The ArticuLight

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Motivation

Current Problems with light sensor systems:

- Light fails to turn on
- Lens of sensor becomes obstructed, dirty or old
- Expensive cost for detecting motion and installation (Approx. $400)

Solution:

To create a motion-controlled lighting system that will be controlled through hand gestures to move, rotate, and adjust brightness levels of the light for the user to work on projects on workbenches at any time of day. We are hoping this will help eliminate shadowing, as well as creating a hands-free device, so the user can use both hands while working on their project. We felt this needed to be invented because we feel this will allow for users to finish and produce final projects at a faster rate.

Goals and Objectives

ArticuLight offers:

- Hands-free light for work benches
- Edit movement through creating hand gestures in view of camera
- Rotation of light angle through hand gestures
- Make light bright/dim through hand gestures
- Allows for less shadowing when working on a project

Market Requirements

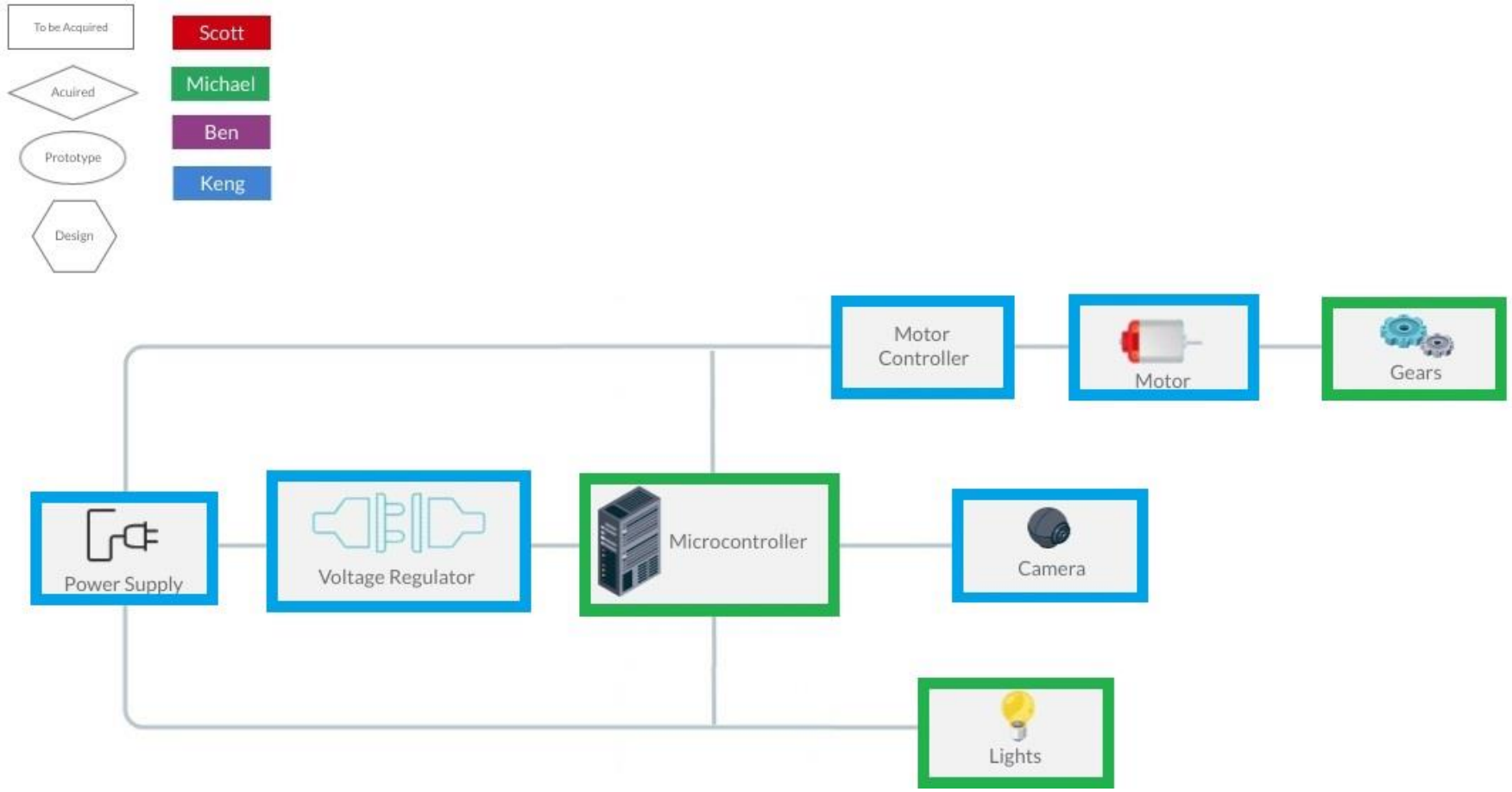
Specifications	Description
Pitch/Yaw and Angle/Degrees of Freedom	- Up to +/- 90° of movement left and right (yaw) - Up to +/- 90° of movement up and down (pitch)
Robot Vision	Will use a camera to identify hand gestures to control the movement of the actuators
Stand	The mount will be modular: - Mountable - Scalable by adding additional lights
Environmental Robustness	Able to handle temperature and humidity variation: - 20° to 100° temperature range - Waterproof and dust proof
Response Time	Software to hardware interface will have a response time less than 3 seconds
Manual Reset/Zeroize	Device will be able to manually stop and reset the system

Key Specifications

- Accuracy: how close the device will move the light source to focus on specific location.
- Durability: Number of uses and sustained usage of device
- Actuation Time: time taken when computation is finished to complete the movement
- Computation Time: Time it will take the system to read a gesture from the camera and send a stimulus to perform actuation

Engineering Specifications	Value
Accuracy	<= 1 cm
Durability	1000+ uses
Actuation Time	Between 3 – 5 seconds
Power Input	120V AC
Weight	<= 7 lbs
Computation Time	<= 2 seconds
Arm Length	24 inches
Light Voltage	120V

Hardware Block Diagram



Hardware Components

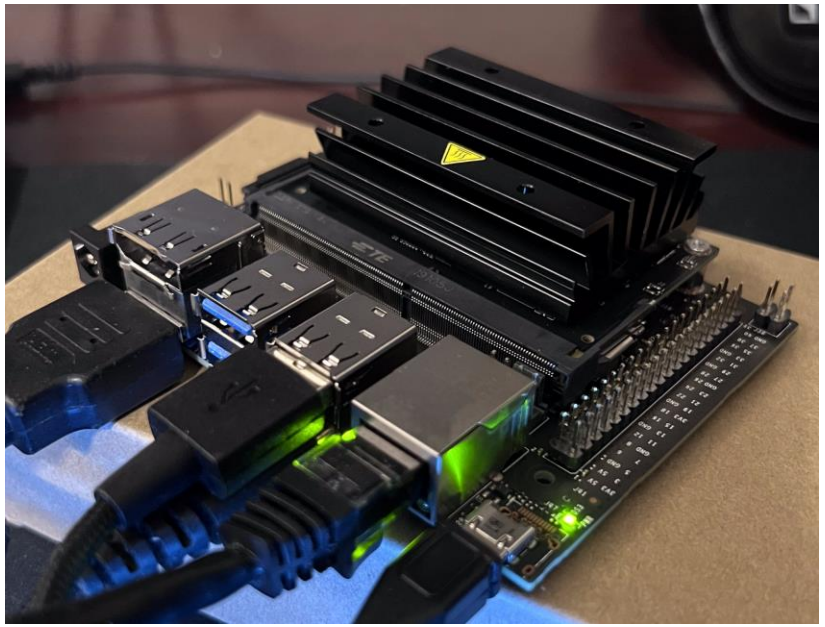
Microcontroller

- We chose the ATmega328P microcontroller because we felt it had the best specs for our project and is compatible with our motor controller.
- Some of these specs include but are not limited to:
  - Input voltage: 1.8 - 5.5 V - DC
  - Operating voltage: 1.8 - 5.5 V - DC
  - Digital I/O pins: 27
  - PWM channels: 10

MCU	ATmega328P	MSP430G2553
Input Voltage (V-DC)	1.8 - 5.5	1.8 - 3.6
Operating Voltage (V-DC)	1.8 - 5.5	1.8 - 3.6
Digital I/O pins	27	83
PWM channels	10	8
Flash Memory (KB)	32	16
Price (USD)	~5	~3

Jetson Nano Developer Kit

- Implementing deep learning such as vision requires a decent amount of processing. The Jetson Nano is marketed for embedded deep learning and will be used in this project.
- Features:
  - "Jetpack" - A modified Ubuntu Linux installation
  - 128-core Maxwell GPU for parallel AI tasks
  - ARM A57 CPU
  - CSI camera connections
  - 40 pin GPIO header
  - 5V 2A input, 3.3V pins



Motor

- We decided to choose a Servo Motor for our design. We felt this was the best motor to choose because of the specifications it had, such as great rotational angle and able to handle the most weight as you will see in the table below compared to other servo motors.

