Project Deliverable M : Final Project Report

Introduction to Product Development and Management for Engineers and Computer Scientists

GNG2101

Team A 06

Visionary

AI Object Identification

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Abstract

This project required us to provide a solution for our client, who is a blind patient with hypoesthesia at the Saint-Vincent Hospital, to be able to know what food is on his table. This means that it is necessary that the product be accessible to a person who can not see, and who has limited dexterity. After meeting our client and understanding his pain, the product we have designed, uses AI object detection and when activated by voice, is intended to recognize common objects such as cutlery and food, and to verbalize it to our patient. This report explains in great detail the design process we performed to develop our product. This report will look closely at our client meetings and the significance of client feedback. It establishes a problem statement based on the customer pain followed by a list of needs, metrics, target specifications, benchmarking, conceptual design, project planning and a series of prototypes and tests. It discusses in detail the financial aspects, business model and economic analysis of our device. Finally, it discusses our final product, provides a user manual, design files and cites our resources so that students in the future can continue working on this project without any issues, using our report.

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1. Introduction

During our first client meeting, we noticed that a product was needed to facilitate the life of patients who suffer from sight deterioration. We asked our client to demonstrate how he locates objects on a daily basis. From observing, it was evident that it took far too long and he was not aware of what he was consuming until he consumed it. These issues sparked an idea of using AI to locate and identify all objects on his table. A design which was hands free, voice activated, and where our client was able to operate it without supervision was a must. Our final design uses the Python language for easy maintenance, and is implemented into a Raspberry Pi for bluetooth capabilities. The bluetooth enables us to link our design with our client's Google Home, which he already uses on a regular basis for weather and sport updates. This design is very adaptable to different lifestyles and is integratable with other cheap software.

2. Design Process

2.1. Problem Statement

Our client struggles with locating and identifying food and beverages on his table. He is also unaware of most objects shape and feel due to hypoesthesia, making it hard for him to know what he is eating and touching. Essentially, he was in need of a map of his table which was relayed to him via audio**.** We decided to design a system that can locate and identify food on his table.

2.2. Benchmarking

Google TensorFlow Object detection API :

Google's TensorFlow is an open source library which can be used for many different purposes such as numerical computation, robotics, and AI. It is Python and C++ compatible, making it user-friendly as they are common machine languages. Due to TensorFlow being open source, it is easily manipulated and altered for the user's needs.

Link to customer needs:

- Is open source - 2 priority points

- User friendly - 3 priority points
- Easy to install - 4 priority points
- Touchless functionality - 5 priority points

TOTAL = 14 priority points

AI Object Recognition (University of California) :

Aydogan Ozcan of the University of California has developed a very efficient and fast AI recognition software using simple detectors. It is capable of identifying digits and clothing items. The prototype creates a model which consists of pixels which transmit light at different wavelengths. It is paired with a 3D printer and a laser which then processes the reflected light into their database. It is then sorted into its correct category by focusing the light onto the right detector. On average, it is 91.75% accurate at detecting images or moving objects.

Link to customer needs:

- User friendly - 3 priority points
- Sturdy - 3 priority points

TOTAL = 6 priority points

Microsoft Azure Computer Vision:

This software created by Microsoft is able to analyze images, read the text (handwritten and typed), recognize celebrities and landmarks, analyze videos, and voice to text. This software also uses a large database of images and runs it through a source code. The images taken are compared and the software computes a percent match based on database images. From here, the highest percent match is the output. It can perform up to 100 transactions per second. The program has a free trial offered for 7 days but no data can be saved after the trial has expired. After that, one must sign up for the software and the pricing is as follows:

1) Base software: $3.65/10 000 transactions
2) S1 tier includes web search, image search, news search, video search, entity search, autosuggest, and spellcheck: 250 transactions per second (tps), $8.51/1000 transactions

3) S2 tier includes web search, autosuggest, and spell check: 100 tps, $3.65/1000 transactions

Link to customer needs:

- Portable - 5 priority points
- Unlimited battery life - 4 priority points
- Easy installation - 4 priority points

TOTAL= 13 priority points

2.3. Metrics

Table 1 : List of Metrics and Needs

Metric #	Needs #	Metric	Importance (1-5)	Units
1	1	Voice recognition range suitable to listen human voice.	5	dB
2	2	Suitable amplitude wave generation for human ear.	5	Hz
3	3.4	Total mass.	4	grams
4	1,3,4,12	Internet connection.	4	Mbps
5	3,4,5	Higher amperage battery.	4	mAh
6	6	Flexible lateral joint.	3	Degrees
7	7,11, 13	Sleek design.	4	cm^3
8	8,11	High young’s modulus of the build material.	4	MPa
9	4,7,9	Unit manufacturing cost.	5	CAD

10	10	Vertical movement range.	4	cm
11	8,11	Properly sealed.	4	mm
12	11	Non-permeable material.	4	N/A^2
13	12	System response time.	3	ms
14	12	Suitable code.	3	Python
15	13	Flexible mounting brackets.	4	Degrees
16	14,15	Intensive testing.	5	Hours
17	13,15	Time to assemble and disassemble.	5	Minutes
18	13	Less parts.	3	List
19	8,11	Ultimate tensile strength.	4	MPa

2.4. Target Specifications

Table 2 : Set of Target Specifications

#	Metric	Units	Marginal Value	Ideal Value
1	Voice recognition range suitable to listen human voice.	dB	60<x>90	50 < x >100
2	Suitable amplitude wave generation for human ear.	Hz	20 < x >20k	20 < x >20k
3	Total mass.	grams	700	600
4	Internet connection.	mbps	10	50

5	Higher amperage battery.	mAh	10000	15000
6	Flexible lateral joint.	Degrees	70	90
7	Sleek design.	cm^3	110	84
8	High young's modulus of the build material.	GPa	2.3	3
9	Unit Manufacturing cost.	CAD	150	100
10	Vertical movement range.	cm	10	5
11	Properly sealed.	mm	0.05	0
12	Permeability.	N/A^2	0	0
13	System response time.	s	3	1
14	Programming language.	Python	-	-
15	Flexible mounting brackets.	Degrees	90	180
16	Intensive testing.	Hours	5	10
17	Time to assemble and disassemble.	Minutes	3	2
18	Less parts.	List	-	-
19	Ultimate Tensile Strength.	MPa	40	50

2.5. Conceptual Design

Promising/Feasible Solutions:

1.The AI Object Identifier will be mounted on the users table. It will be placed directly on top of his table, and will be able to be moved up/down, left/right and forward/backwards. This will allow the AI Object Identifier to get a clear view of everything on the users table.

