Autonomous NERF Turret with Facial Recognition (ANT-FR)

UCF ECE Senior Design Project

Meet the Team

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Computer Engineer

- Machine Learning
- Artificial Intelligence
- Robotics Design

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Computer Engineer

- Front End Development
- Back End Development
- Embedded Systems

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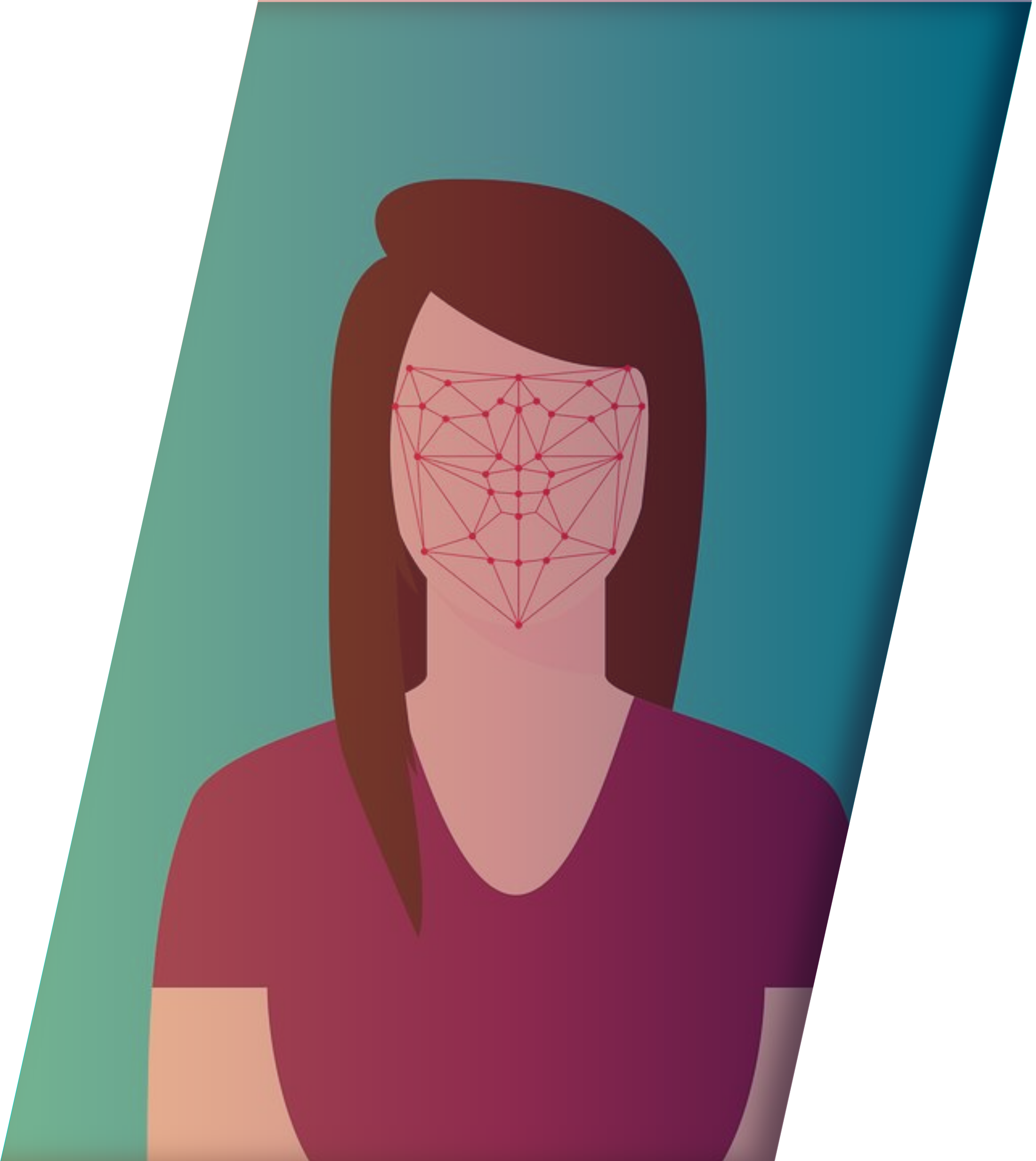
Electrical Engineer