Motor	Operating Voltage (V)	Rotation Angle (degrees)	Stall Torque (kg)	Price
HPS-3527SG	5-7.4	270	35	$33.99
DS3218MG	4.8-6.8	270	20	$15.99
DS3225	4.8-6.8	180	25	$20.99
MG996R	4.8-7.2	180	12	$13.99
HST-35H	9-12.6	240	35	$23.99

Camera

Camera	Raspberry Pi Camera Module 2	Raspberry Pi High Quality Camera	Arducam IMX219 Visible Light Fixed Focus Camera	Arducam IMX219-AF Programmable/ Auto Focus Camera	Arducam IMX219 Low Distortion M12 Mount Camera
Image sensor	IMX219	IMX477	IMX219	IMX219	IMX219
Maximum Resolution	8 megapixels	12 megapixels	8 megapixels	8 megapixels	8 megapixels
Horizontal FOV (degrees)	62.2	Depends on lens sold separately	62.2	65	75
Full Resolution Frame Rate	N/A	N/A	21 fps	21 fps	21 fps
720p Frame Rate	60 fps	60 fps	120 fps	120 fps	120 fps
Price	$25	$50	$19	$30	$32

Socket Specifications using an LED Bulb

Light Socket	E-12	E-19	E-26	E-39
Power (W)	75	60	60	660
Voltage (V)	125	125	250	240
Luminosity (Lumen)	400	840	800	36000
Size (mm–diameter)	12	19	26	39
Weight (oz)	6.4	2.04	0.564	8.2

Relay

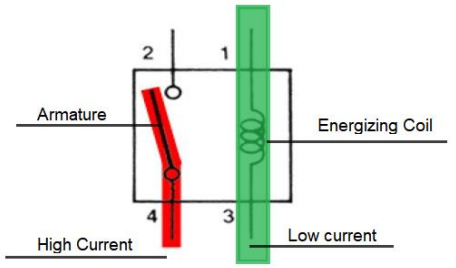
Solid State:

- No moving parts
- Lasts much longer
- Higher cost

Electro-mechanical:

- Normally open or closed
- Can carry a large amount of current
- Parts tend to wear out more quickly

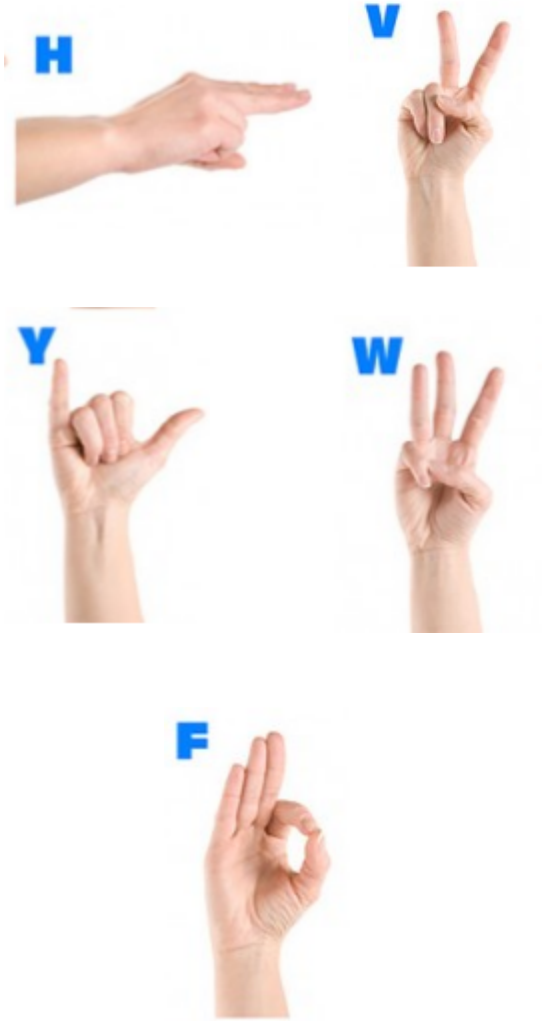
Specification of Relay	Solid State	Electro-Mechanical
Operating Current	70 mA	12.5 mA
Output Voltage (DC)	30 VDC	Cannot drive DC output
Output Current	0.1A to 10A MAX	0.1A to 2A MAX
Single Channel Relay Price	$7 - $12	$9 - $15