2. A Smart plate that tells our user what is in each section when he gets closer to a specific compartment. Since the menu is finite, it’s easy to pre-feed all the food items in the plates system.

3. A Proximity sensor and camera mounted on users finger to detect close by objects. Camera is bluetooth to a Raspberry Pi with AI object identification software.

Group Design Concept :

The AI Object Identifier will be mounted to the table. A camera will be attached at the tip and will look at everything on the users plate and will verbalize what is on it. This can be repeated at the users request. Raspberry Pi with OpenCv and Python will be used to program the product. It will be powered with a battery. We will need a camera, power cord, Raspberry Pi, microphone, amplifier and speaker.

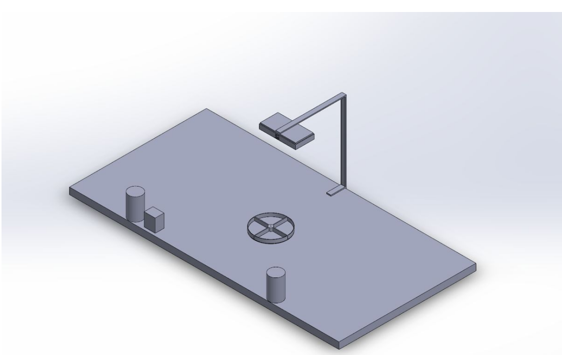


Figure 1 : Initial concept design

2.6. Analysis

The device, designed on solidworks, greatly helped us to envision what our final product would look like. In the very first CAD design, a table is shown with the device mounted onto a stand overlooking a plate. This is what we envisioned the product would look like. Later, a detailed CAD showed how all the parts (Raspberry Pi, speaker, camera, microphone) would be mounted inside the case. The CAD designs created near the start of our product development are very close to the final product we have created. The hardware consists of the device casing, the stand and the electronic parts. The stand used, was recycled from a previous years project, which is essentially used to hold your cell phone while driving. It is able to bend and move around and the clamp which is on it is big enough to hold our device securely. The case was 3D printed, since it is free to use and would reduce the total cost of the product. Moreover the material used for 3D printing is PLA which satisfies our material strength requirements. Our case was printed in 3 different parts, the casing wall, top lid and bottom lid, due to time constraints in the makerlab. A drill press to drill holes for securing screws and hot glue were used to bind our casing together. All the electronic parts were bought online.

2.6.1. Software

There were six steps to preparing and building the software for the AI Object Identifier. First, we formatted and downloaded NOOBS onto a 64GB SD Card, which we put into the Raspberry Pi. We then attached the Raspberry Pi to a power source, and to our monitor using an HDMI cord. We started up the Raspberry Pi and made sure it was completely updated. Second, we installed Tensorflow, using Open Source Code from the internet. Third, we installed OpenCV, for the object detection examples used for our product. Fourth, we compiled and installed Protobuf. This took about six hours to compile and dowNload. Fifth, we set up the Tensorflow Directory Structure and the PYTHONPATH VariabLe. Lastly, we made sure the Pi camera was connected to the Raspberry Pi.

2.6.2. Design Analysis Related to the Concept Design

In hindsight, the design for the AI Object Identifier fulfills all the aspects of our concept analysis criteria which makes it the best and most feasible design. All materials are readily available, and the product can be completed in a feasible time. We used OpenCv/Python for so it can easily be modified by us. For now, we were not able to manipulate the code to be able to connect to a google home for voice recognition and converting text into speech, but the device is successfully able to determine objects and tell what they are. Moreover, the code is able to identify most of the things including food, and also has a multi recognition feature.

2.6.3. Hardware and Software Integration

For the hardware and software integration, we mounted all the electronic hardware raspberry pi, speaker, camera inside the casing. The code was then downloaded and run on the pi which has an external micro SD storage. It is important to know that the code is huge due to its database hence we used a 128GB micro SD card. The device can be easily plugged in and turned on using the switch. The cord can be put in the micro usb port in the device.

