Air Reach: IoT Gesture Appliance Communication System Design

20 Years in the Future Concept Report

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Air Reach

"Bringing a whole new convenience to everyday life"

Air Reach is a company innovating the way people with restricted mobility control their lives. This product will empower users with the ability to interact with objects with the use of hand gestures. This product will be able to control any WiFi enabled appliance with ease. The wearable device is comfortable, lightweight and very easy to use. An in home consultation will allow the company to provide the customer with a custom fit product as well as thoroughly explained instructions and lessons. A few hand gestures and theoven will be preheating to the desired temperature. A few hand gestures and a user does not have to move from their comfortable bed to turn off of the lights. A few hand gestures and there is no need to look for the remote to change the TV channel. The possibilities are endless with Air Reach.

The wearable device is comfortable, lightweight and very easy to use. An in home consultation will allow the company to provide the customer with a custom fit product as well as thoroughly explained instructions and lessons.This product will enable customers to take control of the world around them.

Introduction

The concept “Air Reach” is an IoT device that will allow users to control objects in their home that are capable of connecting to the internet. An IoT (Internet of Things) device is an everyday object interconnected with the internet and other components to give it a function beyond its normal use. (Citation, I don’t even like this sentence) The device would be worn on the hands of the user. The user would then perform registered hand gestures in order to interact with any appliance they choose.

The original idea for this concept stemmed from a want to help people with disabilities. With that in mind, this concept, “Air Reach”, will be a great convenience to those who have restricted mobility within their homes. Restricted mobility can be used to describe anybody that requires the assistance of devices such as wheelchairs, crutches, motorized chairs, walkers or similar products.

This user would also have to have appliances with WiFi capabilities. Appliances such as lights, ovens, refrigerators, washer, dryer, microwave, shower, door locks will eventually be transitioned into a series of appliances that can be connected to the internet. For example, Samsung produces a Smart Refrigerator that is WiFi enabled. This refrigerator has the ability to keep track of what it contains inside and is programmed to have features that allow the device to stream music and other outlets. The global smart home market will be at a value of 53 billion dollars by the year 2022.[7] This is a very promising statistics for Air Reach.

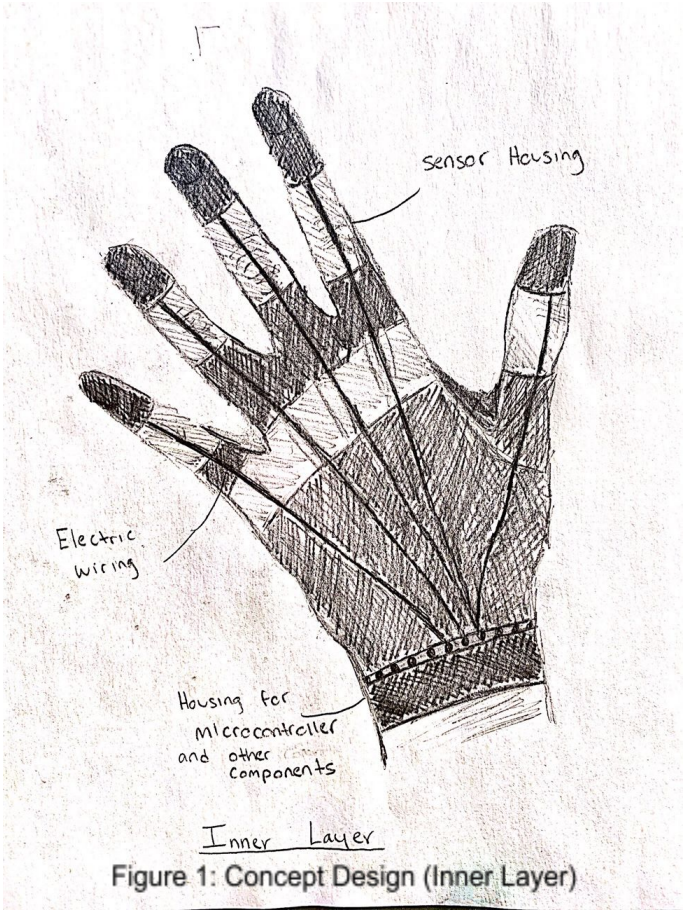


Figure 1: Concept Design (Inner Layer)

In order to connect hand gestures to commands for smart appliances, different electrical components will be necessary. In the original design, the device is worn on the users hand like a glove. A micro controller will be used to control the other components involved. A microcontroller in simple terms is a small computer in a single circuit board. Sensors will be placed on the digits of the hands. These sensors will be used to track the movement of the digits and hand to check which gesture is being

performed. The microcontroller will have WiFi capabilities that will allow the device to interact with other WiFi enabled devices on the network. The microcontroller will be programmed to recognize what gesture the hand is doing based on the output data from the sensors on the digits. The user will choose the hand gesture that corresponds to a specific device. For example, if the user wanted to interact with a light. Upon set up they would choose a hand gesture that registers to the light. This will eliminate confusion in terms of what device is being communicated with. The electrical wiring will be laced on the inner layer of the glove. The microcontroller will be housed in the glove in the area closest to the wrist.