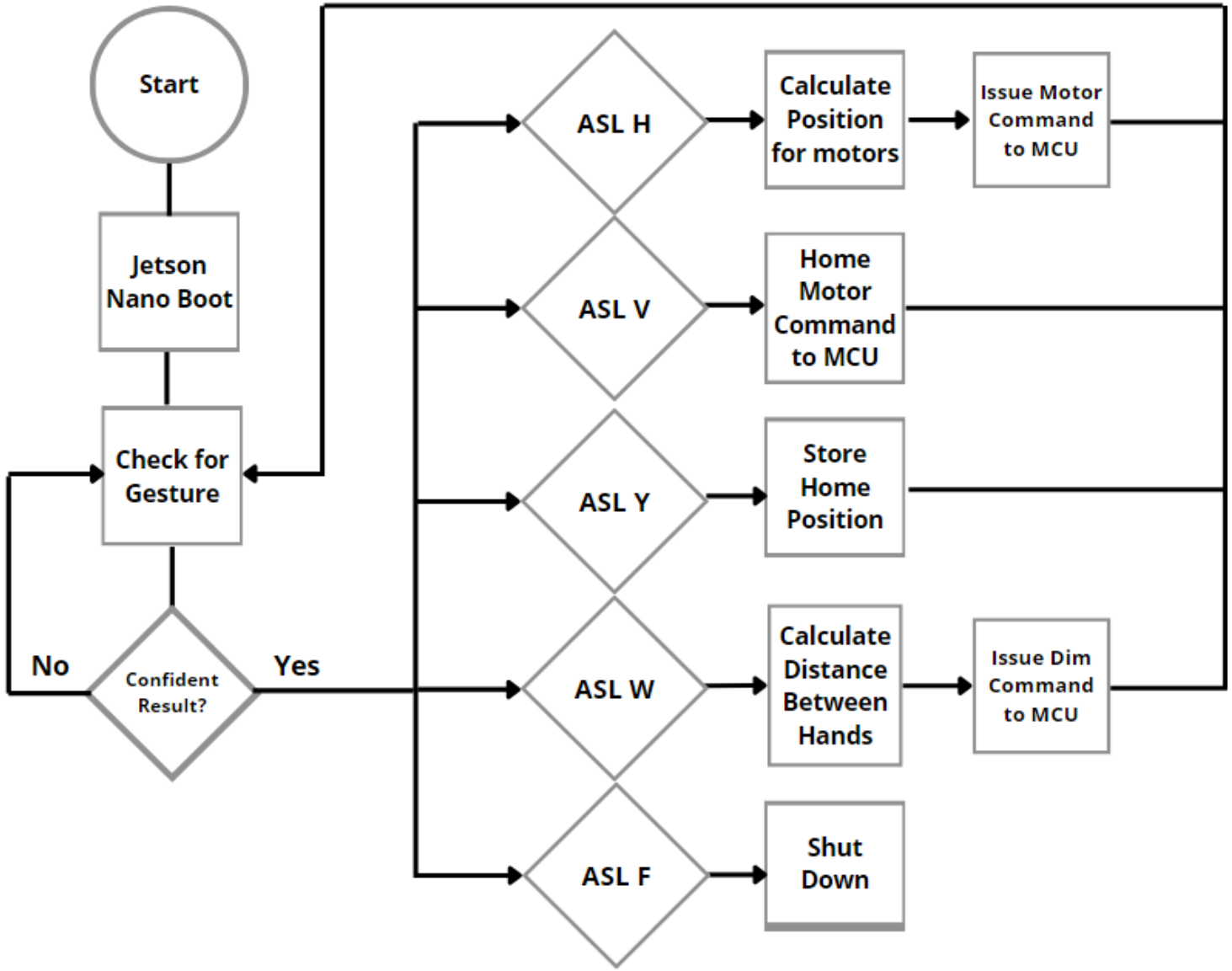


Voltage Regulator

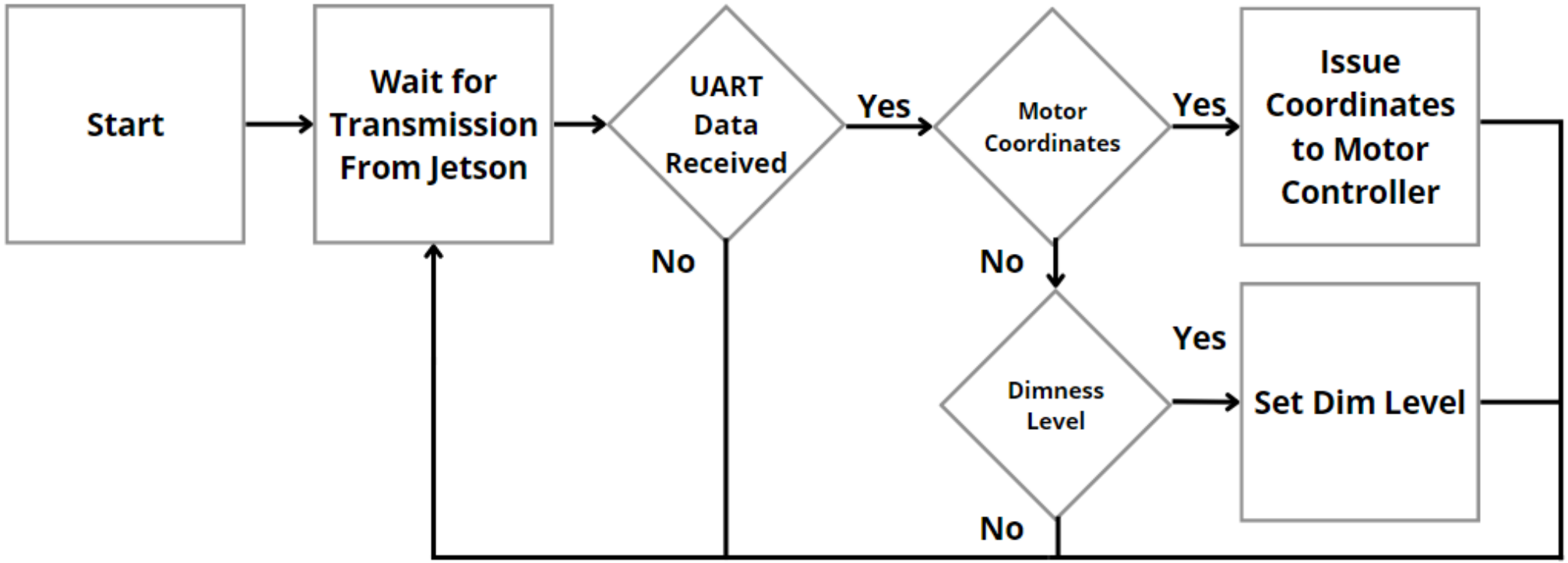
Type of Regulator	Linear Voltage Regulator	Switching Voltage Regulator
Pros	• Low output ripple voltage • Fast response time to load or line changes • Low electromagnetic interference (EMI) and less noise	• More complex design, which allows for handling higher power efficiency • Able to provide output, which can be greater or less than or invert the input voltage
Cons	• Efficiency is low • Requires large space – heatsink is needed • Voltage is above the input cannot be increased	• Higher output ripple voltage • Slower transient recovery time • EMI produces very noisy output • Very expensive

Jetson Nano Software Block Diagram





Microcontroller Software Block Diagram



Machine Learning Software

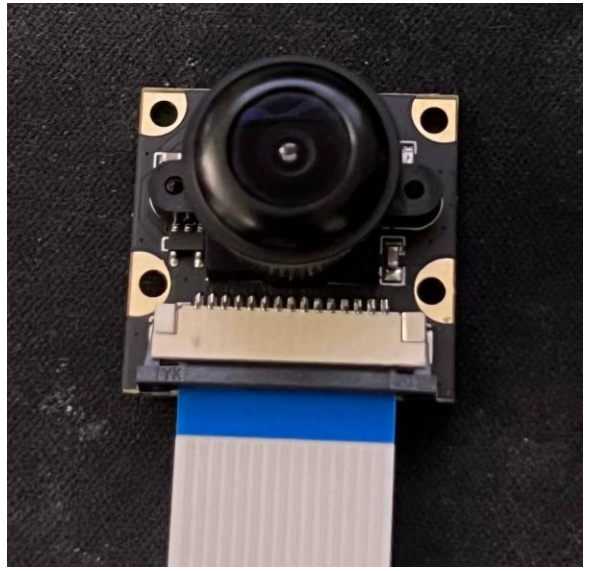
- Jetson-inference: visual detection in real time using Jetson Nano
- Uses TensorRT with C++ and Python releases
- Contains libraries with multiple compiled models for different uses: object detection, semantic segmentation, image classification, posenet
- Object detection and posenet will be used
- PyTorch: Used for retraining the selected model to detect ASL alphabet letters

Machine Learning Models for Gesture Detection

Model	SSD-Mobilenet-v2	Pose-ResNet18-Hand
Architecture	Standalone. Uses convolutional neural networks with global average pooling.	Requires use of other ML models such as SVMs for gesture detection. Uses convolutional neural networks.
Accuracy	Most accurate of available models	Depends on implementation
Speed	Fastest of available models	Depends on implementation
Return type	Classification label and location in image	Vector key points for each part of hand

Computer Vision Software

- Already implemented by NVIDIA
- Accesses MIPI CSI camera through `csi://0` path
- Instantiates camera feed as an object with image as property
- Removes need for dedicated software such as OpenCV – faster and more streamlined programming



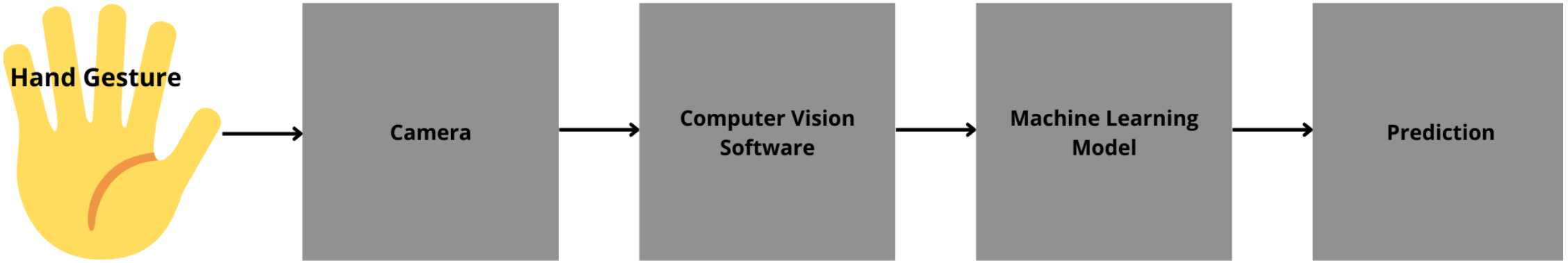
What's the difference?

