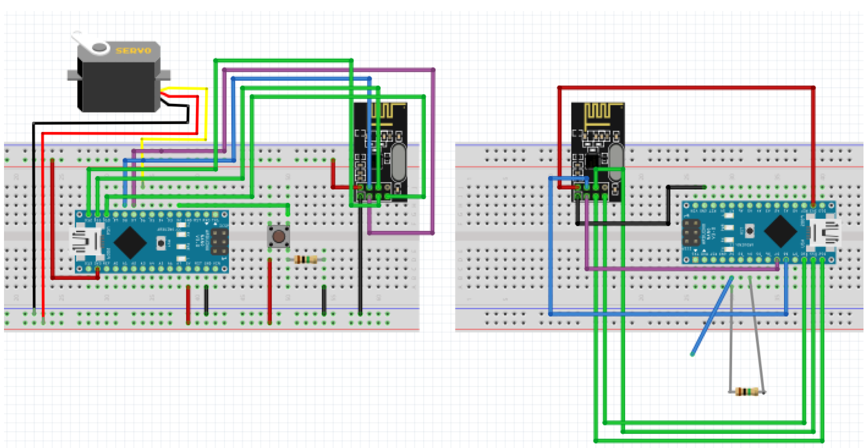


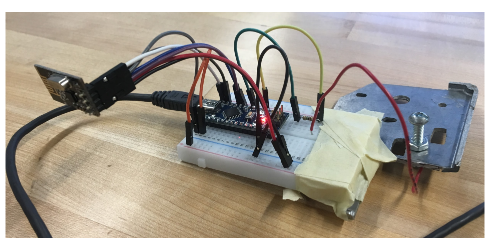
Figure 2: Prototype two circuit diagram

Changes to prototype

The largest changes in this prototype were to the mechanical design. Instead of the initially proposed gear design, we used a simplified open-source design for our light switch actuator. The mechanism now uses the rotational motion of the servo motor and a lever which is curved to flick the switch.

Figure 3: Image of prototype two actuator

Additionally, we removed the clamp and magnet attachment mechanisms for the sensor casing and wall casing respectively. Both will be fastened to their respective surfaces using *Command Strips*, as per changing client needs and hospital regulations.



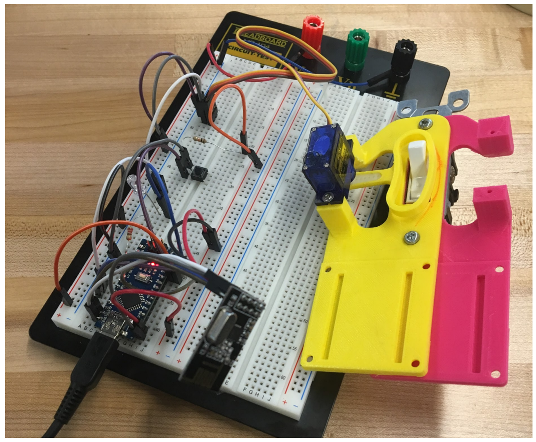


Figure 4: Images of prototype two assemblies

Design Verification

To verify the overall end effectiveness of our product, we will have to ensure that it meets a few key requirements. The client must be able to easily interact with the sensor device and have it recognize the input. The device must be able to operate on battery power and send the signal to the wall actuation device. The actuation device must provide enough force to flick the switch and the lever and motor assembly must be strong enough to withstand many repeated flicks without breaking or wearing down. To verify these, we will perform rigorous testing, much of which has already been accomplished. However, we will need to change the test environment to reflect that which our final product will have. The light switch in the client's room is much stiffer and will likely require a more powerful servo motor, and our touch sensor material will be sheet steel. We will need to verify the functionality of this material for our capacitive touch code. In addition we will need to arrange a final client meeting to test and tune the motor to the client's light switch. Once these key specifications are verified we can confidently say our final device will be fully functional and does indeed work "very well", and provides the solution to the original issue faced by our client.

8 Final Solution

In our final solution a number of changes were made to original design and the prototypes. We laser cut clear acrylic sheets to replace the cardboard design and to create an aesthetically pleasing case for the servo. We replaced the old 9g serve with a new 25g servo as to make sure that the servo provides enough energy to flick the switch reliably. We used a perf board to decrease the size of the circuit that was originally on the breadboard. All 3D printed parts were printed again and some parts were added, such as the housing for the radios and circuit boards for both devices. We also had to design and 3D print a new light flicking mechanism to fit the new 25g new servo.

Range testing

To test the range of our radios, we simulated the level of radio frequency interference that would be found in the hospital by performing the testing in the Makerspace during peak hours. The device was tested by actuating the switch on and off twice at varying distances. We began with a distance of 1m, and increased by 2m intervals until we reached a distance of 15m, or triple the maximum distance found in the hospital. There were no missed radio signals. The results of the testing are summarized in the table below.

