Hand-Gesture Vending Machine

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Jhamori Williams-Austin [Computer Engineering]
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Group 1

Introductions

We'll be right here!

Hussein Shelleh

Electrical Engineering, Photonic Science & Engineering

Jhamori Williams-Austin

Computer Engineering

Logan Terrell

Computer Engineering

Tyler Bornemann

Electrical Engineering

Jhamori
Williams-Austin

Overview and Motivation

The overview of the hand gesture vending machine is that it is an alternative to in-use and modern vending machines without the use of the touch controls, intended to have a selection of three to five snacks for a user to choose from.

The motivation behind this project stems from a proactive approach to address health and hygiene concerns, particularly in the context of illnesses like COVID-19.

Motivation correlating to this project also comes from convenience and accessibility.

Jhamori Williams-Austin

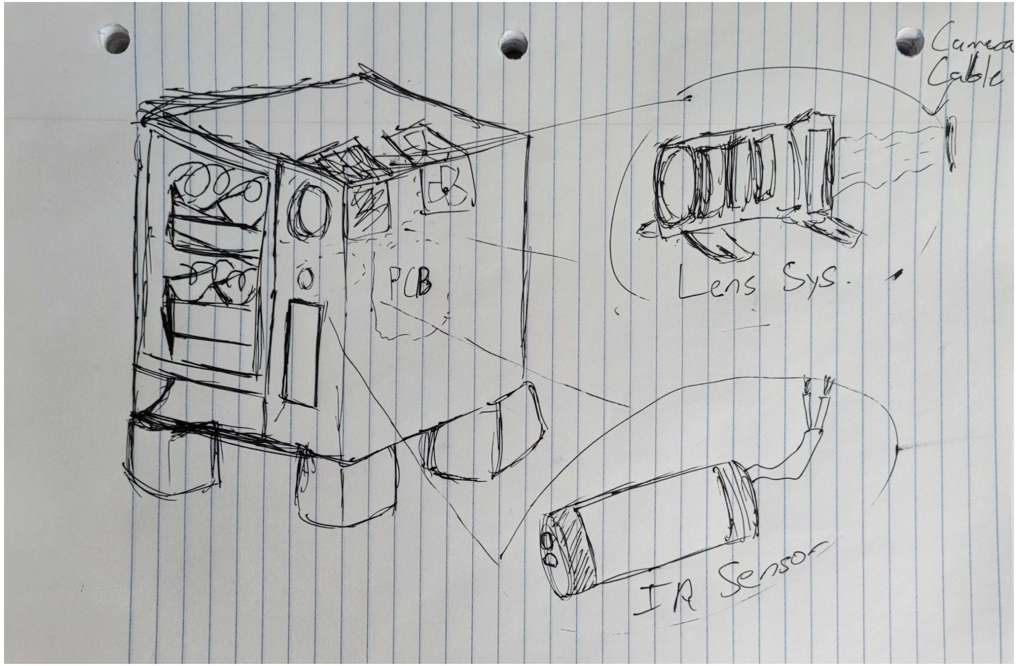
Goals and Objectives

The overall goal for this project is to create a completely hands-free vending machine that utilizes object detection of hand gestures and a card reader to select the desired item.

Goals	Objectives
Screen will turn on when a person is in the vicinity of the motion detection.	IR Sensor connects to the microcontroller, microcontroller connects to the screen
Machine will need to be able to take in information from a camera system and output commands to the system.	Lens System connects to Camera, camera connects to the AI development kit, connect AI development kit to microcontroller.
If customer is detected all lights in the vending machine should turn on.	IR Sensor connects to the microcontroller, microcontroller is connected to and turns on LEDs

Logan Terrell

Design Sketch



Jhamori Williams-Austin

Engineering Requirements

Maximum Voltage and Amperage	15 V, 10.5 A
Operational Temperature	< 90°F / < 33.3°C
Size	≤ 2’x2’x 2’ / ≤ 61cm x 61cm x 61cm
Weight	≤ 26.5lb / ≤ 12kg
Cost	≤ $700.00
Coding Language	CpE **must** be at least familiar with it
Gesture Detection Accuracy	≥ 80%
Response Time	< 15s
Motion Activation Accuracy	≥ 80%