The Original Sketch of the Concept Design

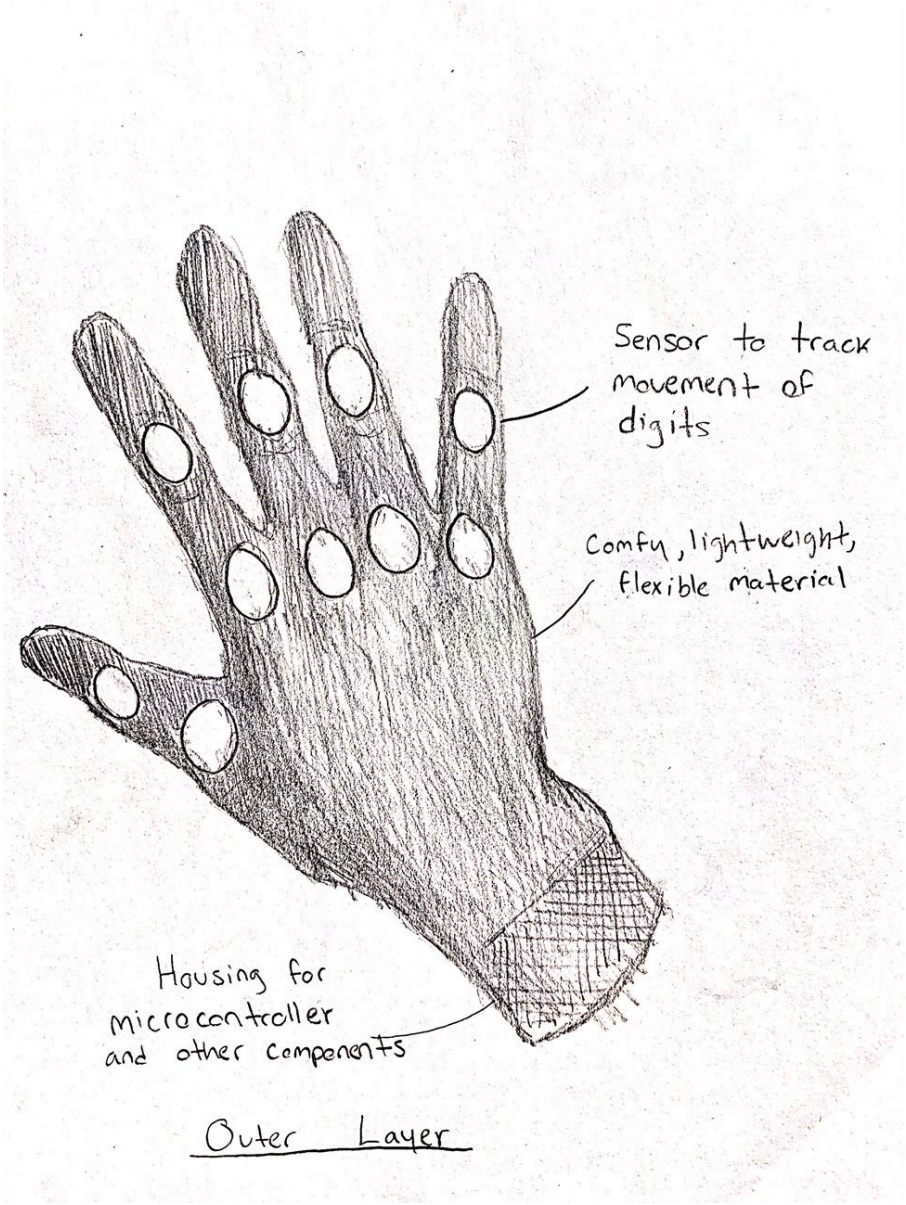


Figure 2: Original Concept Design (Outer Layer)