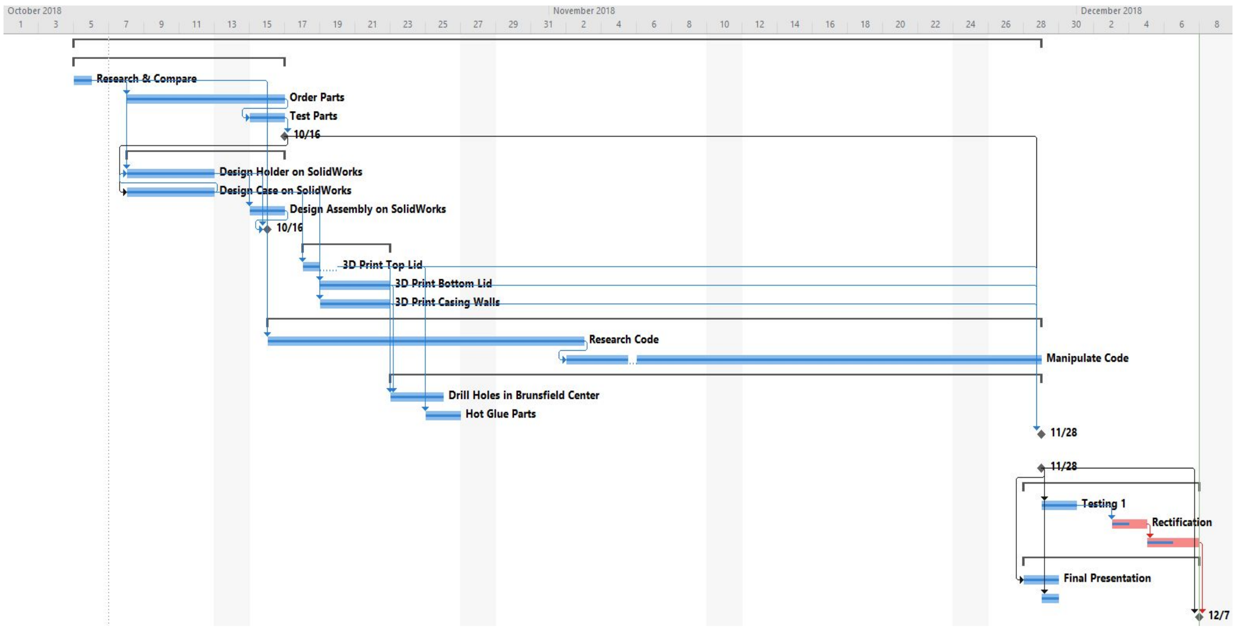
3. Project Planning

3.1. Project Planning

Figure 2 : Task List

		Task Mode	Task Name	Duration	Start	Finish	Predecessors
1	✓		**Product Development: AI Object Identifi**	**39 days**	**Fri 10/5/18**	**Wed 11/28/18**	
2	✓		**Procurement and Testing**	**8 days**	**Fri 10/5/18**	**Tue 10/16/18**	
3	✓		Research and compare parts	1 day	Fri 10/5/18	Fri 10/5/18	
4	✓		Order Parts	7 days	Mon 10/8/18	Tue 10/16/18	3
5	✓		Test Parts	2 days	Mon 10/15/18	Tue 10/16/18	4
6	✓		Parts ready to use	0 days	Tue 10/16/18	Tue 10/16/18	5
7	✓		**Design Prototype on Solidworks**	**7 days**	**Mon 10/8/18**	**Tue 10/16/18**	
8	✓		Device holder	5 days	Mon 10/8/18	Fri 10/12/18	9,3
9	✓		Device Casing	5 days	Mon 10/8/18	Fri 10/12/18	6
10	✓		Final Assembly	2 days	Mon 10/15/18	Tue 10/16/18	8,9
11	✓		Design Complete	0 days	Tue 10/16/18	Tue 10/16/18	10,8,9
12	✓		**3D Print Parts**	**3 days**	**Thu 10/18/18**	**Mon 10/22/18**	
13	✓		Device Casing - Top Lid	1 day	Thu 10/18/18	Fri 10/19/18	9
14	✓		Device Casing - Bottom Lid	2 days	Fri 10/19/18	Mon 10/22/18	9
15	✓		Device Casing - Casing Walls	2 days	Fri 10/19/18	Mon 10/22/18	9
16	✓		**Software Development**	**32 days**	**Tue 10/16/18**	**Wed 11/28/18**	
17	✓		Research OpenSource Code	14 days	Tue 10/16/18	Fri 11/2/18	3
18	✓		Code Manipulation	18.5 days	Fri 11/2/18	Wed 11/28/18	17
19	✓		**Hardware Completion**	**27 days**	**Tue 10/23/18**	**Wed 11/28/18**	
20	✓		Drill press holes	3 days	Tue 10/23/18	Thu 10/25/18	13,14,15
21	✓		Hot glue parts	2 days	Thu 10/25/18	Fri 10/26/18	13,14,15
22	✓		Assemble Device with circuitry	0 days	Wed 11/28/18	Wed 11/28/18	6,13,14,15
23			**Testing**	**8 days**	**Wed 11/28/18**	**Fri 12/7/18**	
24	✓		Testing 1	2 days	Thu 11/29/18	Fri 11/30/18	22
25			Rectification	2 days	Mon 12/3/18	Tue 12/4/18	24
26			Testing 2	3 days	Wed 12/5/18	Fri 12/7/18	25
27			**Presentation and Handover**	**8 days**	**Wed 11/28/18**	**Fri 12/7/18**	
28	✓		Final Presentation	2 days	Wed 11/28/18	Thu 11/29/18	22
29	✓		Design Day Presentation	1 day	Thu 11/29/18	Thu 11/29/18	22
30			Handover to Client	0 days	Fri 12/7/18	Fri 12/7/18	26

Figure 3 : Gantt Chart



It is evident in the Gantt Chart that since inception we knew our critical path and dependencies. Meaning, there are tasks in the chart which are predecessors of other tasks and if they are not completed on time the timeline of the succeeding tasks will increase consequently.

Due to some technical difficulties all the connectors in our chart did not convert to red, but it can be witnessed in the testing and rectification tasks. It is also imperative to notice that our project plan is based on achievement of 4 milestones, last one being a handover to the client.

We were successfully able to achieve 3 out of the 4 milestones, but due to improvement potential and lack of skills required to achieve them, the device won't be given to our client this semester. More than 90% of the tasks are complete which is portrayed by the length of the smaller bar inside the bigger bar. Testing 2 requires further manipulation of the code, which upon completion will allow us to handover the device to our client.