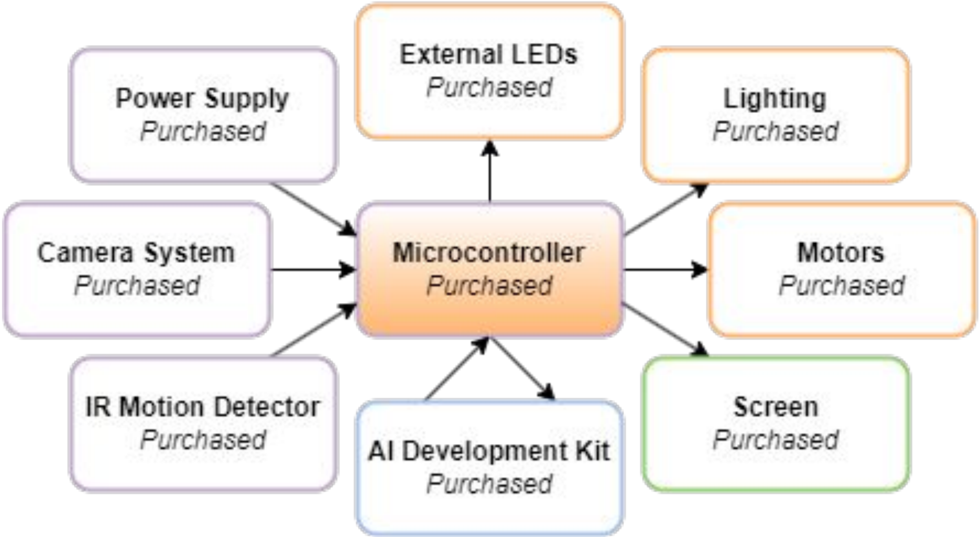
Hussein Shelleh

Physical Device Design

- *Welded metal framework*
- *Sheet metal or shaped wood walls w/ transparent plastic window*
- *3D Printed Motor Spirals and ‘Cups’ for holding snacks*
- *Rubber to line the bottom and sharp points for safety*

- *Design Dimensions: ~50cm in every direction.*
- *Snack Window: ~30cm x 30cm*
- *Snack Access Point: The Sides.*

Hardware Lineup



Hussein S.
Jhamori W-A.
Logan T.
Tyler B.

Hussein Shelleh

Tyler Bornemann

Microcontroller (MCU)

- *Low power*
- *Enough GPIO pins*
- *Easy to work with*
- *Affordable*

Name	Processing Power	Operating Voltage	GPIO	Development Tools	Price
MSP430FR6989	84 MHz	1.8V - 3.6V	83 GPIO pins	CCSTUDIO IDE	$10.77
ESP32-WROOM	240 MHz	3.0V - 3.6V	34 GPIO pins	Arduino IDE	$3.00
STM32F429ZI	180 MHz	1.7V - 3.6V	168 GPIO pins	STM32CubeIDE	$14.34

Tyler Bornemann

Fans

- *Airflow*
- *Noise*

Name	Input Voltage	Size	Acoustical noise	Max RPM	Price
CFM-120C	5V	120mm	24.8 dB	1500 RPM	$6.19
NoiseBlocker XS2	8V	50mm	21.1 dB	4000 RPM	$10.95
Noctua NF-P12	12V	120mm	25.1 dB	1700 RPM	$16.95

Jhamori Williams-Austin

LEDs

- *Intended as lighting solely for consumer benefit.*
- *Bright light, single-color LEDs - preferably white.*
- *Eventually went with C513A LEDs*

Name	Brightness (lumens)	Power Dissipation	Color Options	Viewing Angle	Price
WP154A4SUR EQBFZGC	200 mcd - 3600 mcd	75 mW - 102.5 mW	Red, Green, Blue	50 Degrees	$2 each
C513A	5400 mcd	120 mW	White	55 Degrees	$0.28 each
XLUR12D	39 mcd	75 mW	White	30 Degrees	$0.28 each
LM301B	3000 mcd - 5700 mcd	520 mW	White	120 Degrees	$0.40 each

Jhamori Williams-Austin

Screen

- *Necessary to show different snack options - and to request confirmation.*
- *ILI9486 driver for SPI communication.*
- *Eventually went with the Hosyond 4 Inch TFT LCD display.*

Name	Size	Resolution	Voltage	Color Depth	Price
TFT LCD	4 inches	480 x 320 pixel	3.3V - 5V	16-bit to 24-bit	$38
OLED Display	2.42 inches	128 x 64 pixel	3.3V - 5V	10-bit	$55
Touchscreen Display	4 inches	320 x 480 pixel	3.3V - 5V	24-bit	$70

Hussein Shelleh

Power Supply

- *Component is necessary to interface with an outlet.*

- *Eventually went with the ALITOVE 24V 6A 144W Power Supply.*

Name	V_{In} [V]	Max Output	Connector	Contacts?	Price
ALITOVE 24V 15A	110 AC/220 DC	24V, 15A	None	Exposed	$23.99
ALITOVE 24V 6A	100 AC/240 DC	24V, 6A	Barrel, 5.5mm x 2.5mm	Enclosed	$23.99
TRIAD WSU240	100 AC/240 DC	24V, 1A	Barrel, 5.5mm x 2.1mm	Enclosed	$13.32

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Motor Comparison

AC Motor:

- Uses Alternating Current, be it Single Phase or Three Phase
- Requires several wires - more GPIO pins
- Larger
- More Expensive

DC Motor:

- Uses Direct Current
- Only needs two wires - fewer GPIO pins
- Smaller
- Cheaper

Hussein Shelleh

Motors

- *Must be a **DC** Motor.*
- *Must be small but able to move at least one kilogram.*
- *Eventually went with G-12 N20 Mini.*

Name	Size	V_{In} [V]	I_{In} [A]	Torque	Price
N20 Micro	~8.5mm x 11mm x 20mm	5V - 12V	0.04A	< 1kg*cm	~$2.00
G-12 N20 Mini	~10mm x 12mm x 30mm	5V - 12V	0.04A	2kg*cm	~$4.50
ASLONG JGY-370	~8cm x 3.5cm x 3cm	12V	0.3A	10kg*cm	~$16.00