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Table 8: Range testing table

Motor testing

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2A Bench Supply	High	Yes	Yes

Table 9: Motor testing table

Sensor testing

To test the prototype, the metal surface was touched with various forces and durations to ensure that it is sensitive enough to meet the specifications from deliverable B. This testing also ensured that there is no jitter (false detection of button pressing) in the system. The table below details the results of the testing. Taps are short touches, while holds are prolonged touches. The Arduino consistently detected the touch inputs and turned on and off the LED built into the Arduino.

Touch Type	Pressure Applied	Touch Detected
Tap	light	yes
Tap	medium	yes
Tap	high	yes
Hold	light	yes
Hold	medium	yes
Hold	high	yes

Table 10: Sensor testing table

Figure 5: Images of final prototype

9 Business model

Introduction

For the disabled, everyday tasks like turning on and off the lights can be impossible. Tools that can give them back their independence can be life changing. This document outlines the business model for an accessibility device that allows lights to be turned on and off remotely. The document also covers the reasoning for choosing the business model, the analysis of all assumptions made and the feasibility of the model.

Business Model

Chosen business method

We will manufacture a device based on what potential customers want and /or need, and sell said product to medical institutions where these people can use our device. Individuals who want the device can also buy it directly from us. These devices will have limited operational life, so by selling replacement parts, warranties and repair certifications we can create additional revenue streams, and also make it cheaper for those who buy in bulk and those who heavily use the device.

Business model canvas

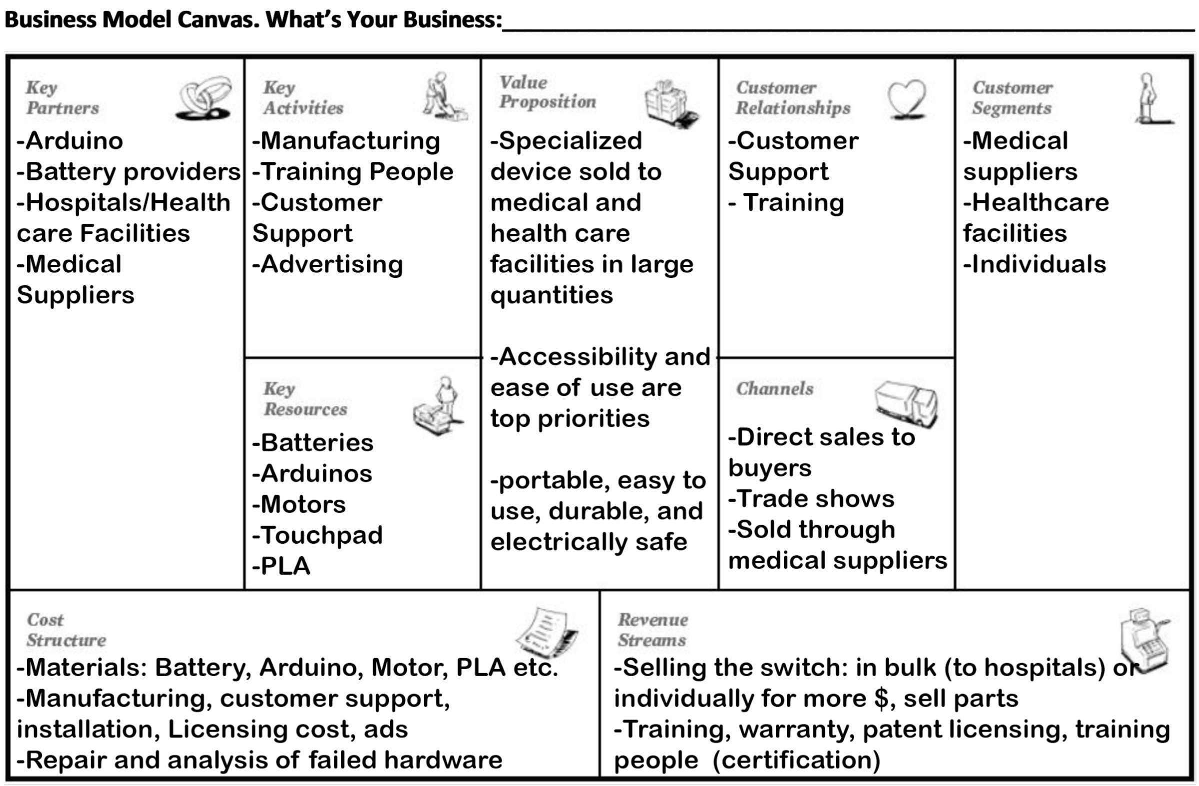

Figure 6: Business model canvas

Analysis

For this business model we are making these core assumptions:

- The customers will know what they want
    - Before creating our MVP we will need to consult some potential customers who know what product they would be willing to buy
    - We are assuming they know the specifics about the product they want
- Our key partners will be willing to work with us
    - We are assuming that we will be able to create a business relationship with our key partners (ex. Arduino is willing to supply us with their product for manufacturing the light flickr)
- The Market exists
    - We have not done any research in the market, we only have one customer with this specific problem
    - To make this business plan feasible their would have to be enough individuals and/or Medical suppliers who are willing to purchase our product

- Customers will have assistance
    - Assistants will be able to be trained as part of the customer relations part of the business
    - For us to sell training their need to be people who can/want to be trained

Our product focuses on accessibility rather than a smart-home solution which opens us to a market with much fewer competitors. Overall, this makes our business model feasible because we offer safety and affordability, which is necessary for a product of this type to be used in hospitals and healthcare facilities.

Previous Work

The previous work done on the project marketed the solution as a smart-home solution. This allowed them to reach a larger market. However, the smart-home market is saturated, and our solution is much better suited to the accessibility market. By catering to the niche of the accessibility market we can focus our efforts on meeting the needs of healthcare institutions. Such needs include electrical certifications, and not being internet connected.

10 Economic Analysis

Cost Classification

1.

Costs	Fixed	Variable	Direct	Indirect
Cost of materials		x	x	
Loans	x			x
Salaries	x		x	
Storage rental space	x			x
Marketing	x		x	
Patent lawyer	x		x	
Safety certification	x			x
Building	x			x
Equipment	x			x
Price	Fixed	Variable	Direct	Indirect
Individual product	x		x	
Bulk product		x	x	
Training professionals	x			x
Individual parts	x		x	

Table 11: Cost Classification

Cost and Income Statement

Income statement (2019-21)

Lumos

Income statement

1/1/2019

Revenue	2019	2020	2021
Sales of device	100 000	200 000	250 000
Sales of parts	5 000	10 000	15 000
Warranties	5 000	10 000	12 500
Training	1 500	2 500	4 500
Patent licensing	0	3 000	6 000
Cost of goods sold			
Materials	10 000	20 000	25 000
Manufacturing	2 000	4 000	6 000
Gross Profit	99 500	201 500	257 000
Operating expenses			
Marketing expenses	6 000	12 000	18 000
General + Admin exp.	10 000	3 000	3 000
Depreciation exp.	600	800	1000
Operating Income	82 900	185 700	235 000
*No interest or tax			
Net income	82 900	185 700	235 000

NPV Analysis

Net present value is the difference between cash inflow and cash outflow.

Cash Flow analysis

Cash flow year 1

Cash in		**Cash out**	
Cash sales	111 500	Expenditures from operations	28 600
Current borrowing	50 000	Cash spending	1 000
		Bill payments	5 000
		Salaries	125 000
		Marketing	5 000
		Purchase of equipment	10 000
Total cash in	161 500	**Total cash out**	174 600
Net cash flow	-13 100		

Cash flow year 2

Cash in		**Cash out**	
Cash sales	225 500	Expenditures from operations	15 800
Current borrowing	25 000	Cash spending	2 000
		Bill payments	10 000
		Salaries	150 000
		Marketing	12 000
Total cash in	250 500	**Total cash out**	189 800
Net cash flow	60 700		

Cash flow year 3

Cash in		**Cash out**	

Cash sales	287 500	Expenditures from operations	22 000
Current borrowing	0	Cash spending	3 000
		Bill payments	7 500
		Salaries	200 000
		Marketing	18 000
Total cash in	287 000	**Total cash out**	250 500
Net cash flow	36 500		

NPV:

Year	**Cash in**	**Cash out**	**Present value**
1	161 500	174 600	-13 100.00
2	250 500	189 800	42 081.81
3	287 000	250 500	72247.10