- Power System
- Printed Circuit Board (PCB) Design

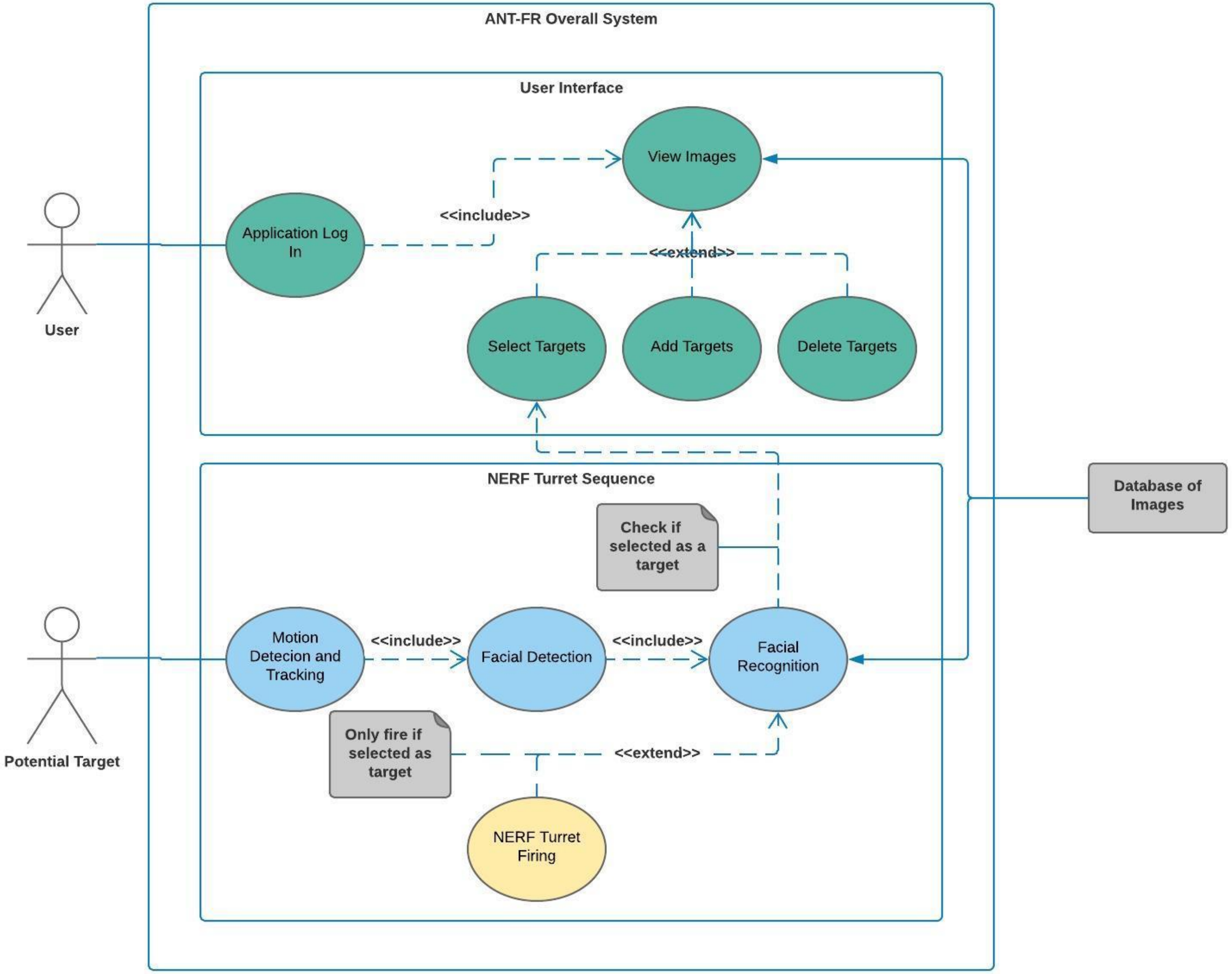


What is ANT-FR?

- Overall Goal
  - Our project goal will be to design and build a functioning alpha prototype of an Autonomous NERF Turret that utilizes facial recognition software to lock onto targets.
- Desired Outcomes
  - A database of faces is collected as potential targets.
  - An application (Mobile desired) allows you to select a target of interest; Optionally upload new faces of targets.
  - If an individual matching that face comes into the field of vision, the NERF gun should autonomously track the individual and fire at center of mass.
  - Gun should try to minimize false positives and not aim at faces directly.