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Sensor Types (For This Project)

Active/Reflective Sensor:

- Signal is sent from the IR sensor
- Sensor reads the bounced-back signal
- Less interference issues
- More expensive

Passive/Absorption Sensor:

- Signal is solely read from the environment
- Temperature difference is the key factor
- More interference issues
- Cheap

Hussein Shelleh

Motion Sensors

- *Must be accurate. Must work within short and very short ranges.*
- *Eventually went with E18-D80NK.*

Name	Accuracy	V_{In} [V]	Active Range	Active Angle	Price
HC-SR501	Moderate	5V - 20V	3m	120°	~$3.00
Dioche Universal	High	24V	2.5m	30°	~$30.00
E18-D80NK	Very High	5V	3cm - 80cm	10°	~$7.00

Logan Terrell

Camera

- *The resolution had to range from 720p to 1080p*
- *The camera had to use employ CSI-2 protocol*

Name	Size (mm)	Resolution	Sensor	Connection	Price
LI-IMX219	150x25x15	8.08 MP	Sony IMX219	CSI-2	$44.60
Raspberry Pi Camera Module 3	25x24x11.5	11.9 MP	Sony IMX708	CSI-2	$25.00
Arducam IMX477P	8.6x8.6x5.2	12.3 MP	Sony IMX477	USB 3.0	$149.99

Logan Terrell

AI Development Board Comparison

- *Eventually went with the NVIDIA Jetson Nano.*

Technology		Jetson Nano		Google Coral		Raspberry 4 Pi	
Factors	**Weight**	Raw	Weight	Raw	Weight	Raw	Weight
Cost	35%	7	2.9	5	1.75	10	3.5
Performance	30%	9	2.7	7	2.1	4	1.2
Size	20%	5	1	8	1.6	6	1.2
Camera Port	15%	10	1.5	2	0.3	5	0.75
	Total:		**8.1**		**5.75**		**6.65**

Logan Terrell

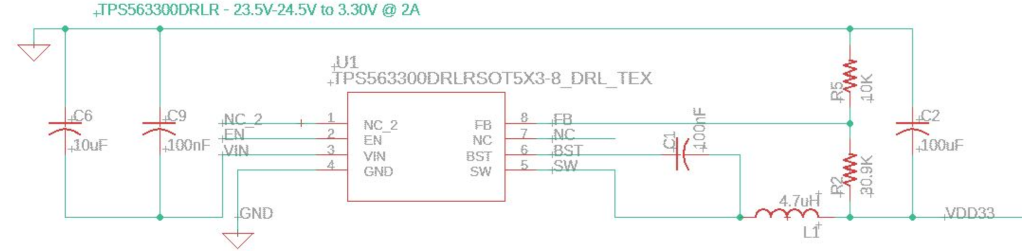
AI Development Board Comparison

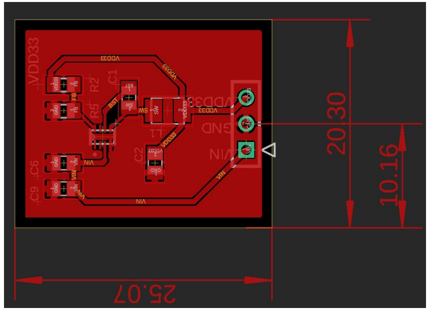
- *Purpose:*
- *Will execute object detection model on camera input and return the results.*
- *Utilizes GPU.*
- *Designed specifically for AI development.*

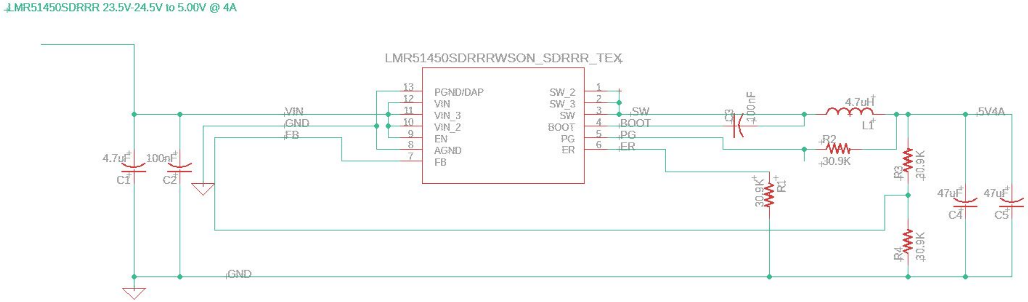
Specifications	Values
GPU/AI Accelerator	128-core Maxwell @921 MHz/472 GFLOPS
CPU	Quad-core ARM A57 @1.43 GHz
Memory	4 GB 64-bit LPDDR4 25.6 GB/s 1600 MHz
Camera Ports	MIPI CSI-2 camera connection