Computer Vision Software

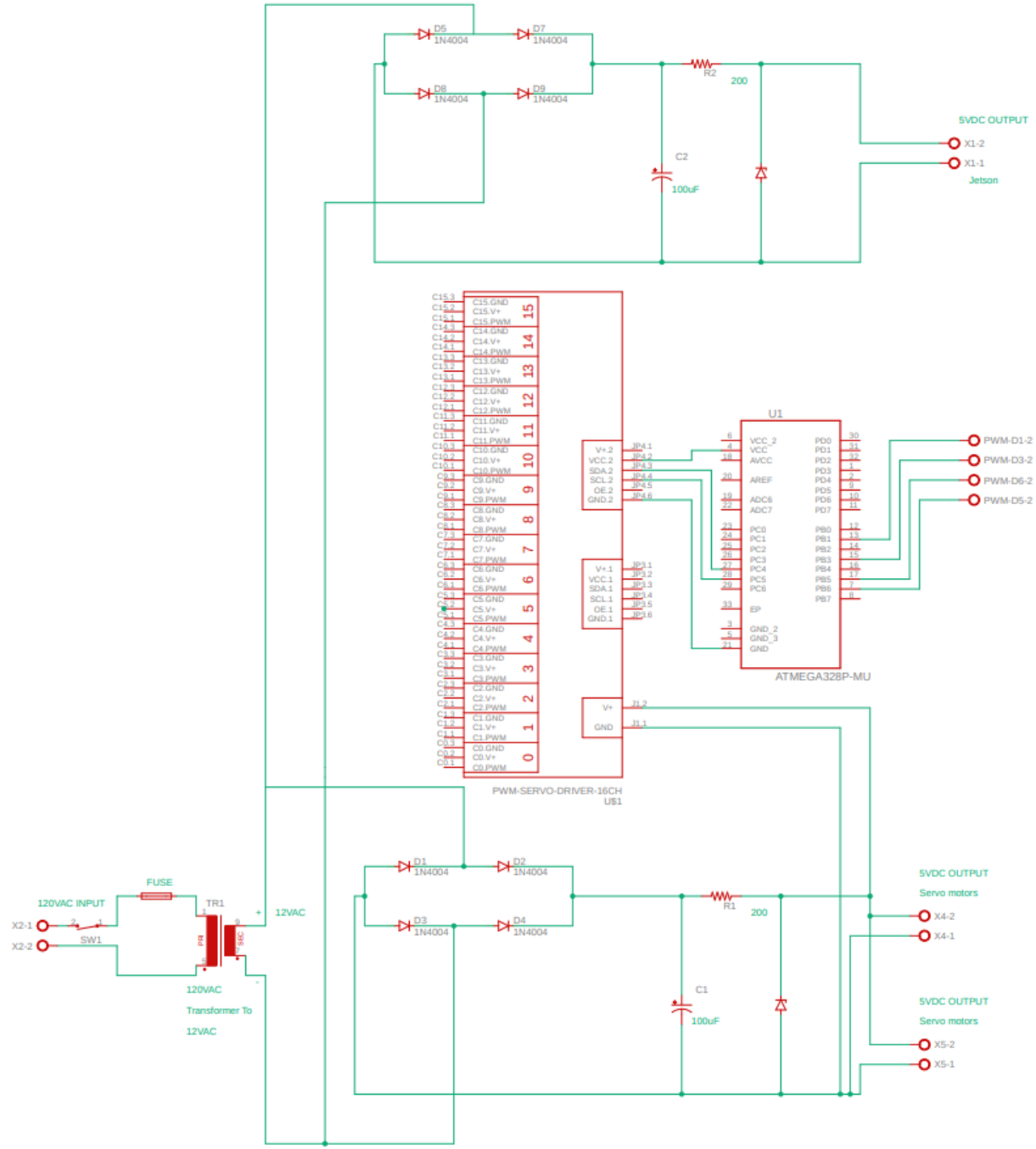
- Converts image data from camera to useful data for machine learning model

Machine Learning Software

- Utilizes a model for classifying images from data supplied by computer vision software