3.2. Feasibility Study

Technical:

We are a team of two mechanical engineers, one electrical engineer, and one civil engineer. Our project is mainly software and mechanical related, however, we as a group have a wide range of skills. We have expertise in mechanical design and the coding language Python. Our mechanical engineers were responsible for the solidworks design portion and 3d printing. Solidworks is available to students in school computer labs and the 3D printers are located in the makerspace. Our electrical engineer was responsible for developing and modifying the AI object identification software. Our civil engineer has expertise in design as well, so mechanical tasks were completed by him as well.

Economic:

Due to the complexity of our project, the budget given was used entirely. A Raspberry Pi and a camera was must, which take up nearly 70% of our budget. Some parts were designed and 3D printed for free with the school's ressources. The parts were ordered from the cheapest local sources, ensuring no delivery issues occured. The current cost of the project is around $135.

Legal:

Considering we used open source code for AI object identification and working on this project for a social cause rather than gaining any profits, there are no legal obligations or limits attached to it whatsoever. However, it was made sure that no content was used without citing its sources to maintain code of conduct.

Operational:

The concept we decided to pursue is hands free and uses voice recognition. This compliments our client the most because he is blind and has no feeling in his hands.

Scheduling:

Our Gantt chart clearly defined each task, its duration and the task owner. This helped us coordinate well to reach project goals, and finish the final product before the deadline. Most goals and milestones were completed on time, until integration between software and hardware approached. Minor mishaps arose such as: speaker amperage and Raspberry Pi amperage being incompatible, and voice to text API failure.

4. Prototyping

Testing was performed only on our high fidelity prototype because it was the first tangible product we had. Once the the software and hardware were integrated, we ran the product. As of now, it needs internet connection to access the database of photos. Many different objects were tested and most came back positive. The speaker needed must either be: bluetooth connected to the Pi or a wired speaker and an amplifier. During testing of audio, nothing happened. Through research, it was found that the Pi was unable to power the wired speaker without an amplifier. This lead to the use of a bluetooth speaker due to time constraints. The voice to text API was the next addition needed but was unable to be completed. From prototype two to three, the 3D printed stand was disregarded, as it did not function well with mobility. A flexible stand worked very well when tested.

4.1. Prototype I

Figure 4 : Low fidelity cardboard prototype

4.2. Prototype II

Figure 5 : Moderate fidelity CAD prototype

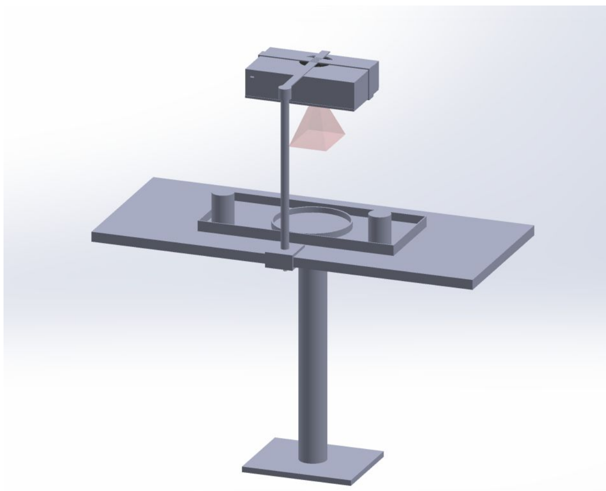


Figure 6 : Case assembly including Raspberry Pi, speaker, camera, and breadboard

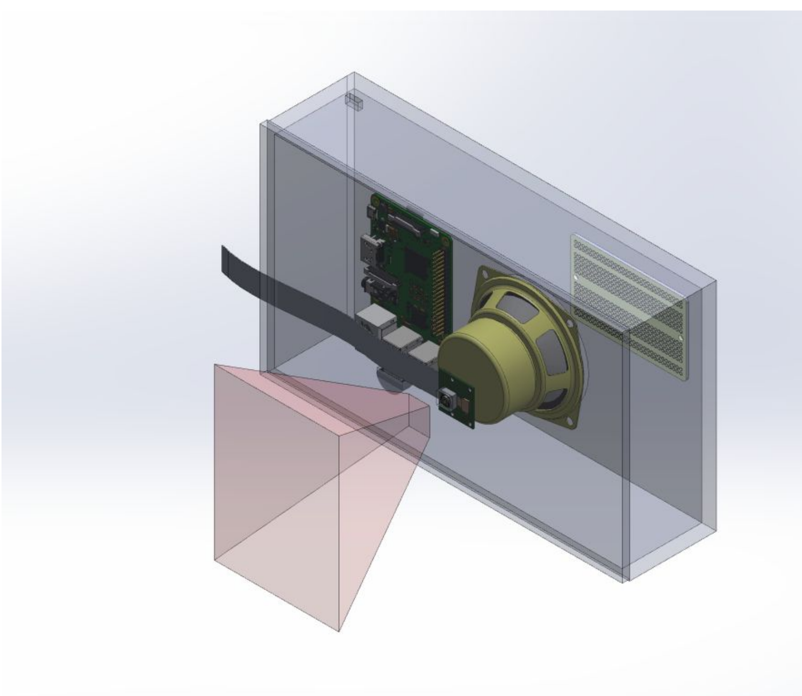
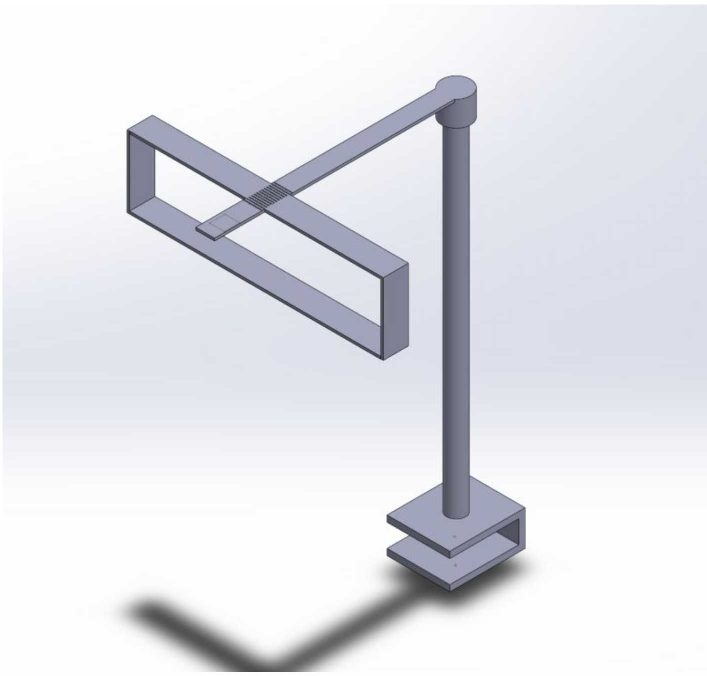