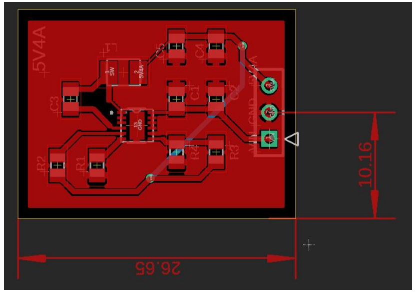
Tyler Bornemann

Regulators



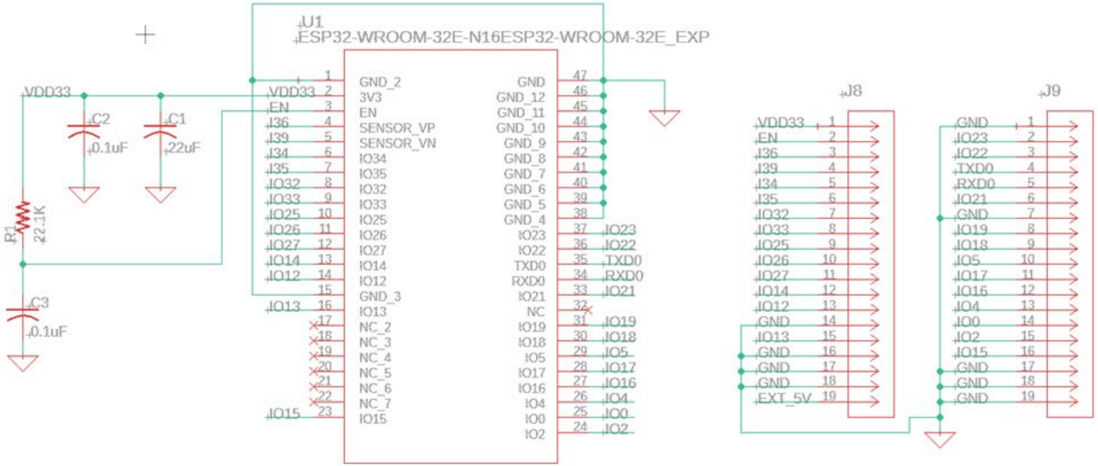






ESP32 Module

Tyler Bornemann



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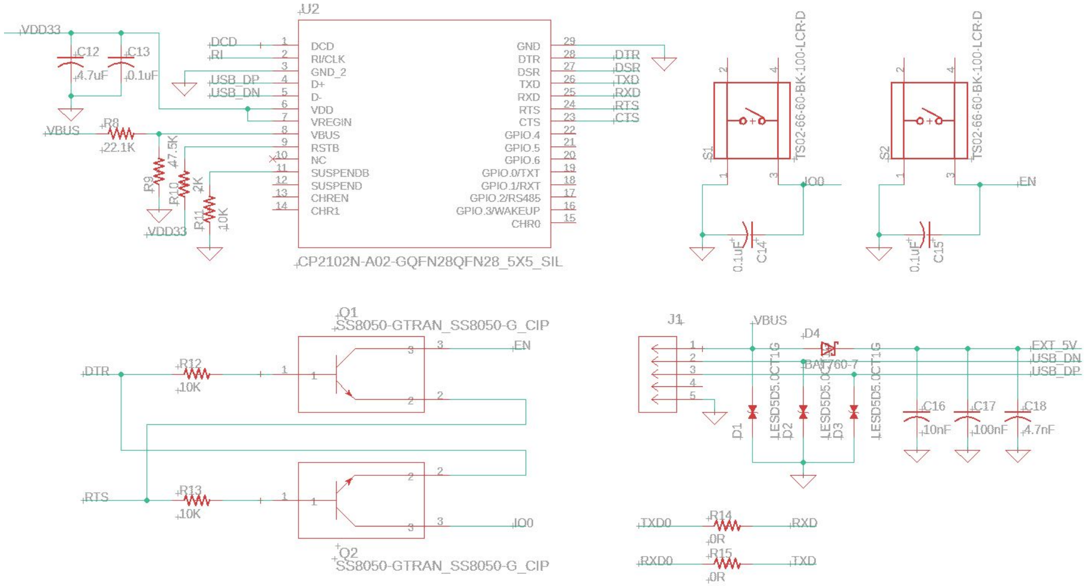
RS232C Communications