Mind Mapping

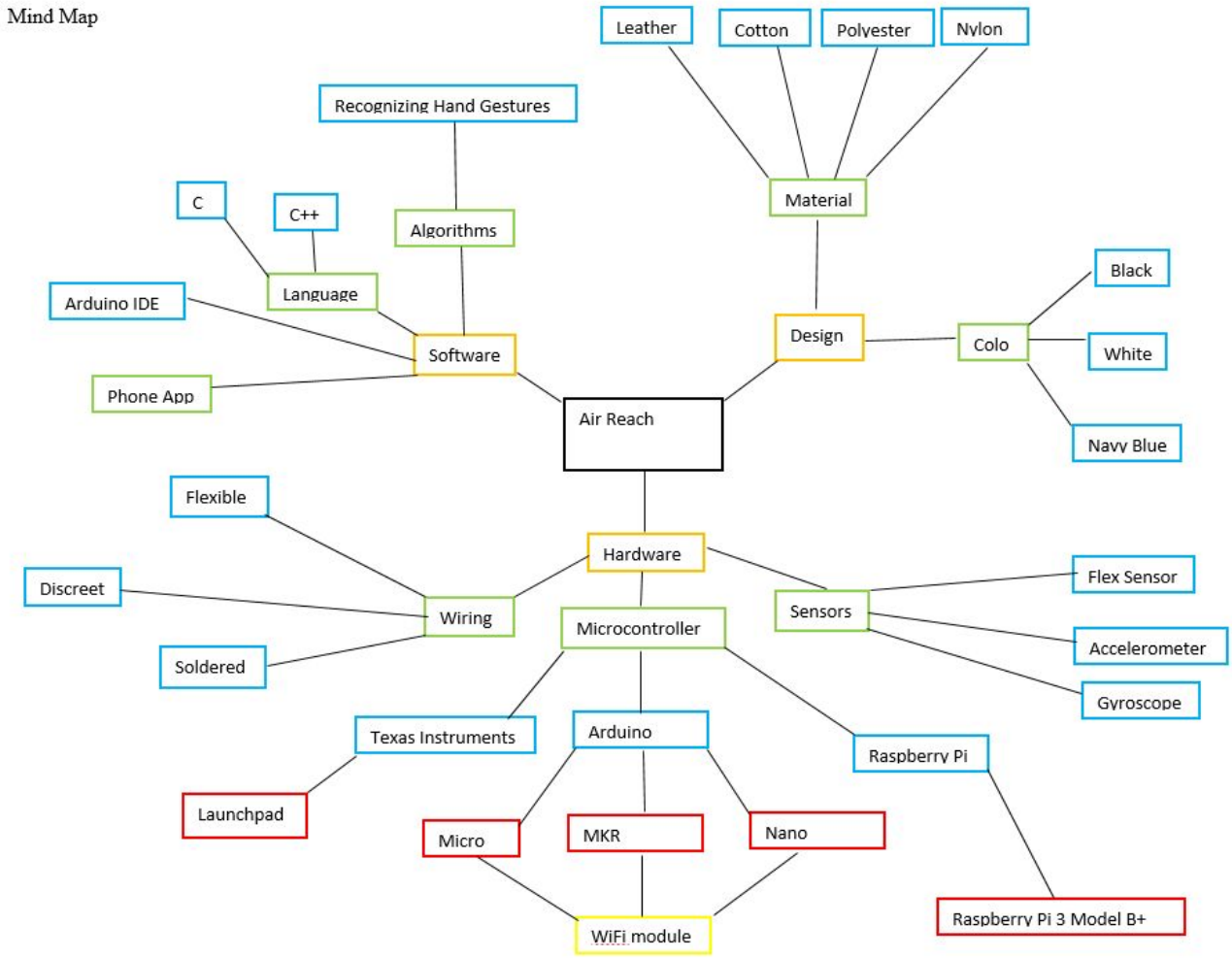


Figure 3: Mind Map

System Level Customer Needs and Specifications

Customer Pain Points	Customer Requirements	Product and Performance Specifications
Being unable to reach things	Ability to interact with things from a distance	The device will allow for interaction with appliances anywhere in the home that are connected to the internet.
Technology is complicated	Ability to understand and comprehend technology	When a device is purchased, a personal consultant will come to walk through the technology and provide easy to understand documentation with the user.
Having small hands	Ability to have the device fit properly	A custom sized device will be made for each user.

Table 3: System Level Customer Needs and Specifications

Sub-System Level Customer Needs and Specifications

Customer Pain Points	Customer Requirements	Product and Performance Specifications
Being uncomfortable with certain materials	The part of the device that is worn must be comfortable and made from a material that will not bother skin	The glove will be made out a combination of materials that will not irritate skin such as polyester and leather.
The device might not recognize my gestures.	The device must be able to analyze the gestures accurately.	The microcontroller will be embedded with a program that uses algorithms to sort out what hand gestures are being made with good accuracy.

Table 4: Sub-System Level Customer Needs and Specifications

Technology Benchmarking

Microcontroller	Size	Specs
Arduino Nano	43.18 mm × 18.54 mm	Microcontroller: ATmega328 Operating Voltage: 3.3 - 5V 32 KB Flash Memory SRAM: 2KB Clock Speed: 16 MHz Analog Input Pins: 8
TI LAUNCHPAD MSP432P401R EVAL BRD	68.6 mm × 53.3 mm	Microcontroller: MSP432P401R Operating Voltage: 1.6 - 3.7 V 256 KB Flash Memory SRAM: 64 KB Clock Speed: 48 MHz Analog Input Pins: 23
Raspberry Pi 3 Model B+	85.60 mm × 56.5 mm	1.2 GHZ quad-core ARM Cortex A53 1 GB LPDDR2-900 SDRAM Needs Analogue to Digital Converter