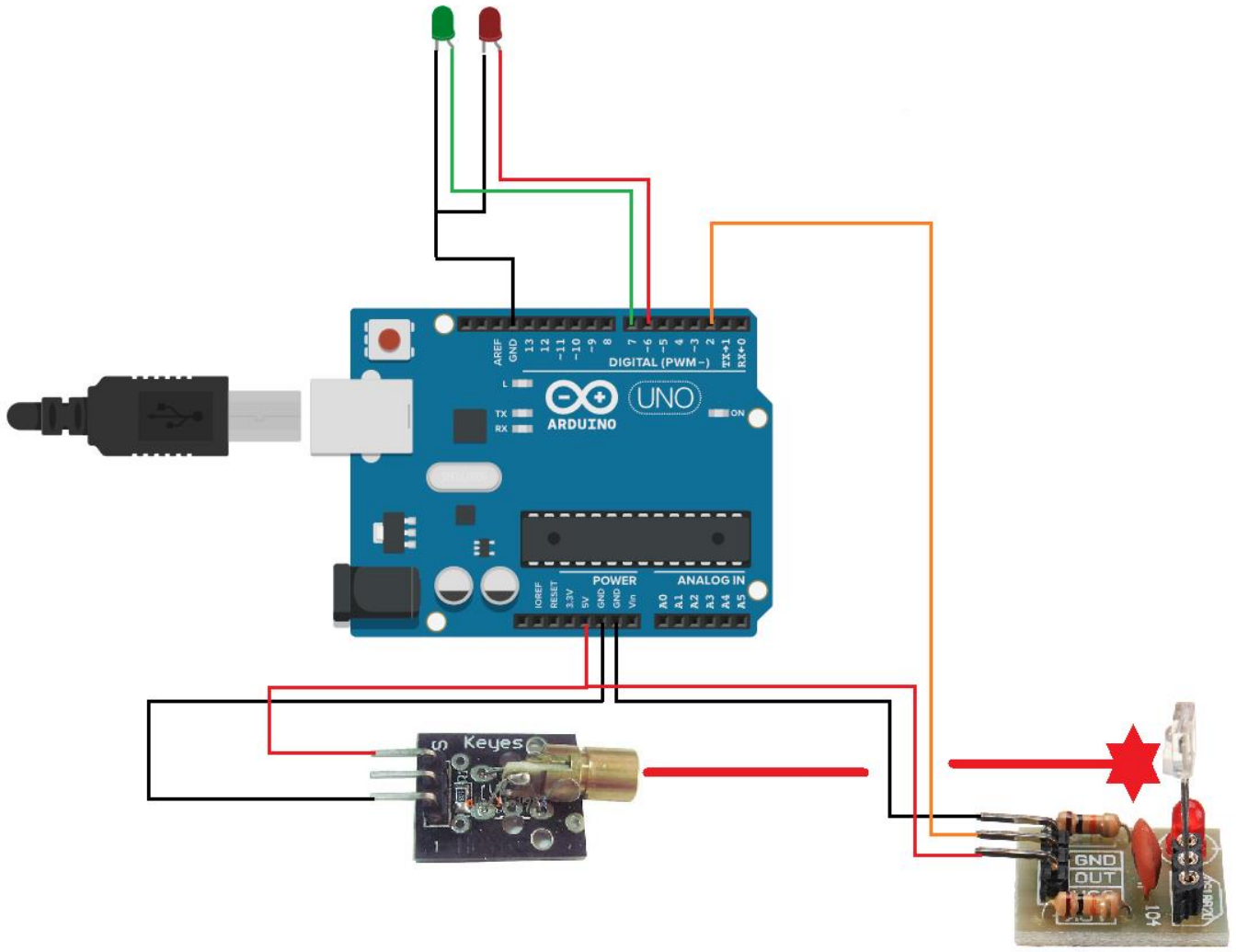


Schematics

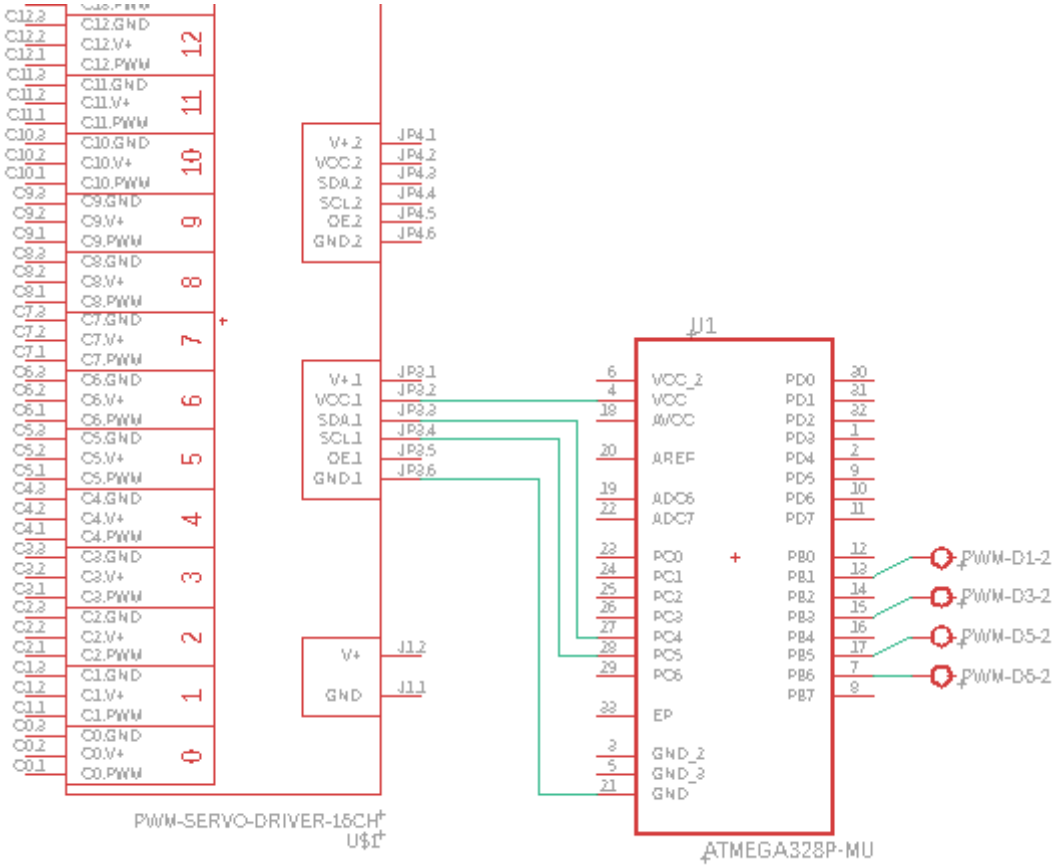

D5
1N4004
D7
1N4004
D8
1N4004
D9
1N4004
R2
200
C2
100uF
5VDC OUTPUT
X1-2
X1-1
Jetson
U1
ATMEGA328P-MU
PWM-D1-2
PWM-D3-2
PWM-D6-2
PWM-D5-2
PWM-SERVO-DRIVER-16CH
US1
D1
1N4004
D2
1N4004
D3
1N4004
D4
1N4004
R1
200
C1
100uF
5VDC OUTPUT
Servo motors
X4-2
X4-1
5VDC OUTPUT
Servo motors
X5-2
X5-1
FUSE
120VAC INPUT
X2-1
X2-2
SW1
TR1
120VAC
Transformer To
12VAC
12VAC

Schematic view of Laser Calibration

- Calibration system design for zeroing servo motors
- Laser would be mounted on top of the arm with the receiver as a detachable module from the base
- Allows us to add an offset to the servo actuation control if needed



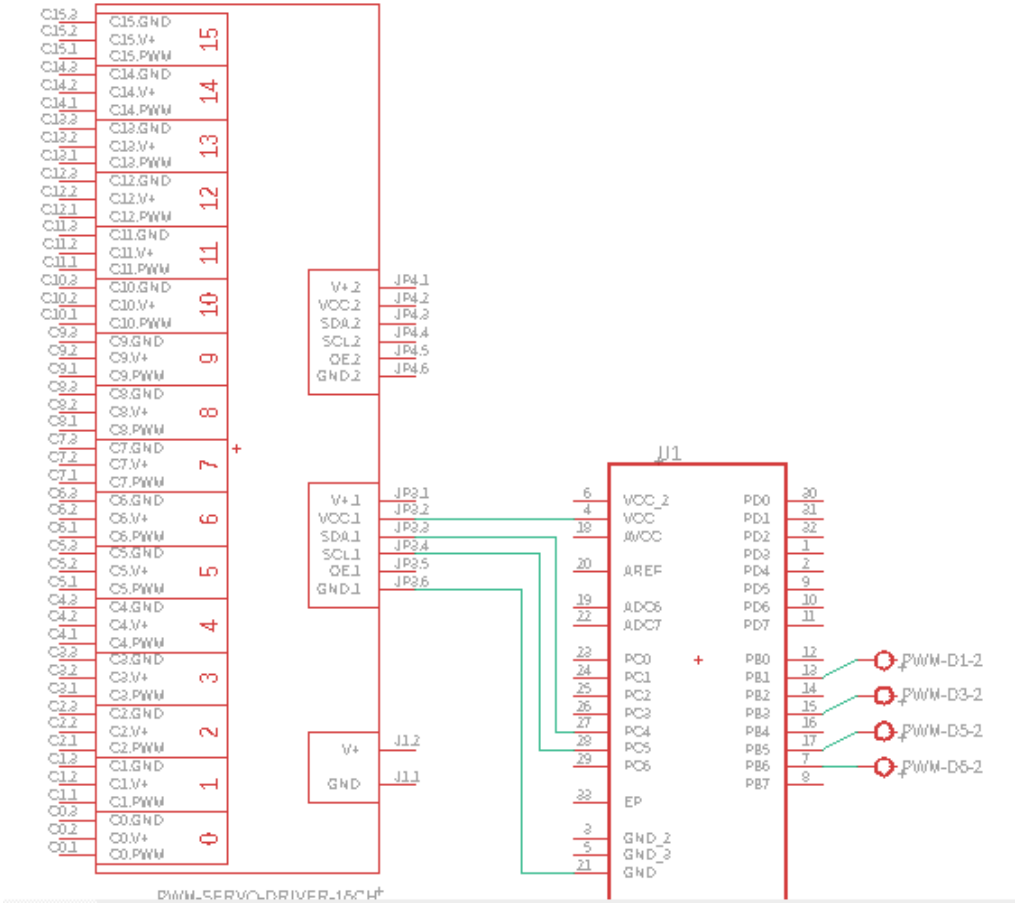
Schematic view of Microcontroller



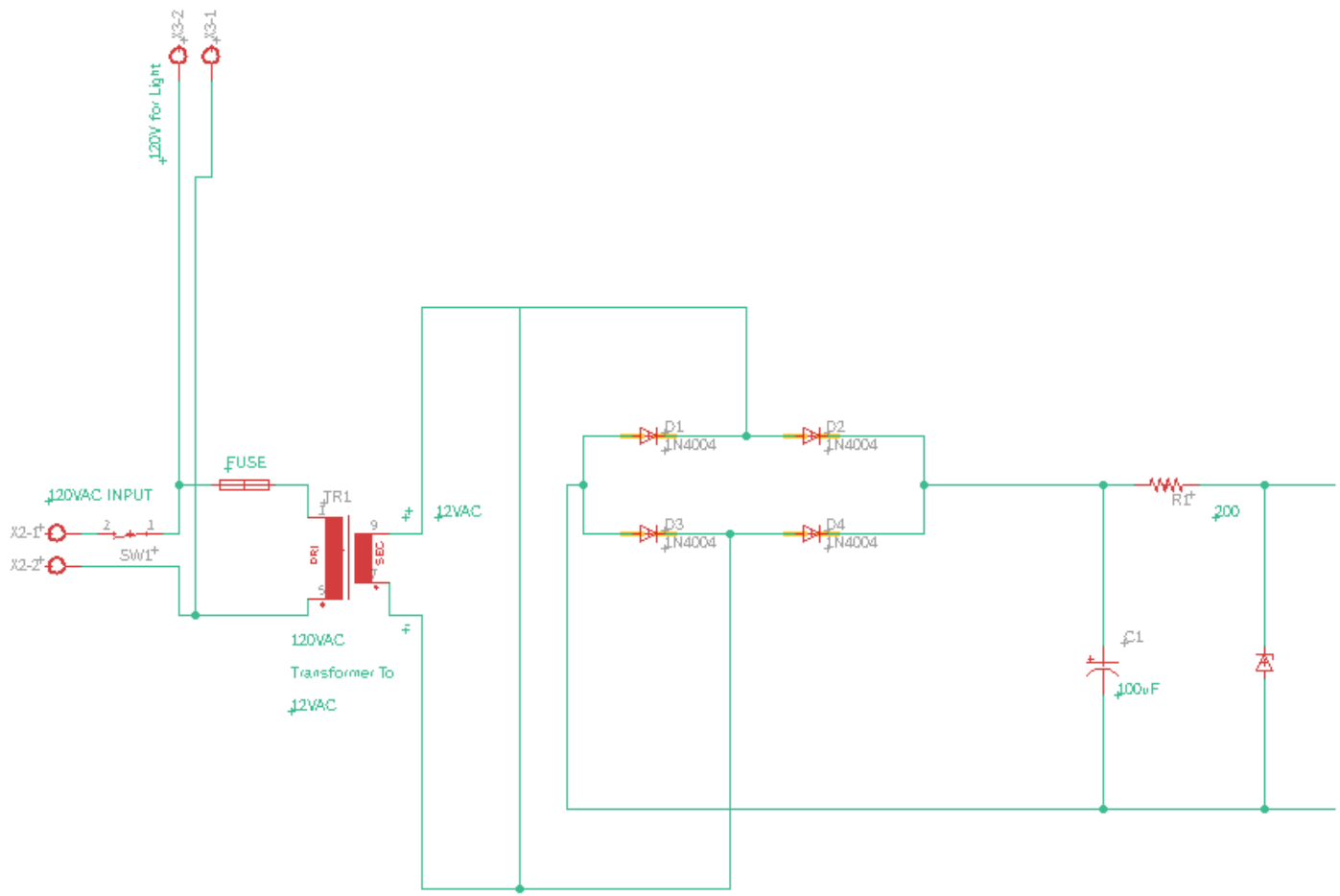
- Allows us to communicate with a servo controller over I2C or send the PWM signal directly to the motors.