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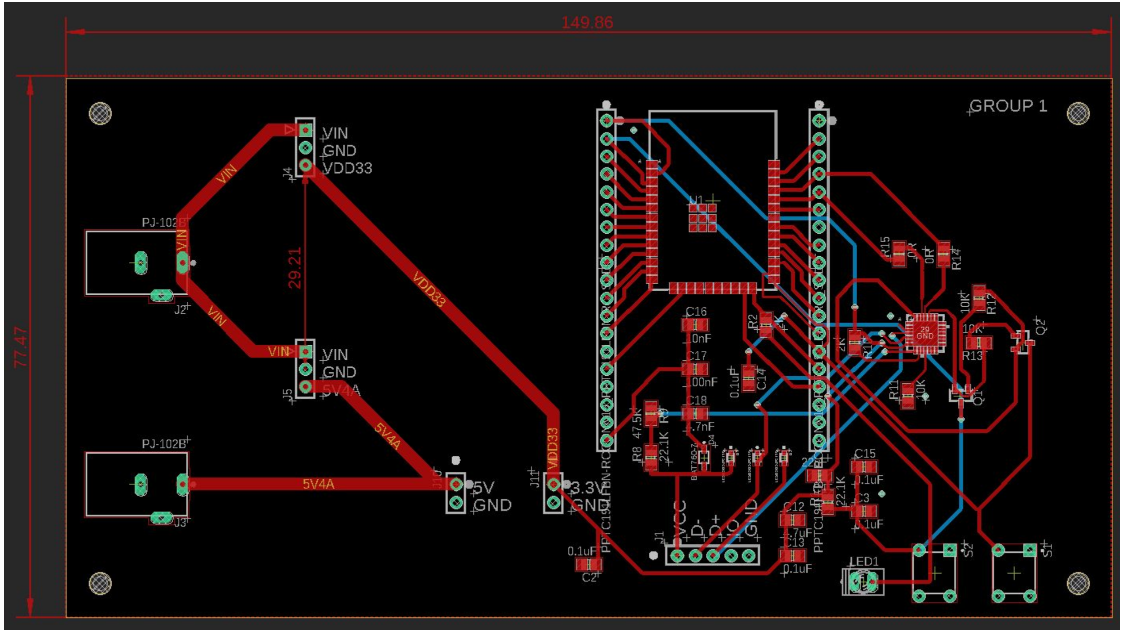
Main Board

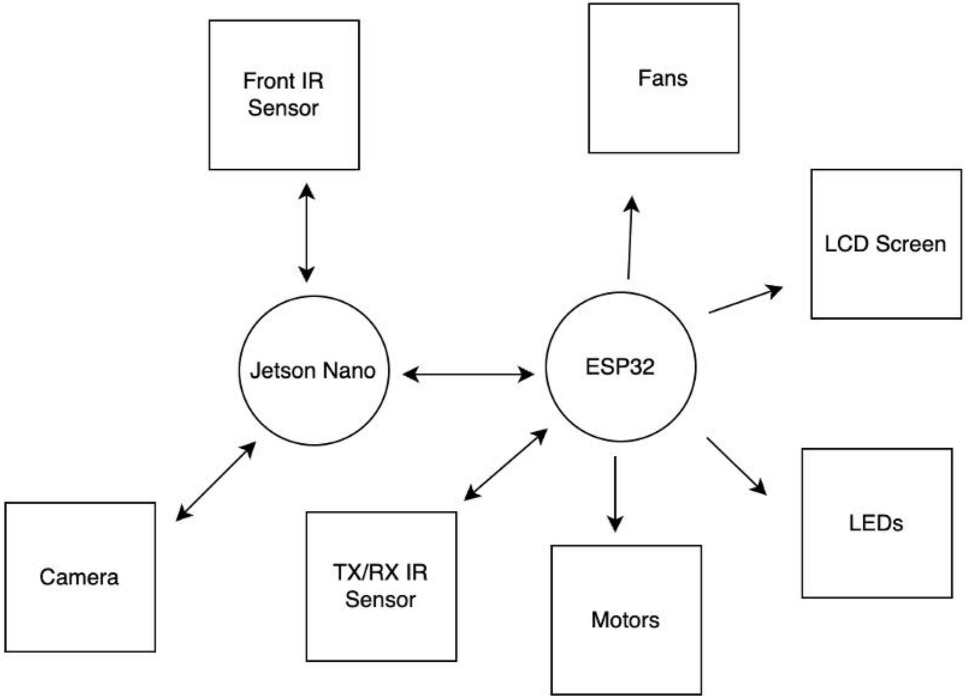


Software Design

Jhamori Williams-Austin

- *The software design is split amongst two main parts, embedded systems and artificial intelligence(AI).*
- *The embedded programming will be controlling things such as the motors, LCD display, the LEDs inside the vending machine, proximity sensors, and fans.*
- *The artificial intelligence software will handle the fast machine learning algorithms and object detection found by our camera system.*