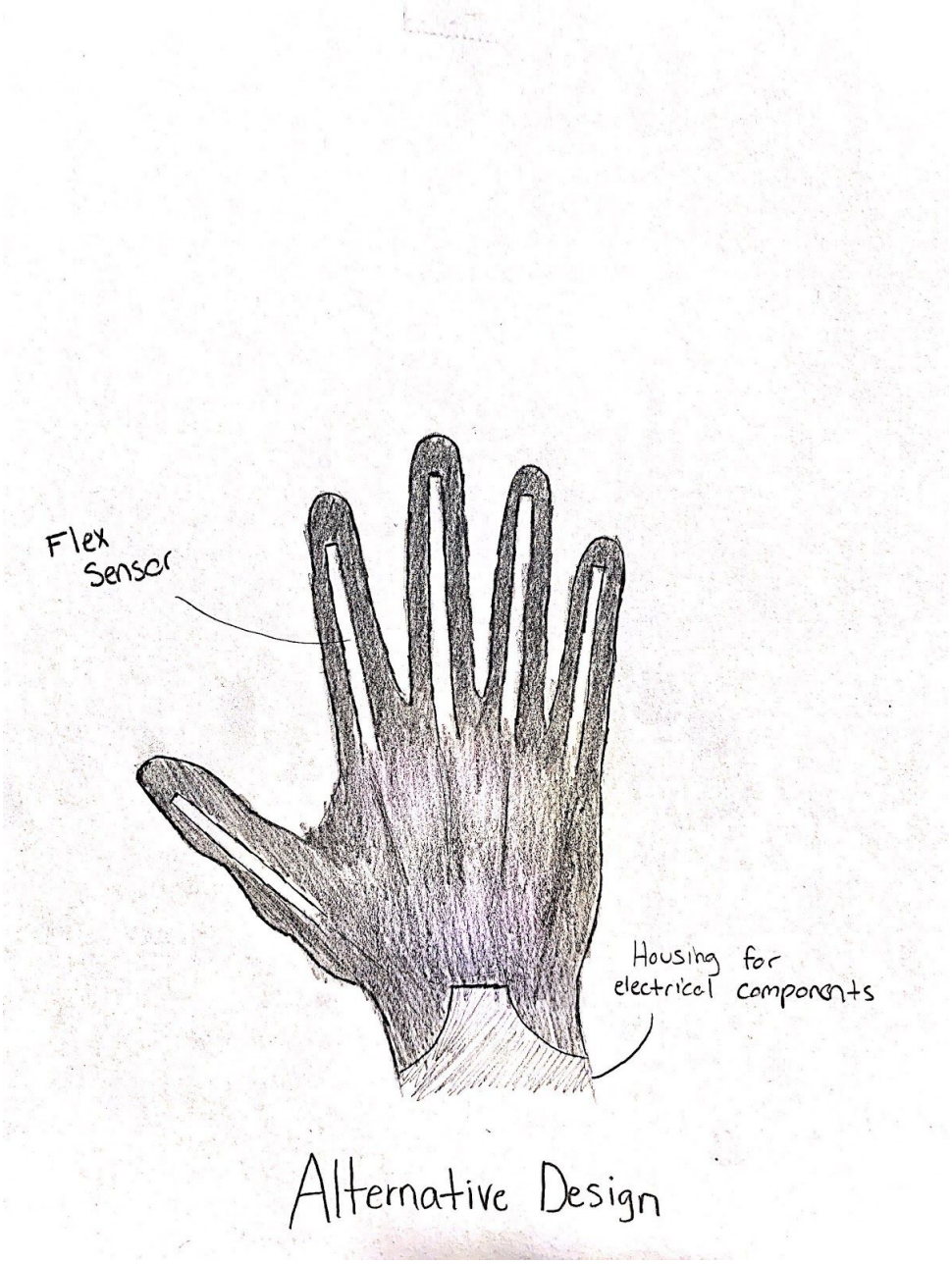
Table 5: Microcontroller Benchmarking [2] [6] [7]

Sensors	Size	Specs
Flex Sensors	55.88 mm in length	5 V Power Supply Outputs resistance value of sensor based on how much it is being bent.
Accelerometer: ADXL377	25.4 mm x 25.4 mm	3.3 V power supply Outputs acceleration measured in the X,Y, and Z axis.