Schematic view of Motor Controller

- Microcontroller communicates with the motor controller over I2C.

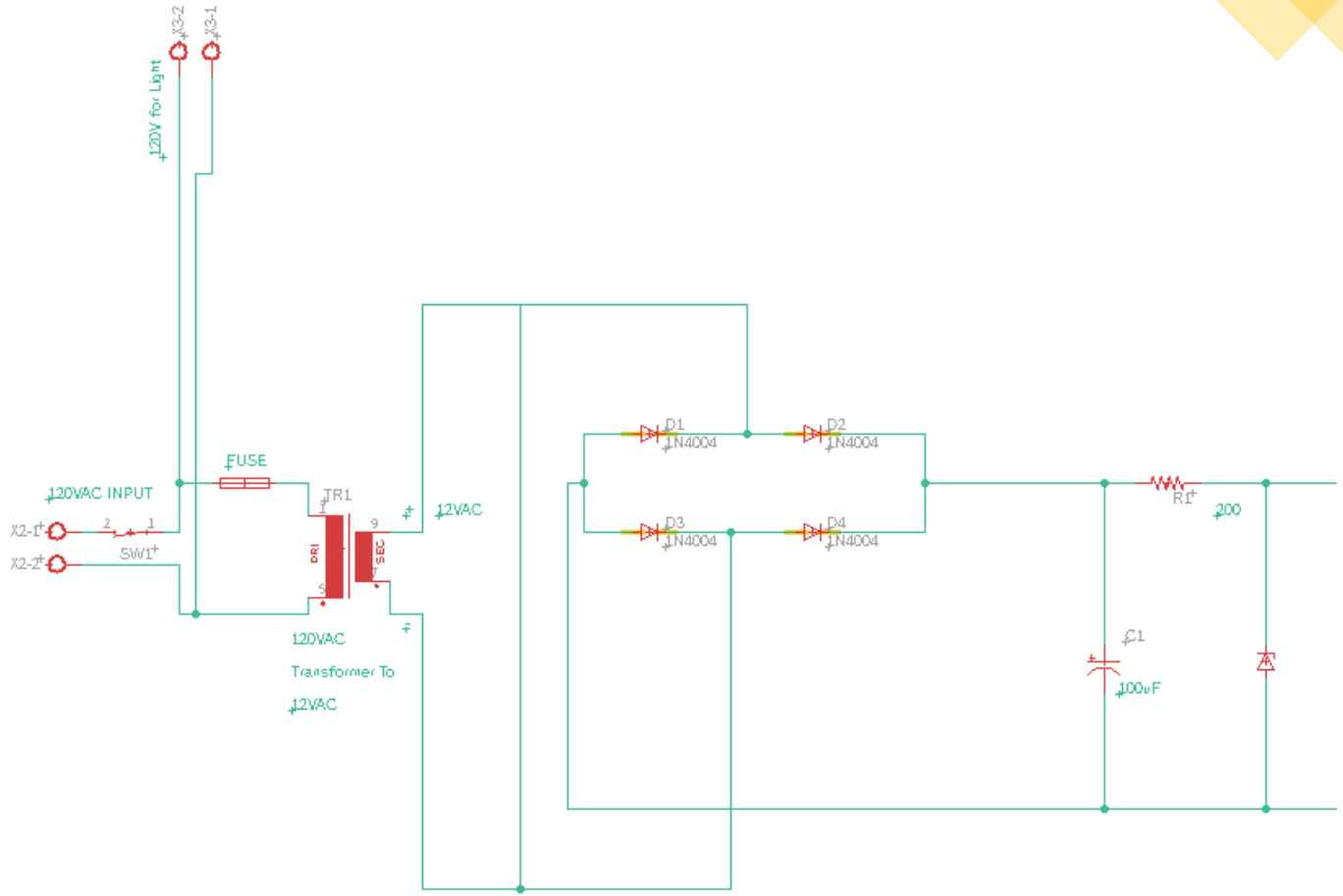


Schematic view of Power Supply/Voltage Regulator



Functionality Hardware (starting from power to voltage regulator)

- Reducing 120V AC to lower voltage
- Converting AC voltage to DC Voltage
- Capacitor to reduce voltage ripples
- Ziner Diode to obtain stable output voltage



Functionality Hardware (After voltage regulator where does it go next)

- After the voltage flows through the regulator it then flows to the Jetson Nano microcontroller
- After the voltage is regulated to fit the specs of the Jetson Nano, the Jetson then powers the motor controller, which in turns then powers the servo motors to adjust the arm of the light.
- Powers the camera

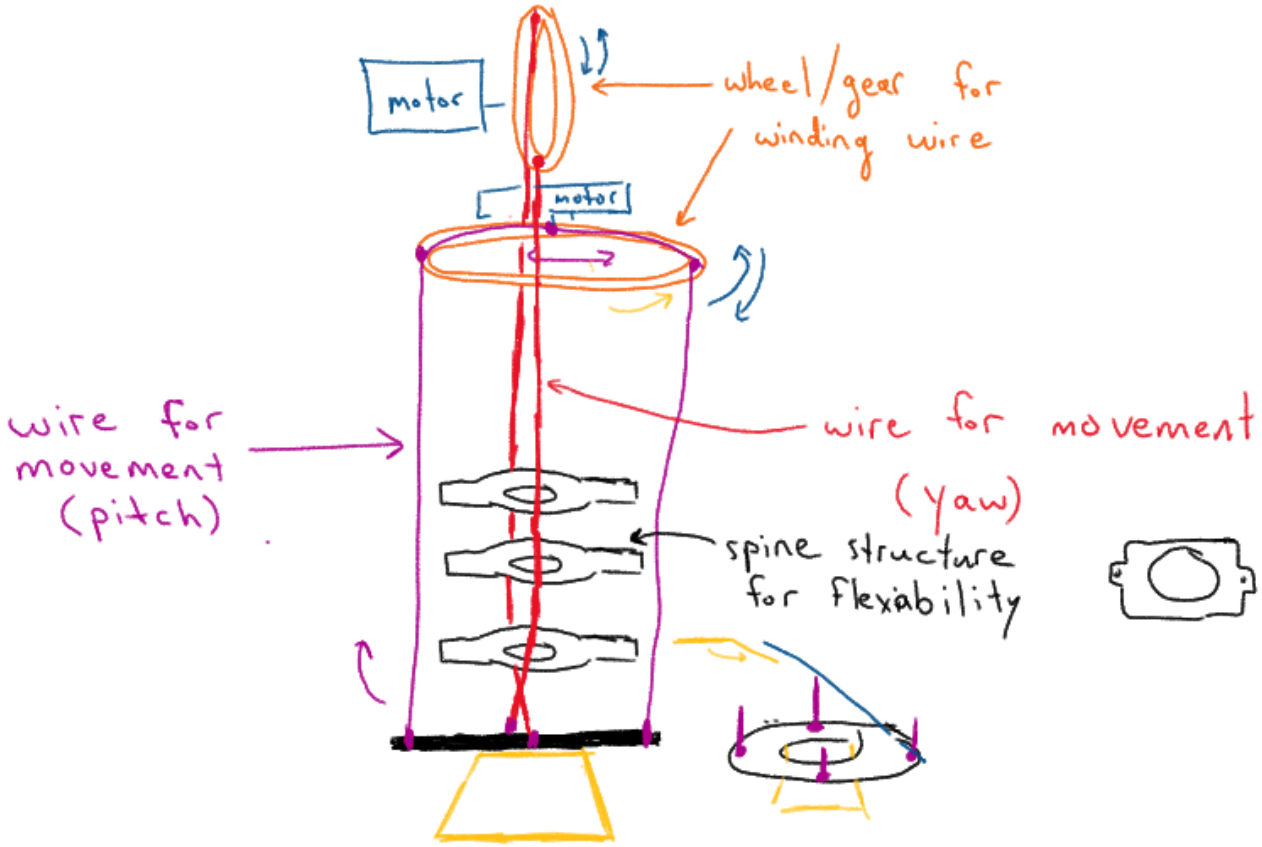
Functionality Hardware (Finish rest of components here)

- Once the arm of the light stops moving, it is up to the user's discretion, on controlling the light through gestures that the camera is programmed to understand.