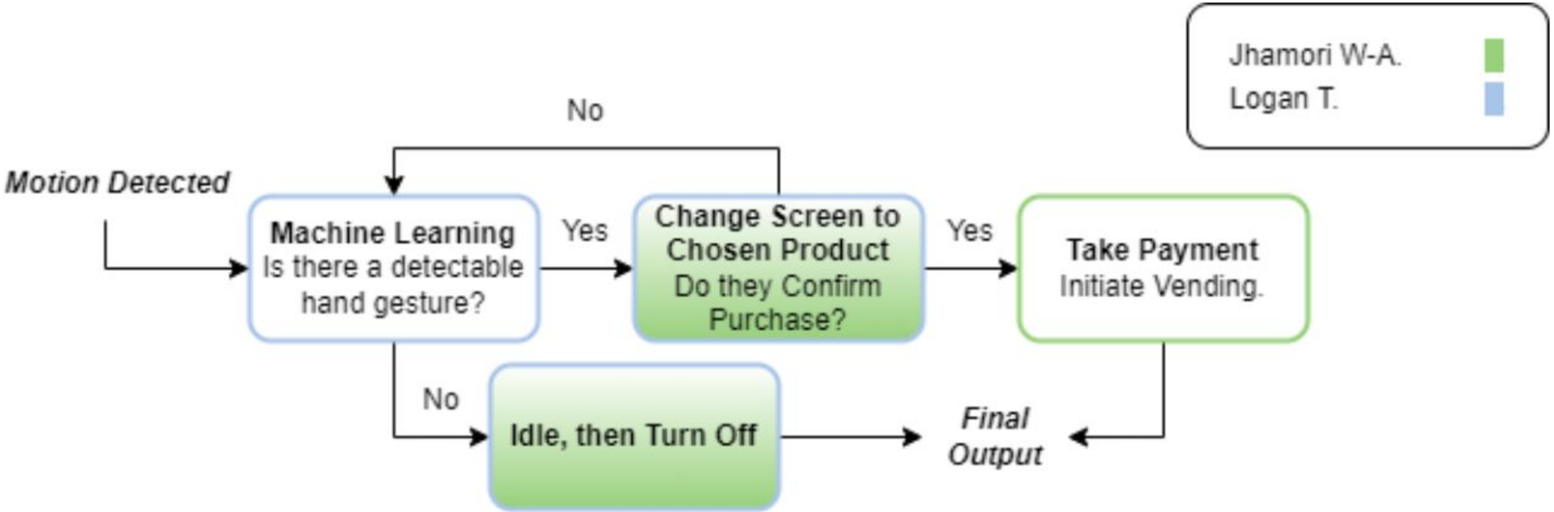
Software Design - State Diagram



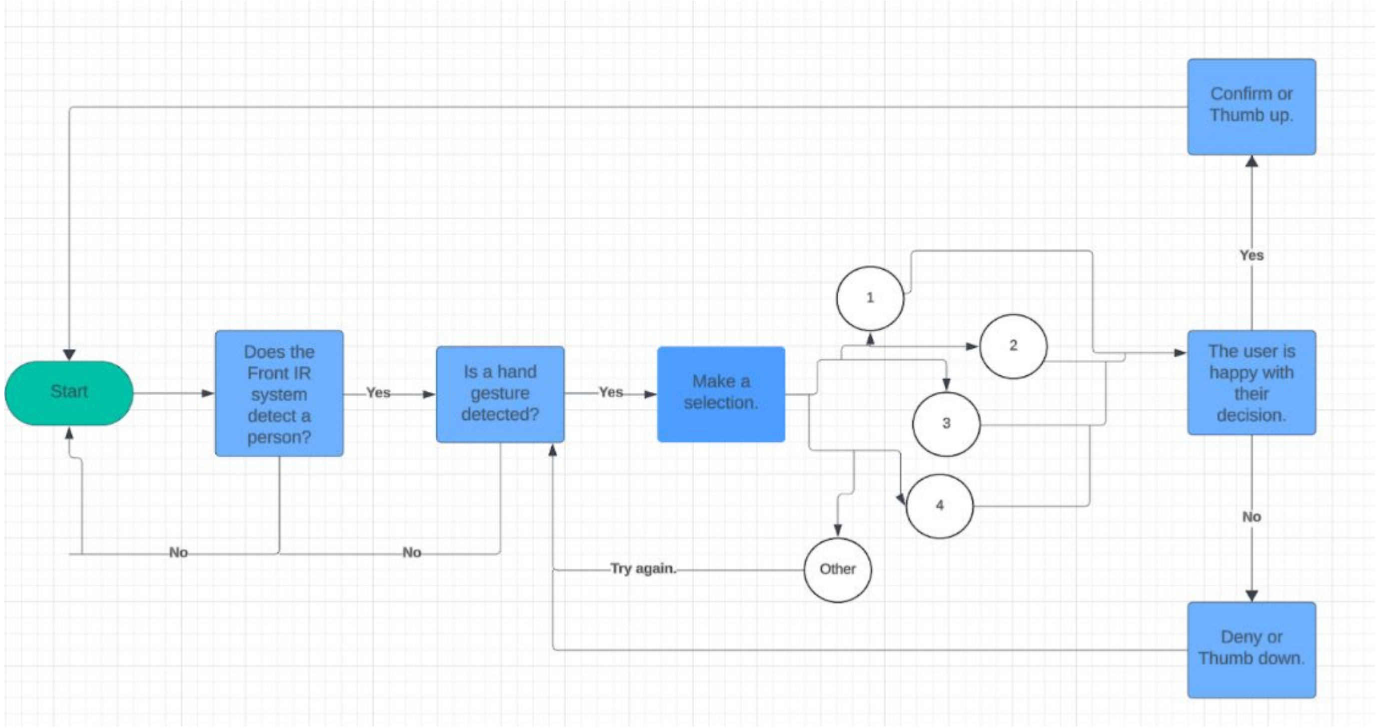
Jhamori Williams-Austin

Software Design - Input Flowchart

Jhamori Williams-Austin



Software Design - User Interface



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Software Design - Object Detection Model

Logan Terrell

When selecting a model, we had to consider training methods that specialize in some sort of image classification; the model will need to be able to tell the difference between hand gestures. There were three primary training models including Unsupervised Learning, Reinforcement Learning, and Supervised Learning that all specialized in different things.