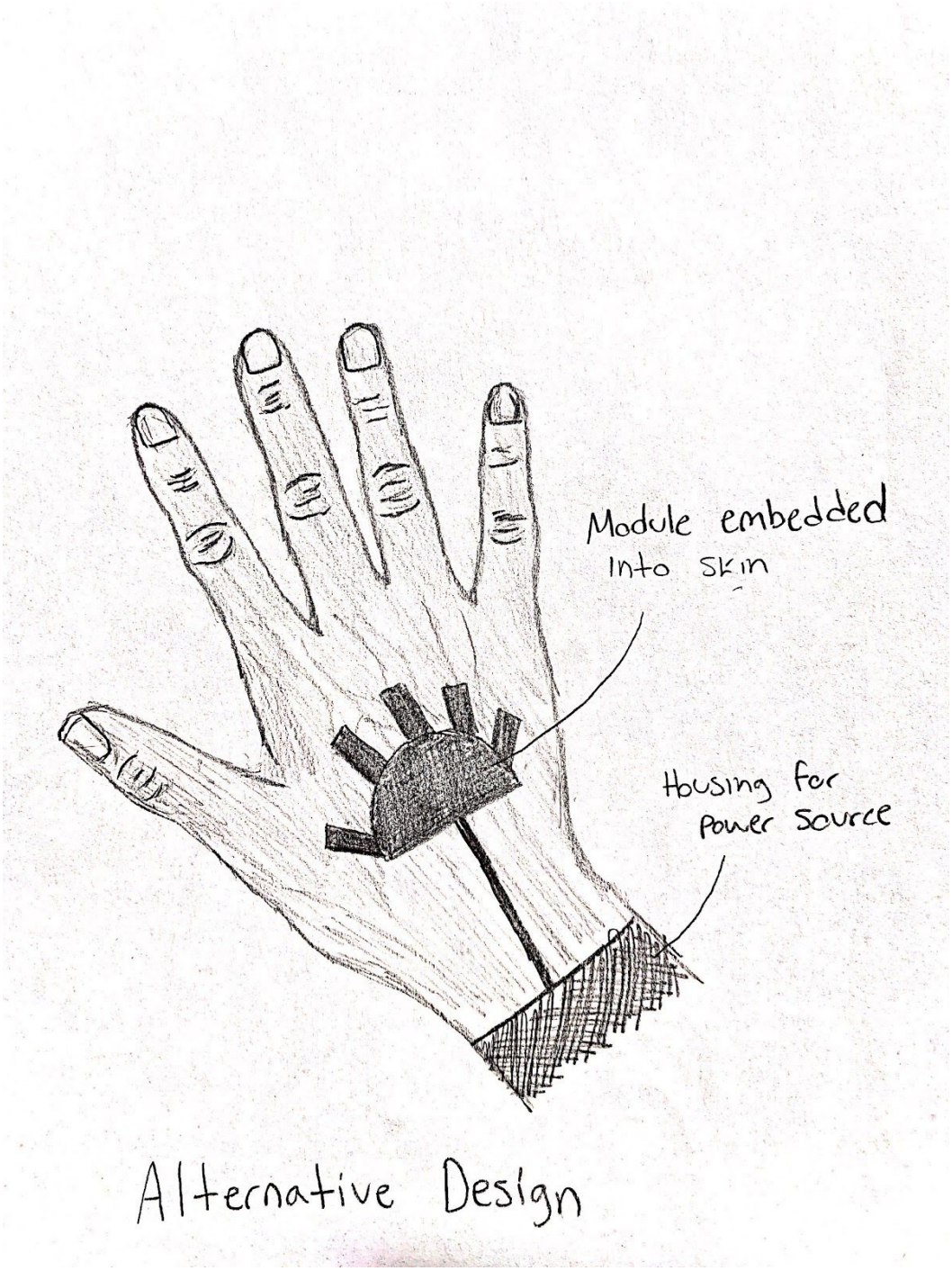
Table 6: Sensor Benchmarking [3] [4]

Concept Alternative Designs

Alternative 1: This alternative design explores a path different than a glove for the system. The device is worn on the fingers with connected rings. These rings will house the sensors that will be tracking hand gestures. This is a futuristic technology, therefor the prototype for this concept will not be able to use this design, however, in the future it may be a viable option. An alternative design to this would to have the whole system housed in one ring.



Alternative 2: This design is another version of the original concept idea. The material on the the digits will have embedded flex sensors that will be able to read the bending of digits. This is the design that the prototype will be based on. The design contains technology that can be acquired in today's market and will perform properly.



Alternative 3: This alternative design takes a further step into the future. This design has the device that senses gesture implanted into the users hand. The device will be able to read muscle movement within the hand. Microchips/Devices embedded into human skin is not a common practice today, but it may be in the distant future. This design has technology that can not be used for the prototype.

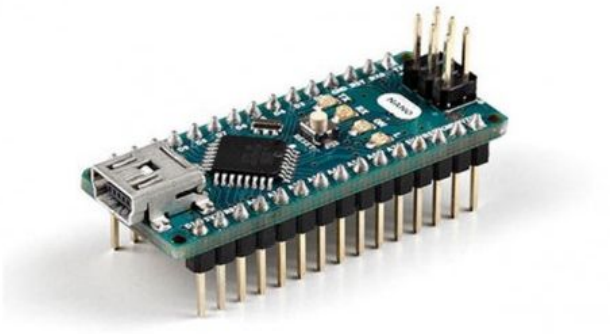
Concept Alternative Selection Pugh Matrix

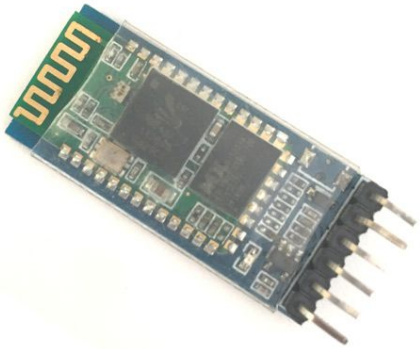
Design Strength/Weakness Analysis					
Evaluation Criterias	**Priority**	**Original Design**	**Alternative 1**	**Alternative 2**	**Alternative 3**
Accuracy	5	S	+	+	+
Product Cost	5	S	-	S	-
Ease of Customer Use	5	S	+	S	-
Technology Readily Available	5	S	-	S	-
Ergonomics	4	S	S	+	-
Development TIme	3	S	-	S	-
Appealing Design	2	S	S	+	-
Sum of Positives			2	3	1
Sum of Negatives			3	0	6
Sum of Sames			2	4	0
Weighted Sum of Positives			10	11	5
Weighted Sum of Negatives			13	0	24
Total of Positives - Negatives			-3	11	-19

Concept Selection Legend	Priority Scale
Better: +	High (5)
Worse: -	Low (1)
Same: S	