Assuming an interest rate of 10%

Break Even Analysis

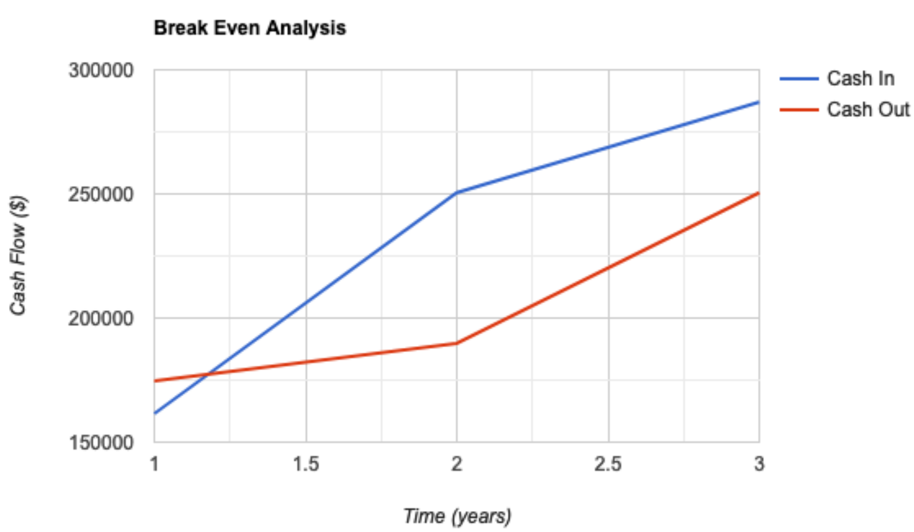

Figure 7: Break even analysis

Analysis of assumptions

In this analysis of the economics of our project several key assumptions were made. It was assumed that interest and taxes were negligible. As a result, they would not affect the outcome of the analysis. We assumed that the founders were able to procure the patent. It was also assumed that the founders would be able to procure a large enough bank loan that the business could be started. Furthermore, the company was expected to have enough customers to break even within the first three years.

11 Conclusions and Recommendations for Future Work

Going through the design process and working with a team has been a valuable learning experience. Many important design and engineering lessons were learned in the course of this project. The final design was reached through a combination of team discussion, design iterations, and testing. Using engineering design process, we were able to create a final product that worked very well, and was aesthetically designed. Recommendations for future work include refining the casing design, developing a more accurate battery lifetime analysis, and optimizing the flicker design to be able to use command strips. What is more, if we had designed a custom circuit board, we could have extended the battery life. Finally, we would recommend that future designs be water and dust resistant, so as to be IP67 compliant.

12 Bibliography

APPENDICES

APPENDIX I: User Manual

Important Features:

The device consists of two main components, both of which employ capacitive touch sensors. The devices communicate via radio transceivers which send the signal from the user input device to the flicker device which actuates the light switch. Encased in the user input device are three AA batteries, which can be easily accessed by unscrewing the back plate from the electronics housing.

Function and Capabilities:

The devices detect user input by sensing a voltage drop caused by touching a sensitive metal plate. If the portable sensor device is activated, it will send a signal to the actuation device which will then turn on the servo motor to actuate the switch. If the device activated is the actuator, it will take the input directly and turn on the servo. The devices are capable of communicating within a room and flicking a standard toggle light switch when affixed securely to the switch casing. The actuation device is capable of providing enough force to switch normal to moderately stiff switches.

Detailed Installation:

Apply adhesive to back side of device, and align the switch with the hole in the back of the actuator device. You may choose to set-up the sensor device in whatever manner you like. Using adhesive, it will attach easily to any flat surface, or the device can be used like a remote. Be sure to install all batteries correctly on the sensor device to ensure proper function. To remove the acrylic back plate, simply unscrew the hex-head nuts from the bolts found at the top of the device.

Operation & Maintenance Instructions:

To ensure proper function of all devices, ensure that before setting up or using the devices that the user mode is set to “Manuel Gonzales the 16th”. To do this, activate the quantum flux gate located on the back of the device and remove the safety key. This will transport you to the 5th dimension where you will see a pop-up window. Select the correct user from the drop down menu, and click “done”. When first setting up the devices, ensure that three fully-charged AA batteries are installed in the sensor device. The battery case can be easily accessed by removing the acrylic backing of the device. The devices are activated by touching the large metal plates located on the front of the device. These will activate the switch lever and toggle the light switch.

Health and Safety Guidelines or Precautions:

To ensure safe function ensure that the batteries are properly installed to prevent short-circuiting. Do not stick fingers in actuation device while in operation.

Troubleshooting:

Ensure the lever arm is positioned properly, position it in the middle before installing to ensure the switch is aligned properly before powering on. When plugged in the device will re-center itself, so the position of the lever arm should only be centered on the switch to begin. If the capacitive touch sensor is not functioning, the main issue is likely that an exposed wire is interfering with the capacitance. Ensure that when replacing the batteries, no electronic components are coming into contact with any erroneous conductive insulated metal strips.

Technical Instructions:

None. If this device breaks and you don't know how to fix it with the information provided on makerepo, just throw it out. This device is built as simply as possible and will not require any technical information for regular use.

APPENDIX II: Design Files

All the design files can be found on the team's MakeRepo page. The code, Solidworks designs, materials needed, and project proposal are linked there. What is more, there is a description of the project, an informative video, and pictures of our final project.
https://makerepo.com/buzulio/lumos

APPENDIX III: Other Appendices