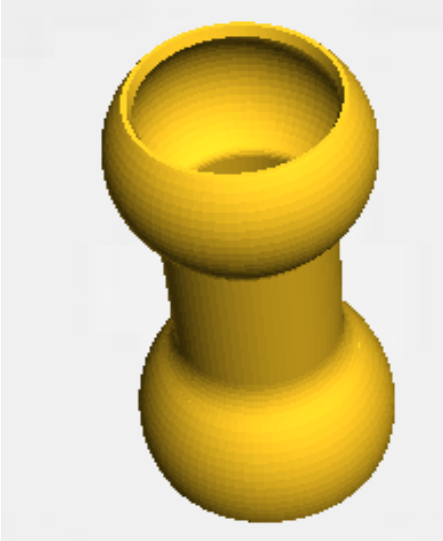
Functionality Software

- When the Jetson Nano detects a gesture with meaning, a signal will be sent to the microcontroller through UART to alter the state of the system
- Microcontroller will communicate with tertiary devices through C++
- The microcontroller will then perform the necessary actions – such as moving the arm via motor actuation and dimming

ArticuLight Frame Concept Design



Rapid Prototyping - Initial Design of Frame



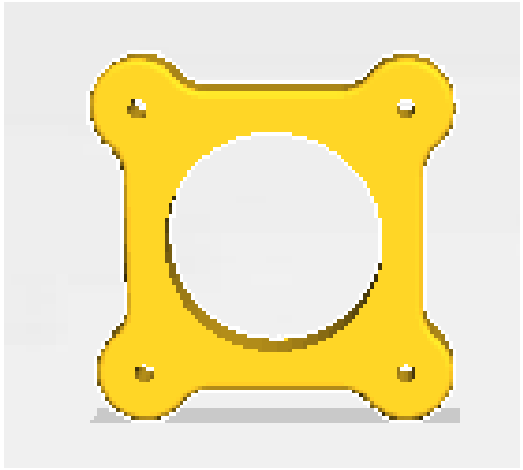
Initial Design of interlocking segments

High degree of mobility

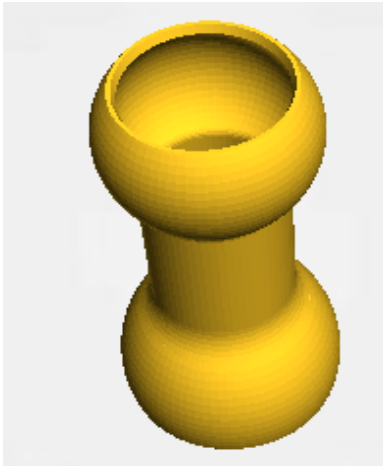
Rigid structure

Light weight

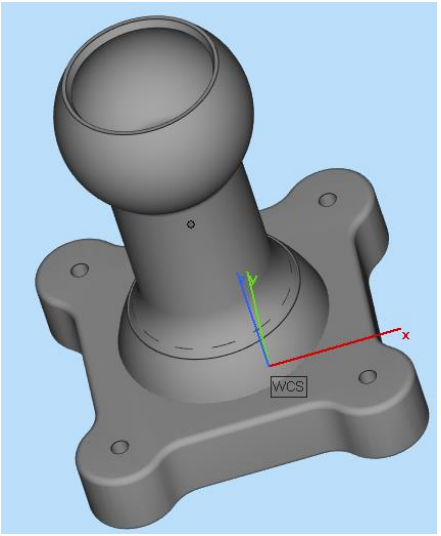
Rapid Prototyping – Wire Guide



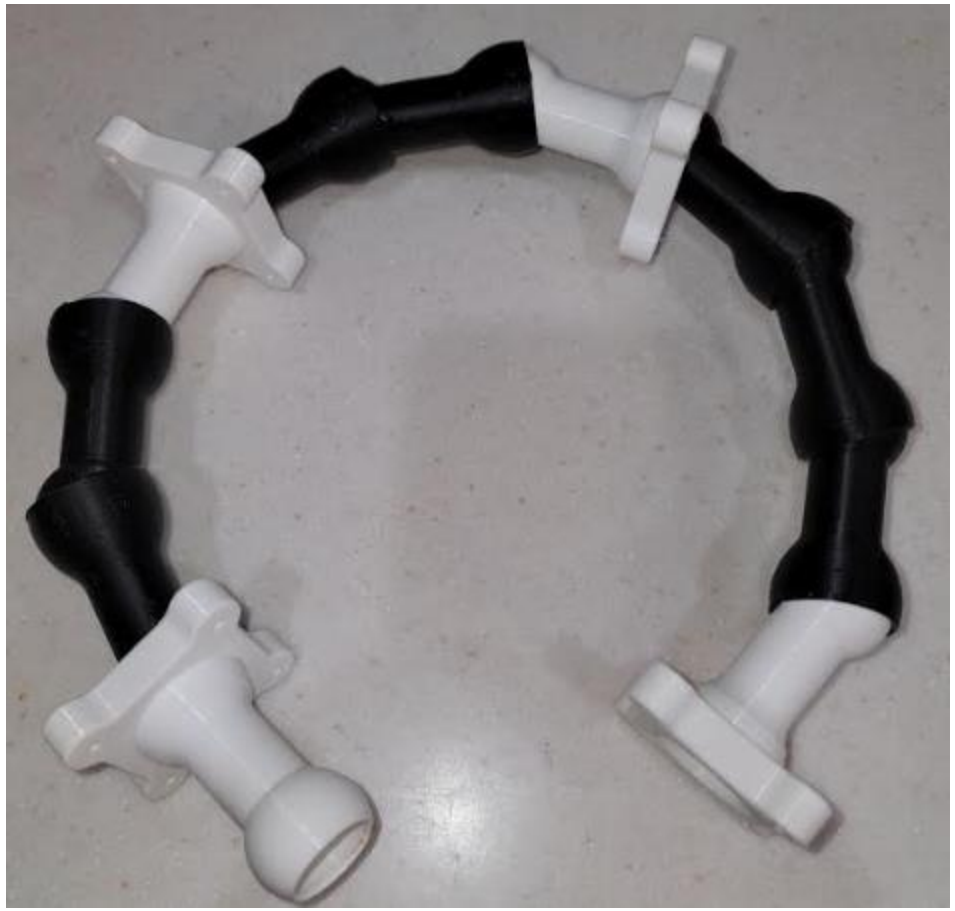
Wire Guide



Interlocking Segments



Rapid Prototyping – Fully Assembled Frame

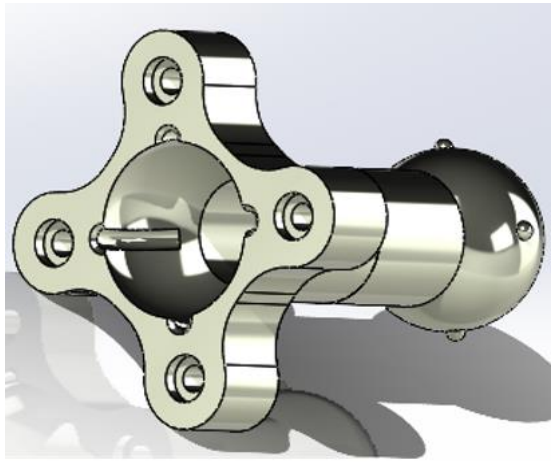


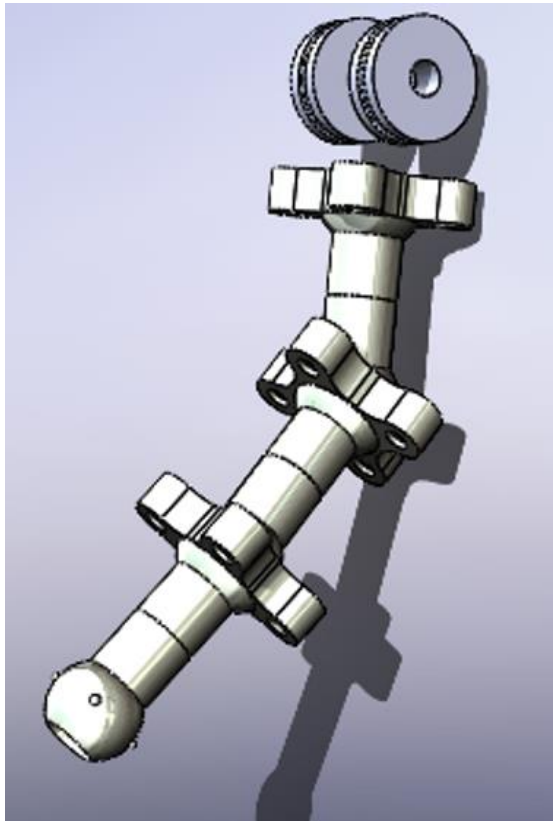
Design Flaws:

- System was too rigid which
- would cause it to crimp when actuated

- System would also rotate during movement, causing the guide wires to wrap around the frame

Rapid Prototyping – New and Improved Design

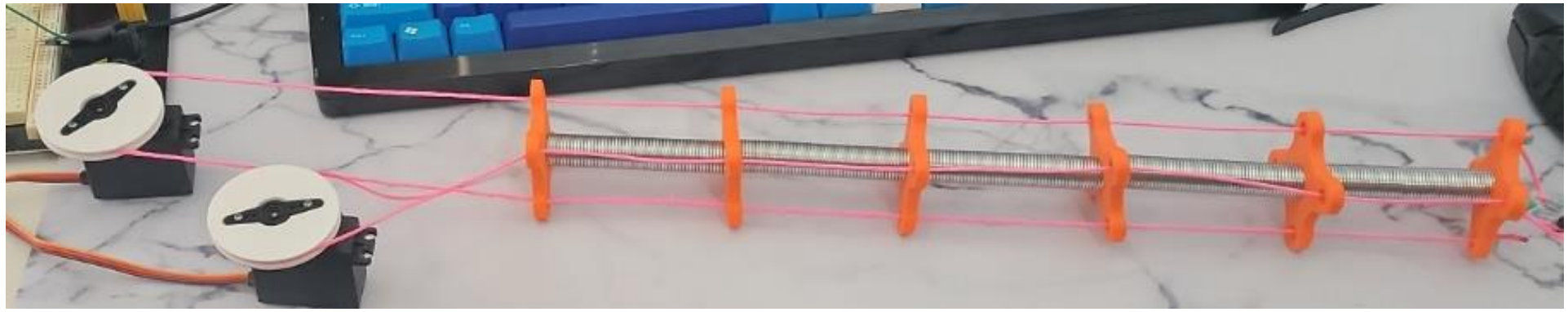




- Dimensions adjusted to allow the connecting pieces to be looser
- Channels added to prevent rotating

Alternate Design of Frame

- Modelled as a continuum robotic arm, allows for very flexible movement
- Will allow us to add 3rd degree of freedom which is one of our stretch goal, extension and contraction



Power options

Wall plug-in

- 12 V Power Supply
- Cord length is 12 feet, however actual length from project to wall outlet is 8 feet.

Specifications
Stable Voltage
Able to plug into extension cord for more length
No discharge

Battery pack power supply

- Allows for portable design if needed
- Stable and clean power
- Different possible types of batteries that can be used

Type of Battery	Voltage (V)
AA , AAA , C, or D	1.5 for non-rechargeable 1.2 for rechargeable
9V	9 for non-rechargeable 8.4 for rechareable
Coin cell	3 non-rechargeable
Flat pack	3.7 rechargeable
Car Battery	12 rechargeable

Administrative

Work Distribution

	Input Power	Voltage Regulation	Software Programming	Gestures
Ben				
Keng				
Michael				
Scott				

Budget and Financing

Part	Quantity	Cost	Seller
NVIDIA Jetson Nano Developer kit	1	$99	NVIDIA
CanaKit 5V 2.5A Raspberry Pi	1	$9.95	Amazon
PNY 128GB Micro SD card	1	$13.99	Amazon
Arducam IMX219 camera	1	$18.99	Uctronics
Servo motor HPS-3527SG	2-4	$26.99 each	Amazon
Adafruit 16-ch controller	1-4	$14.95 each	Adafruit
Metal Wire Loom	2 feet	$19.95 per 18"	Amazon
Electromechanical Relay	2	$10.22	Amazon
E-26 Light Socket	1	$8.99	Amazon
LED Bulb	1	$2.50	Amazon
Frame/Case Material	1	$20	N/A
Noctua NFA4x20 PWM fan	1	$14.95	Amazon
AC Bulb LED Dimmer Module	1	$28.95	Ebay
Total		$326.64 - $425.47	

Project Progress

- Legend: (in percent)

Research: 90

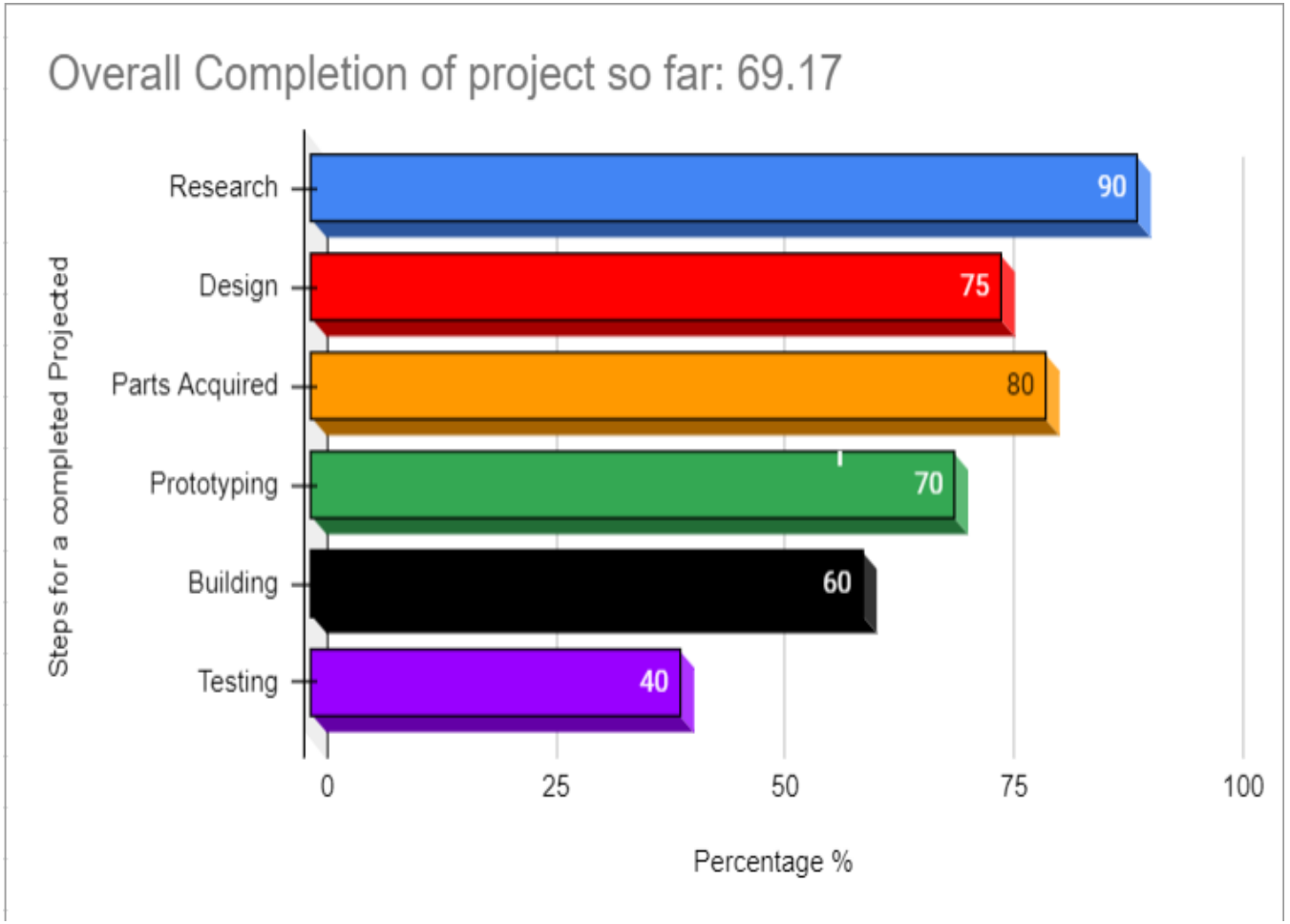
Design: 75

Parts Acquired: 80

Prototyping: 70

Building: 60

Testing: 40



Constraints found during prototyping

- Cord length for power source
- Type of battery to use for a hybrid power mode (so far, we found our design to be powered by batteries it would only last about 10 minutes before batteries are drained). This was tested with AA.

Questions?