Figure 7 : Stand assembly which holds the case assembly and mounts to a table



4.3. Final Product based on Prototype II

Figure 8 : Final product, high fidelity

5. Final Product

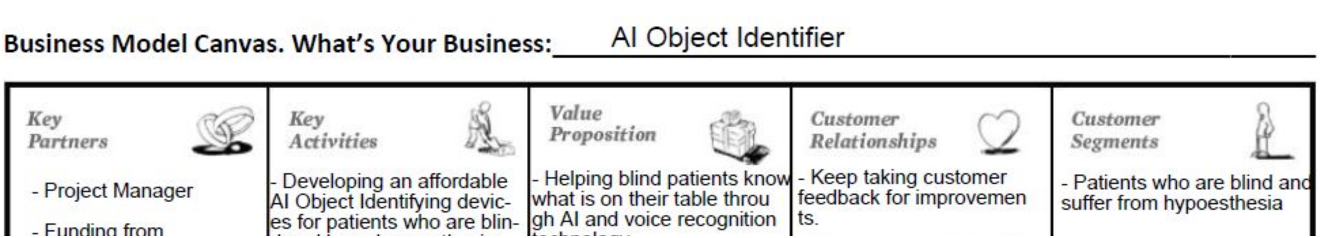
Our final product is not finished. We do not have some of the features initially outlined in the target specifications. The hardware is completely finished, however, some of the code and software needs to be updated. The product is able to use its camera to scan and identify the items underneath the camera however it is not able to verbalize it. This is mostly due to the difficulty we had with the integration of the speaker we had. We needed an amplifier for the speaker to work and unfortunately there wasn't enough time to order one. In addition, we did not implement the hands-free feature which we had planned. This is simply a time issue. In conclusion, our product is able to scan and identify objects using AI technology, however, it is not able to verbalise the items it scans and it is not hands-free.

Video Link: (https://www.youtube.com/watch?v=gCj0FOvYUH4)

6. Business Model

6.1. Business Model Canvas

Figure 9 : Business Model Canvas



Business Model Canvas. What's Your Business: AI Object Identifier

Key Partners	Key Activities	Value Proposition	Customer Relationships	Customer Segments
- Project Manager - Funding from	- Developing an affordable AI Object Identifying devic-es for patients who are blin-	- Helping blind patients know what is on their table throu gh AI and voice recognition	- Keep taking customer feedback for improvemen ts.	- Patients who are blind and suffer from hypoesthesia

6.2. Economics Analysis (NPV analysis)

Figure 10 : Income Statement and Break Even Analysis

Visionary
Income Statement
[CAD $]

	2019												
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Full Year
Device Sale (92 Devices @ $250 each)	250.0	500.0	750.0	1,500.0	2,500.0	2,500.0	2,500.0	2,500.0	2,500.0	2,500.0	2,500.0	2,500.0	23,000.0
Total Net Revenue	**250.0**	**500.0**	**750.0**	**1,500.0**	**2,500.0**	**2,500.0**	**2,500.0**	**2,500.0**	**2,500.0**	**2,500.0**	**2,500.0**	**2,500.0**	**23,000.0**
Cost of Goods Sold	131.6	263.2	394.8	789.6	1,316.0	1,316.0	1,316.0	1,316.0	1,316.0	1,316.0	1,316.0	1,316.0	12,107.2
Gross Profit	**118.5**	**236.8**	**355.2**	**710.4**	**1,184.0**	**1,184.0**	**1,184.0**	**1,184.0**	**1,184.0**	**1,184.0**	**1,184.0**	**1,184.0**	**10,892.9**
Expenses													
Marketing and Advertising	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	600.0
Manufacturing (2 hrs @ $16/hr)	32.0	64.0	96.0	192.0	320.0	320.0	320.0	320.0	320.0	320.0	320.0	320.0	2,944.0
Software Development (120 hrs @ $15/hr)	1,800.0												1,800.0
Federally Incorporating	200.0												200.0
Packaging and Delivery ($25 per package)	25.0	50.0	75.0	150.0	250.0	250.0	250.0	250.0	250.0	250.0	250.0	250.0	2,300.0
Total Expenses	2,107.0	114.0	146.0	242.0	370.0	370.0	370.0	370.0	370.0	370.0	370.0	370.0	7,844.0
Earnings Before Interest & Taxes	**(1,988.6)**	**122.8**	**209.2**	**468.4**	**814.0**	**814.0**	**814.0**	**814.0**	**814.0**	**814.0**	**814.0**	**814.0**	**3,048.9**
Interest Expense													
Earnings Before Taxes	**(1,988.6)**	**122.8**	**209.2**	**468.4**	**814.0**	**814.0**	**814.0**	**814.0**	**814.0**	**814.0**	**814.0**	**814.0**	**3,048.9**
Income Taxes(@10 % for Small Inc.)	198.4	12.3	20.9	46.8	81.4	81.4	81.4	81.4	81.4	81.4	81.4	81.4	929.6
Net Earnings	**(2,187.0)**	**110.5**	**188.3**	**421.6**	**732.6**	**732.6**	**732.6**	**732.6**	**732.6**	**732.6**	**732.6**	**732.6**	**2,119.2**