Model	Specialization
Unsupervised Learning	Finding outliers within a set of points
Reinforcement Learning	Trial and error problems
Supervised Learning	Image classification tasks

Software Design - Object Detection Model

Logan Terrell

When considering the most common classifications under the umbrella of Artificial Intelligence, there exists Machine Learning and Deep Learning.

With AI being the concept of a machine behaving like a human mind, Machine and Deep Learning both specialize in training a model to complete tasks.

What differentiates the two is the ability of Deep Learning to handle much more complex tasks.

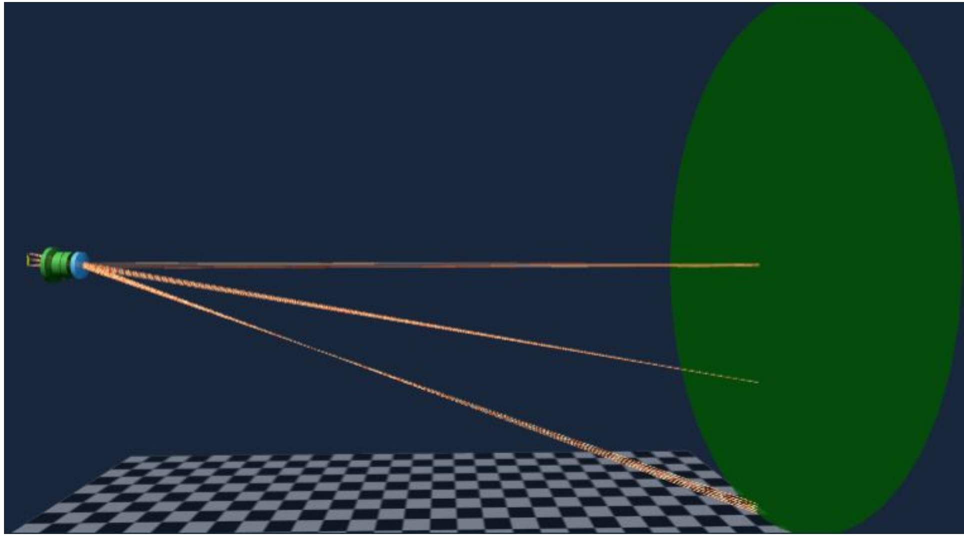
Based off this information, we decided to go with Deep Learning; the model will need to take a frame from the camera and decide if the gesture, depicted in this frame, is an accepted gesture.

Considering all the information stated, we decided to select a Supervised Learning model under the umbrella of Deep Learning because we needed a model that can classify complex, moving, gestures.

Optical Design - Lens System

Hussein Shelleh

- *Four Lens System*
- *Viewing Area (H x W) of ~25cm x 13cm*
- *Camera Area of ~6mm x 3mm*
- *Distance of ~40cm from final lens*
- *3D Printed Housing & Mounting Unit*



Optoelectrical Design - IR Electronics

Hussein Shelleh

- *Initially involved two separate systems of IR Electronics - one being the external sensor and the other being a set of transmitters and receivers to monitor the snacks*
- *Changed to use the same sensors as the external sensor due to functionality issues with the WROOM*
- *E18-D80NK has an adjustable minimum range - very useful for both identifying approaching customers and checking the stock*
- *External E18 will be mounted below the screen in order to avoid risks of eye damage. Internal E18 will be mounted at the end of the snack stocks (near the window) to check if a product is available.*

Design Testing

Logan Terrell

A test will be ran, with the proximity sensor, to assess the ability to keep track of stock in the vending machine.

A test will be ran, with the motors, to assess the ability to activate in reaction to some stimuli.

A test will be ran, with the object detection, to assess the ability to differentiate the different hand gestures.

A test will be ran, with the IR sensor, to assess the ability to startup the machine when motion is detected.

The final test will be everything working together as a complete system.

Challenges and Triumphs

Tyler Bornemann

Challenges:

- Transmitters and Receivers were difficult to use in terms of transmitting data.
- LCD DISPLAY user interface difficulties.
- Object detection programming difficulties.

Triumphs:

- Made progress by switching microcontrollers.
- Gained practical knowledge through the research and experimentation.
- PCB Layout solid from the start.

Budget (So Far)