Table 7: Pugh Matrix

Final Concept Design





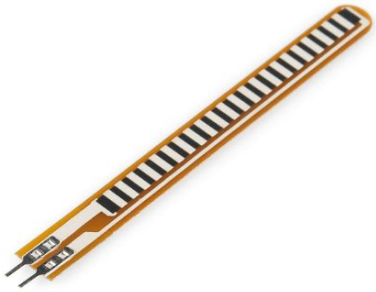


Figure 3: Final Concept Design

In terms of prototyping this final concept design. The hardware that will be chosen is an Arduino Nano, an HC-05 Bluetooth Module and 2.2” Flex Sensors. These items are shown in the pictures to the left of the Final Concept Design in corresponding order. The system will take input from the variable resistance of the flex sensors which will interact with the embedded program on the Arduino. From there, the wifi module will send a signal to a relay module connected to a light in order to turn it on.

Customer Interviews

The interviewees chosen for these customer interviews included two people, Customer 1 and Customer 2, that needed assistance with mobility, and one person who is a caretaker for a person that has restricted mobility. Customer 1 said that the device needs to be very easy to understand. Customer 1 also said that it would be great if the device was very easy to slip on and off. Customer 1 stated that they liked the idea of receiving a custom glove and consultation visit for instruction on how to use it. Customer 1 suggested that there should be some type of delay in the software so that reading hand gestures is more accurate. Customer 2 really liked the idea/ Customer 2 was worried about the safety of the electrical components. Customer 2 suggested that a phone app be implemented as well in the future of the products development for readjusting hand gestures.Customer 3 thought this product would be very beneficial for the market it is targeting. Customer 3 believes the design should be offered in different colors. Customer 3 believes the hardware should be housed in a discrete way without making the glove look bulky. Customer 3 also said that voice command technology should be integrated with the product. The feedback from the different customers has triggered some changes in development of the product. In the future an app would be a great addition to the entire system. Another good idea for the future is voice command. New materials will be tested for comfort and ease of putting on and taking off the glove. Also, the safety aspect of the device will be given the highest priority during development stages.

Updated System Level Customer Needs and Specifications

Customer Pain Points	Customer Requirements	Product and Performance Specifications
Being unable to reach things	Ability to interact with things from a distance	The device will allow for interaction with appliances anywhere in the home that are connected to the internet.
Technology is complicated	Ability to understand and comprehend technology	When a device is purchased, a personal consultant will come to walk through the technology and provide easy to understand documentation with the user.
Having small hands	Ability to have the device fit properly	A custom sized device will be made for each user.
Not Easy to Slip On and Off	A material must be used to enable the worn device to be slipped on and off with ease.	The inner layer of the glove will be made of a material that is easy to slip on such as fleece or cotton.
Bulky Design	The glove has to have sleek housing for the hardware components.	The hardware components will be organized/housed in a way that they are very discreet.
Safety	The glove was must not malfunction or pose any threat to the user.	The hardware components will be wired correctly and input voltage will not exceed the value necessary. Tests will be run to make certain no malfunctions will occur.

Table 8: Updated Customer Needs and Specifications

Updated Sub-System Level Customer Needs and Specifications

Customer Pain Points	Customer Requirements	Product and Performance Specifications
Being uncomfortable with certain materials	The part of the device that is worn must be comfortable and made from a material that will not bother skin	The glove will be made out a combination of materials that will not irritate skin such as polyester and leather.
The device might not recognize my gestures.	The device must be able to analyze the gestures accurately.	The microcontroller will be embedded with a program that uses algorithms to sort out what hand gestures are being made with good accuracy.
No Phone App	The device would be improved with a companion app for the users phone.	In the future, the company can develop and optimal app for the device. The main focus for now is creating just the worn device.
No Voice Command	The device would benefit greatly with voice command features.	In the future, the company can explore voice command technology to give new features to the product.

Table 9: Sub-System Updated Customer Needs and Specifications

10 Question Template

1) What is the unmet market need or general problem? Who has this problem or unmet need? Rating: 5

People with restricted mobility that own smart appliances or that will own smart appliances need an easy way to interact with these appliances. This market is not being touched by similar products such as Amazon's Alexa. This market could be a niche where this product can thrive.

2) Why does this problem or need exist now or will exist in the future? Rating: 5

People with restricted mobility are not able to move around and reach things easily within their homes. This problem has existed and will continue to exist into the future.

3) How is the need being met now or addressed now and at what cost? Rating:4

This problem has many perspectives to it. The one being addressed with this product is the fact that interacting with appliances such as fridges and lights is not very easy for people with restricted mobility. Twenty years from now this product with be able to address this problem due to the increase in smart appliances in homes.

4) What improvements are needed in how the need is currently being met and why? Rating:4

Improvements can always be made in simplicity and ease to use for customers. Not everyone is Tech Savvy, so the easier a system is to understand the better. This product will give users a simple solution to their problems. The need is not being met right now unless house modifications are being made.

5) How will the user measure the value of the improved solution i.e. lower total cost, improved physical performance, better appearance, improved convenience, better quality of life, save more lives and patent expiration, etc. Rating: 4

The user can definitely measure this value in improved convenience and better quality of life. This product will allow them to do daily tasks they may not have been able to do before with ease. This will give them a sense of independence and control.