*BREAK EVEN POINT

Figure 11 : Division of Expenses

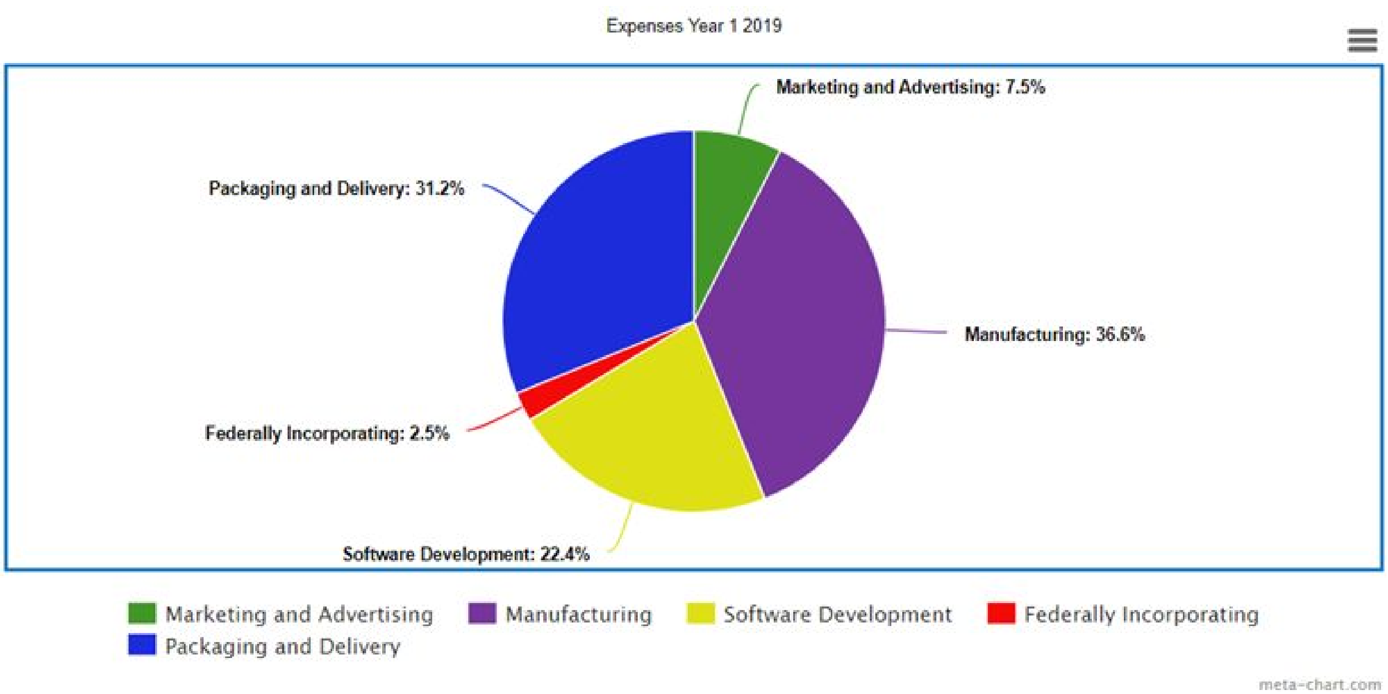
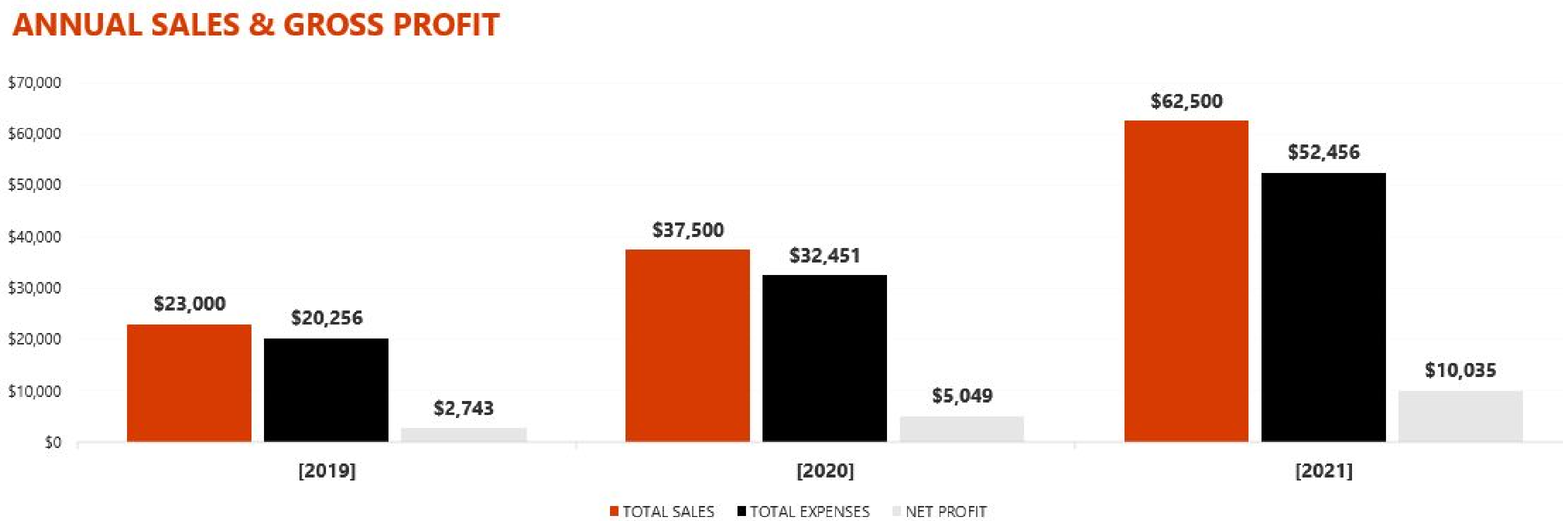