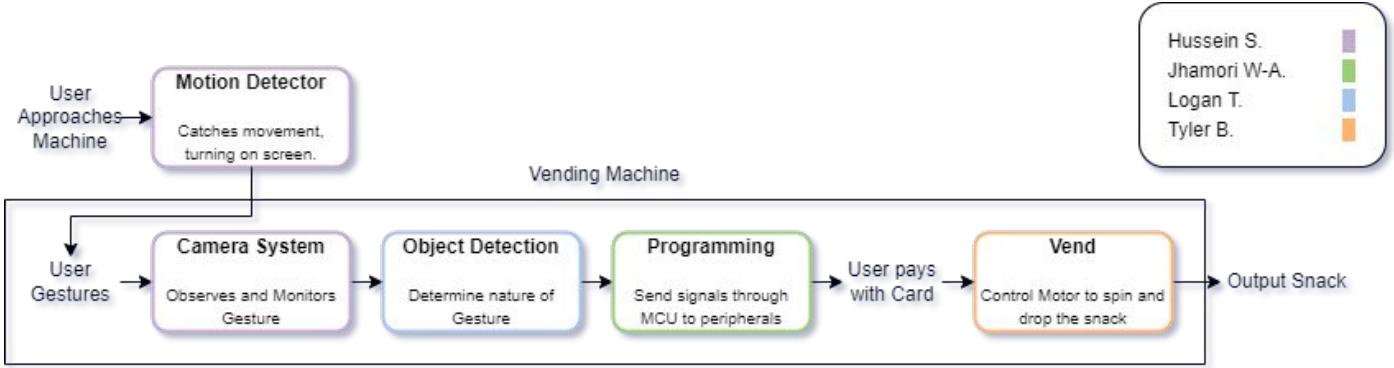
Item	Quantity	Cost
ESP32	2	$24
5V Cooling Fan	2	$8
Screen	1	$20
Jetson Nano	1	$108
Optical Lenses	4	$135
24V Power Supply	1	$26
Motors	5	$22
Other Components and Equipment	A Lot	$72
Total	///	$415

Tyler Bornemann

Hussein Shelleh

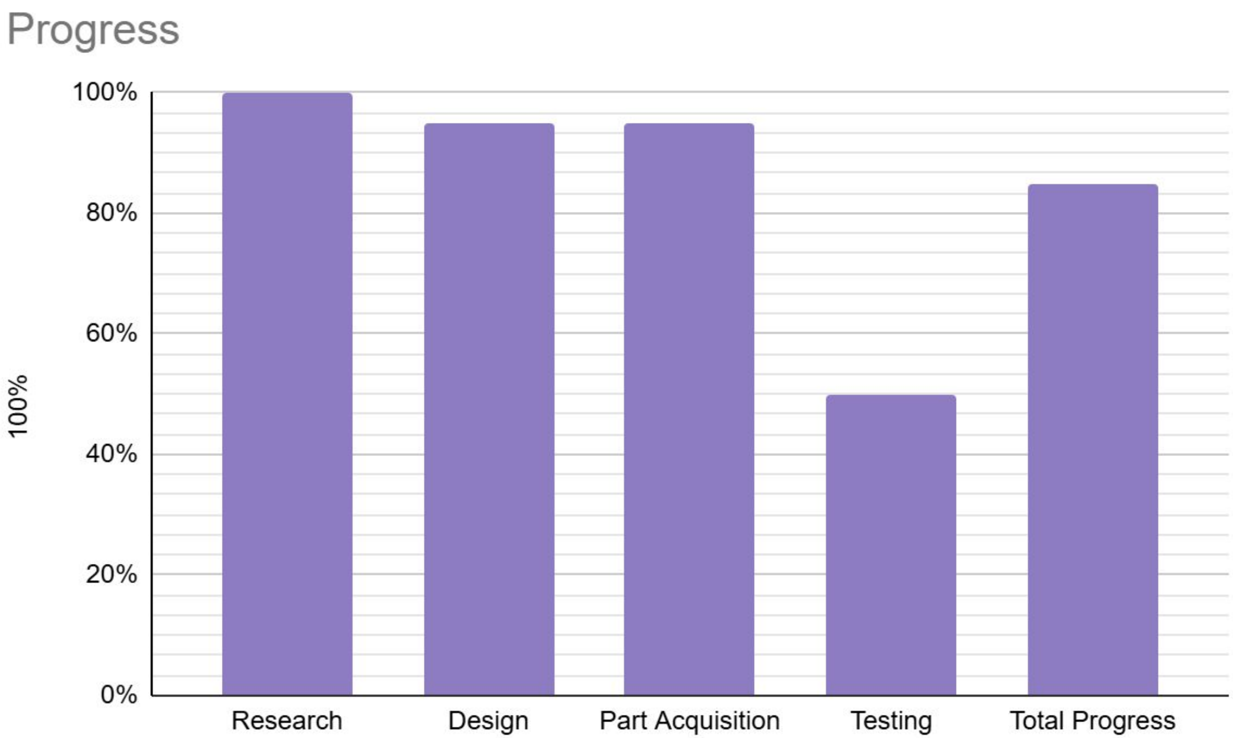
Work Distribution

- ***Hussein Shelleh** primarily handles the PCB positioning and editing, part soldering and installation, and both the Lens System and IR installation.*
- ***Jhamori Williams-Austin** primarily handles the programming of the MCU, the Fan and Motor control, and the GUI for the LCD screen.*
- ***Logan Terrell** primarily handles the AI Development Kit and Object Detection programming.*
- ***Tyler Bornemann** primarily handles the PCB development, initial design Breadboarding, and 3D Print modelling.*



Progress

Hussein Shelleh



To Do?

Hussein Shelleh

To Be Done	How To Accomplish
PCB Testing	*PCB Order is in and on the way. PCB lab was also completed. Once here, solder components and begin system testing.*
Object Detection Testing	*Continue with Training until acceptable, then begin testing. In Progress.*
Shell design	*3D Printing only requires the models - In Progress. The metal welding has been trickier. Unnecessary, but style is important.*

Thank you!

We appreciate your time and attention,
and we hope to hear back from you all.