6) What trends (technology, financial, resources, regulatory, globalization, environmental, competition etc.) will impact the market need and solutions? Rating: 4

The trend of smart appliances in homes will impact the market need and solutions. The smart appliance trend is on the uprise which is good for this product.[7] Sci-Fi movies in the past have shown "Smart Homes" that are completely interactive, and in the near future this could be a reality.

7) Who will be our competitor in meeting this need and why? Rating: 3

As of now, competitors include technology such as Alexa. Amazon's Alexa is already capable of connecting to devices with a wireless connection and communicating with them.

8) What is the basis of our competitive advantage? Rating: 3

The basis of our competitive advantage is the simplicity of our product, the security, and the ease of use.

9) Why does this make sense for ……..I&E team to pursue? What strengths/product will be used and what barriers exist? Rating: 4

This make sense for the I&E team to pursue because it is a product that targets a specific niche. With the movement to smart appliances this product will be beneficial for people to have in their homes 20 years from now.

10) How much money or other benefits can ……..I&E team make on this opportunity? Rating: 1

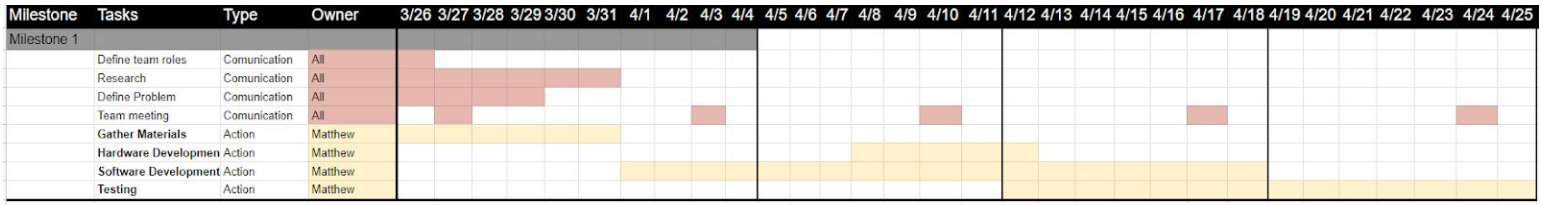
With the prediction for the value of Smart Appliances in the future, if this technology is produced at the correct time the investment opportunity will be a must to have in the portfolio.

Total Rating: 37/50

Rating scale: 1 – almost nothing known 5 – well understood

Go/No Go decision to be made if Rating in each section is > 50%

Gantt Chart



Milestone	Tasks	Type	Owner	3/26	3/27	3/28	3/29	3/30	3/31	4/1	4/2	4/3	4/4	4/5	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19	4/20	4/21	4/22	4/23	4/24	4/25
Milestone 1																																		
	Define team roles	Comunication	All																															
	Research	Comunication	All																															
	Define Problem	Comunication	All																															
	Team meeting	Comunication	All																															
	Gather Materials	Action	Matthew																															
	Hardware Developmen	Action	Matthew																															
	Software Development	Action	Matthew																															
	Testing	Action	Matthew																															

Table 10: Gantt Chart for Prototype Development

Risk Mitigation

One of the main concerns that the group can see people having with this product is electrical malfunction. In order to mitigate this risk the group will pay attention to material used in the development of the product. The glove will have no open wiring and will have all electrical components housed in a material that will have electrical tolerance. The glove will be designed so that no electrical components are touching the skin of the user. The product will be designed very carefully in order to give the consumer the best experience possible. The other main concern for most people is security. Having an IoT device causes concern for hacking due to the fact that it is connected to the internet. However, our device is connected via bluetooth and it is paired manually, so it is much safer than an internet connection. Also, if the product were to ever make the leap to an internet connection, proper security protocol will be put into place in order to protect the user. There would be no point in hacking the glove at any point anyway because the control is in the gestures and a hacker would not be able to make the glove move.

Subsystem Building Process

Glove Subsystem

The glove subsystem is the combination of a hardware circuitry system and a gardening glove. The circuit components include an Arduino nano, HC-05 Bluetooth module, two Flex sensors, an array of resistors and electrical wiring. The system was initially developed on a breadboard in order to troubleshoot functionality issues. One of the issues encountered was that

the HC-05 Transmit Pin (TX) has a 5V output, but the arduino can only had a 3.3V pin input on the built in TX connection. In order to resolve this issue a voltage divider was put in place to lower the voltage being received by the arduino. [1] Another voltage divider was necessary in order to receive proper input from the flex sensor. The flex sensor itself is a variable resistor. The flex sensor and a 47K Ohm resistor were put into a voltage divider. The 47kΩ resistor on the ground side, and the flex sensor on the 5V side, means as the flex sensor's resistance increases the voltage to the analog pin will decrease. [5] The system was tested several times with the "Appliance" Master circuit to make sure it functioning properly prior to soldering. The circuit was taken off of the breadboard and soldered together into a mess of wires. The flex sensors were sewed and taped on to the gardening glove. The other wires and components connected to the flex sensors are an issue on their own. The best solution would be to reduce the wire being used or to create a proper housing for the components.