Figure 12 : Financial Projections

3 YEAR SALES SUMMARY	2019	2020	2021
TOTAL SALES	$23000	$37,500	$62,500
TOTAL EXPENSES	$20,256	$32,451	$52,465
NET PROFIT	**$2,743**	**$5,049**	**$10,035**



It is evident that we will be able to break even in our 7th month of operations. It can be seen that the highest share of cost in the first year is manufacturing followed by packaging and delivery, which is bound to reduce once we shift to mass manufacturing based on higher demand. Costs such as rent and utilities have not been taken into consideration since we are planning to use Makerlab for initial production. Financial projections portray a commendable growth over the first three years of operations, which can highly shift up if we are able to secure investments and sponsorships.

7. User Manual

Features :

1. Bluetooth Connectivity
2. Food recognition
3. Voice activation (Incomplete)
4. Speaker + Headphone compatibility

Functions :

1. On/Off Button
2. Ports

   Power Port x1

   USB Port x4

   Micro USB Port x1

   3.5mm Jack x1 (Headphone compatible)

Installation instructions for manufacturers :

1. Turn on
2. Connect to monitor using HDMI
3. Connect Raspberry Pi to wifi
4. Run code
5. Put object to be scanned under the project
6. See results on the screen

Installation instructions for consumer :

1. Plug in the device
2. Once blue light inside the device is on, give 5 seconds for it to start up
3. It will automatically establish connection with your google device
4. You can activate voice recognition by calling out "Visionary, What's on my table?"

Operations and Maintenance :

1. Since this device has no moving parts, it does not require any maintenance.
2. It is recommended to do an air blow clean on it every month so that no dust sits on the hardware/circuitry.

Warnings :

1. The device is not waterproof. Keep away from any sort of liquids.
2. Keep away from kids under the age of 14, risk of electric shock.

Hazards :

1. Short Circuit: Very low chances, but if there is a burning smell, turn off the system and unplug.

Troubleshooting Guide :

If the device doesn’t seem to work or connect please follow the following protocol.

1. Turn off using the main power button and then turn on again
   OR
2. Shutdown Raspberry Pi through OS
3. If problems still persist, please call our technical team at (TBD).

8. Design Files - CAD Drawings

Note: All dimensions are in IPS.
3D models have been shown in the prototypes.