"Appliance" Master Circuit Subsystem

The master subsystem was comprised of the master devices that the slave devices on the glove subsystem would communicate with. These components included an Arduino uno, HC-05 bluetooth module, 5V Fan, two LEDs, an array of resistors and electrical wiring. This subsystem was created to go inside the housing subsystem. The LEDs would represent some type of on and off functionality and the fan was implemented to show the control the glove could have on smart appliances in the future. Once again the HC-05 bluetooth module need a voltage divider for the Transmit Pin (TX) in order to give the pin on the arduino the proper input voltage. The LEDs all used a 1K resistor on the positive pin in order to reduce noise and protect the resistor from receiving too much voltage and being destroyed. This circuit was the most troublesome of the entire systems development. The HC-05 Bluetooth module setup was not as straightforward as the group had thought and more research needed to be done about it. Once the group figured out how to enable pairing mode in the device it was easy to pair to the module on the glove subsystem for communication. The other challenge put in place was powering a 5V fan with a pin that outputted 3.3V. The group consulted Circuits Professor, Jeffrey Braunstein for advice on the issue. He recommended using a transistor in order to power the fan. A transistor is used to amplify or switch electronic signals and electrical power. A 2N7000 transistor was implemented into the circuit and it solved the problem of not having enough power for the fan. Also, to solve this the microcontroller being used had to be changed. The group switched from an Arduino nano to an Arduino Uno due to the fact that it could regulate a 12V input with ease. The system with the Arduino nano was only receiving 5V from a USB power source. The new system is powered by a 12V power supply that plugs into a power outlet. This circuit was mostly left on the breadboard because it was not necessary to solder everything, however some components were soldered in order to reach certain parts of the housing subsystem.

Prototype Housing Subsystem

The housing that the circuitry of the prototype is built into for this demo is a wooden replica of a washing machine. The circuitry has been embedded into the design and features a speed-adjustable fan, and two LED's.

The speed of the fan is used to demonstrate the possible changing of cycles of the washing machine, and the LEDs are demonstrating an on/off switch.

System Level Results

The integration of each subsystem went very smoothly. This was due to the careful testing of each subsystem before combining them all into one. Only a few changes needed to be made during the integration. A structure was added to the inside of the wooden housing in order to hold the 5V at an appropriate height. Holes were drilled in specific places where the group was going to run wire through. Some soldering had to be done to some electrical components in order to make them long enough to reach their proper place in the wooden housing. The system was expected to run properly during the demonstration due to the fact that the group had tested it prior when the integration was complete.

Demonstration Results

Professors explained to the group that they wanted to see a sense of control between subsystems. This was displayed in the demonstration through the use of the LEDs and 5V fan. The LEDs turned on to corresponding hand gestures. The fan speed was controlled through the combination of hand gestures as well. This system is very capable of many other things and the group would be very interested in attempting to implement them in the future. The demo was a success. Our prototype was effectively able to demonstrate the fundamentals of the innovation we intended to display through our presentation.

The prototype functioned properly during the demonstration because all of the circuitly had been meticulously soldered, and efficiently routed throughout the prototype housing. This allowed for the prototype to be very sturdy and rigid.

From a technical side, the prototype worked correctly because both arduino units were adequately powered. The bluetooth chips on both systems paired properly. The flex sensors functioned properly along with the bluetooth chips to send the changes in resistance values of the sensors to the 'Appliance" Master arduino subsystem. This subsystem then correctly interpreted the signals gathered from the glove sub-system correctly based on their respective gestures.

The Master sub-system then provided correct output based on the specific signals it received in the form of turning the LEDs on and off, as well as adjusting the speed of the fan.

Future Changes

Due to the time contract the prototype was unable to incorporate a feature it was intended to possess: a dial which a user could use appropriate gestures to change the settings, in this case, cycle options of the washing machine.

In the future, the design would attempt to be conformed to a more seamlessly integrated apparatus that would not be large in volume, not have extraneous wires, or have much weight. This would allow for a more user friendly, and convenient experience for the consumer.

Conclusion and Lessons Learned

Upon completing this report, it is very obvious that this IoT can become a reality. The technology is available, however the missing factor is the fact that “smart appliances” in homes will not be trending until years to come. The technology targets a unique niche that similar products do not consider. The success of the device depends on making it so that it is more than just mildly useful, but life changing. This device has the potential to bring an improvement to life for users with restricted mobility. The goal in mind while creating this concept was to find a way to help people and if this device comes to the market this goal can be achieved.

In terms of prototyping, a demonstration of a smaller task could possibly be completed. A task such as interacting with an LED or another light source wirelessly with the use of a worn device and hand gestures. This is due to the fact that a smart appliance is not in the budget and I may not have access to top of the line hardware components that have newer features.

After finishing this report, a lot of new things were learned that will assist in the development of this product. The system organization that was proposed in the concept presentation did not consider the fact that a WiFi/Module receiver will be necessary in the object that the use intends to interact with. During research it was also very apparent that competing with products such as Amazon’s Alexa will not be an easy task. Researching hardware components helped with learning about which components can be used to create the prototype that will be presented at the end of the semester.

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