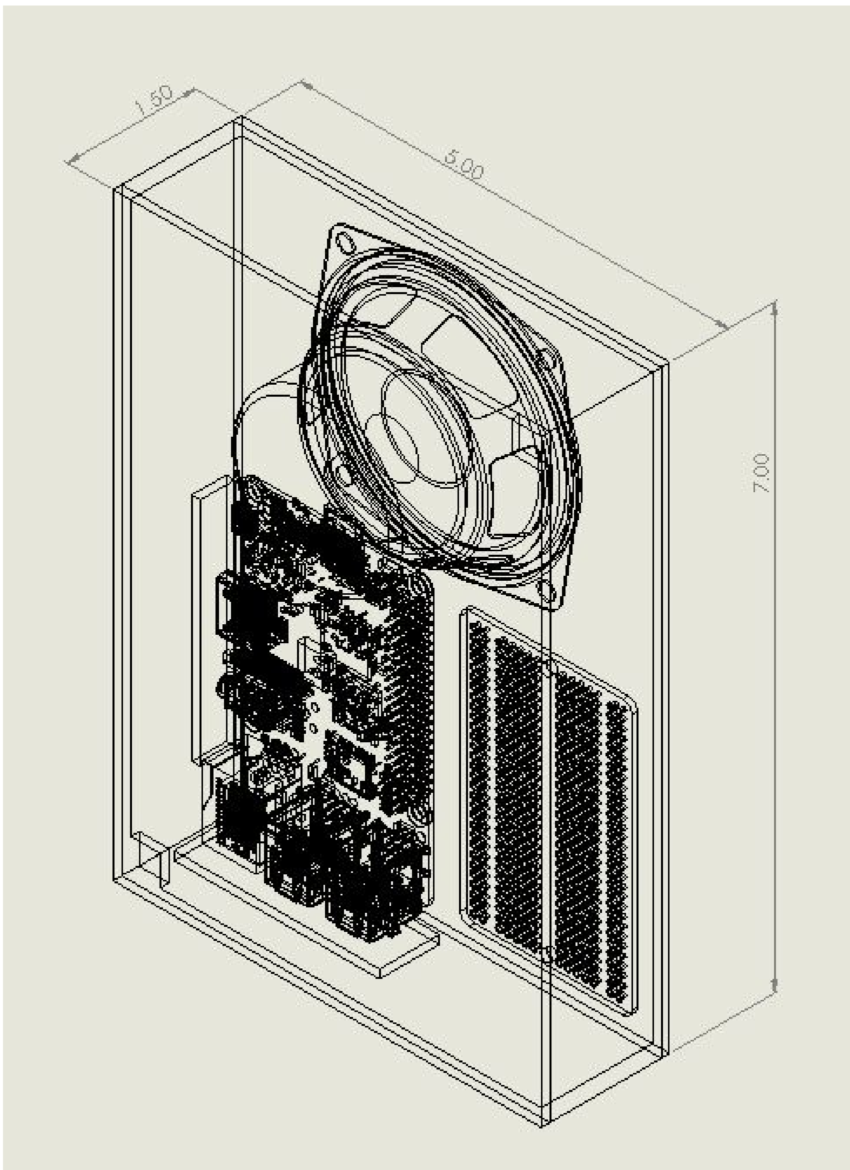


Figure 13 Isometric view of device with components

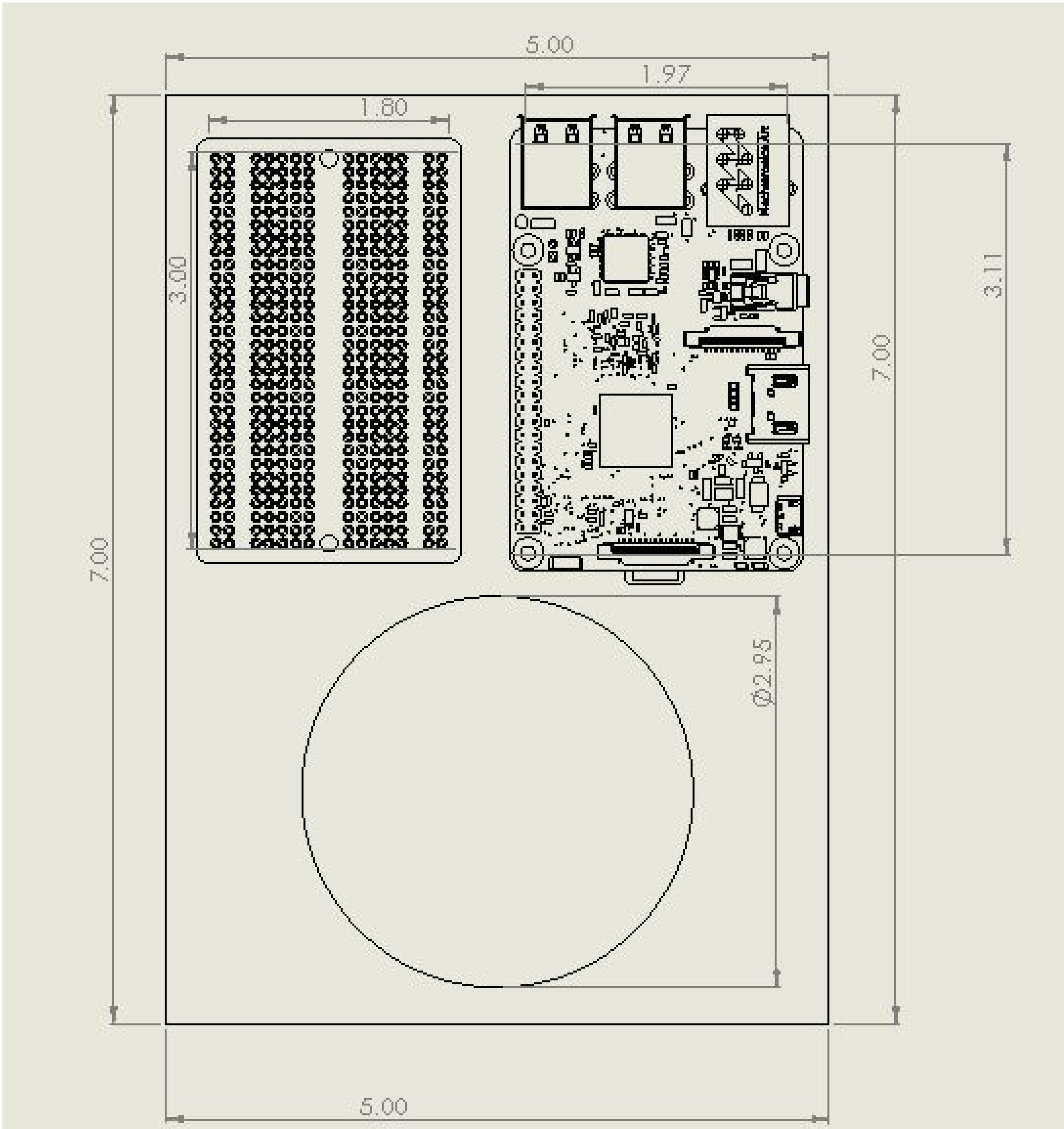


Figure 14 Top view of the top lid

9. Conclusion and Recommendations

This project has really made us adept to the process of determining what the customer pain is, and being able to empathize with the customer to gather out the best of information which can be leveraged towards making a product that actually solves the problem in the best way possible. It made us realize how important client meetings are.

Being able to use a design process to make a minimum viable product, then iterating based on customer input and validation, and then repeating the process until it is clear that the product actually solves the problem is a key takeaway. It is also important to discuss how other aspects that run in parallel with the design process such as project management, financials, economic analysis, marketing, legal and technical and non-technical constraints are equally imperative and contribute towards the best product.

This project has allowed us to be able to use the resources around us to the maximum which includes hardware, facilities and even open source code. It has enabled us to successfully integrate hardware and software which is the backbone of any tangible product these days, while keeping in mind the target specifications and other constraints, to be able to fit in the current market standard.

Even though we were not able to complete the product 100% and hand it over to the client, we have completed 80% of the device features which is way more functionality than a minimum viable product.

For future development of this product, the device will be available in Makerspace and the open source code can be found at https://github.com/EdjeElectronics/TensorFlow-Object-Detection-on-the-Raspberry-Pi . For solidworks files or any other inquiries please feel free to contact us at aqure096@uottawa.ca, ldowd048@uottawa.ca and we will be more than happy to help you out.

Bibliography

EdjeElectronics. (2018, September). EdjeElectronics/TensorFlow-Object-Detection-on-the-Raspberry-Pi. Retrieved Fall, 2018, from https://github.com/EdjeElectronics/TensorFlow-Object-Detection-on-the-Raspberry-Pi