Motivation for Project

N o s t a l g i a



Use Case Diagram

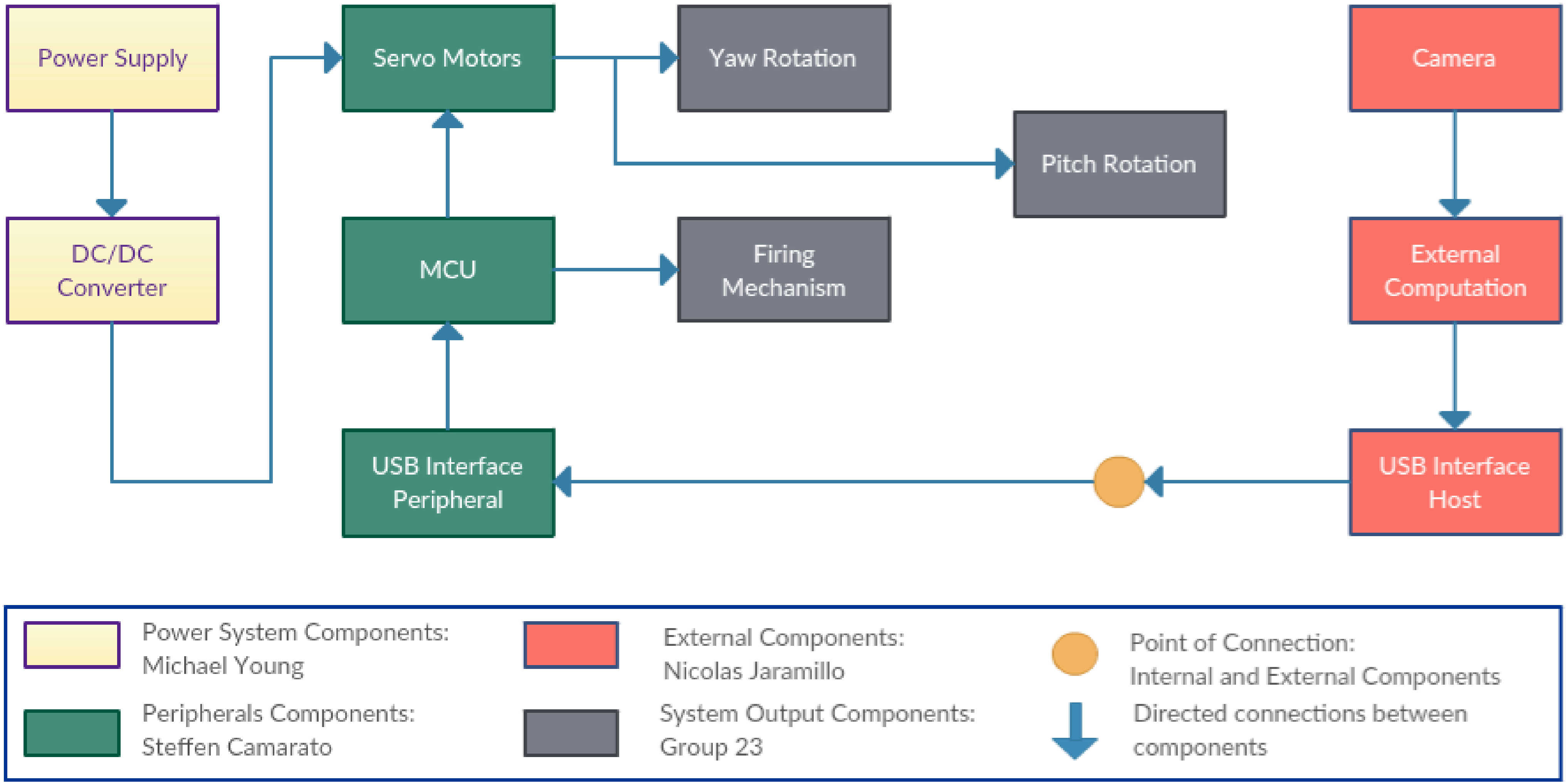
An Overall View

- User can view images in the database
  - Select image as a target
  - Add new images
  - Delete images
- As the target walks into the field of vision of the NERF turret
  - Software follows target on camera
  - Search for and detect a face
  - Run facial recognition algorithms to determine if face is in database
  - Turret fires at a person if they are selected as a target

Project Specifications

Marketing Requirements	Engineering Requirements
Low Cost	<$1500
Software Accuracy	<20% False Positives
Operation Time	>2 Hour Battery Life
Response Time	<10 Seconds Target Acquisition to Tracking
Range of Motion	>135° Yaw Range, >50° Pitch Range
Ease of Assembly	<1 Hour Assembly

Hardware Block Diagram



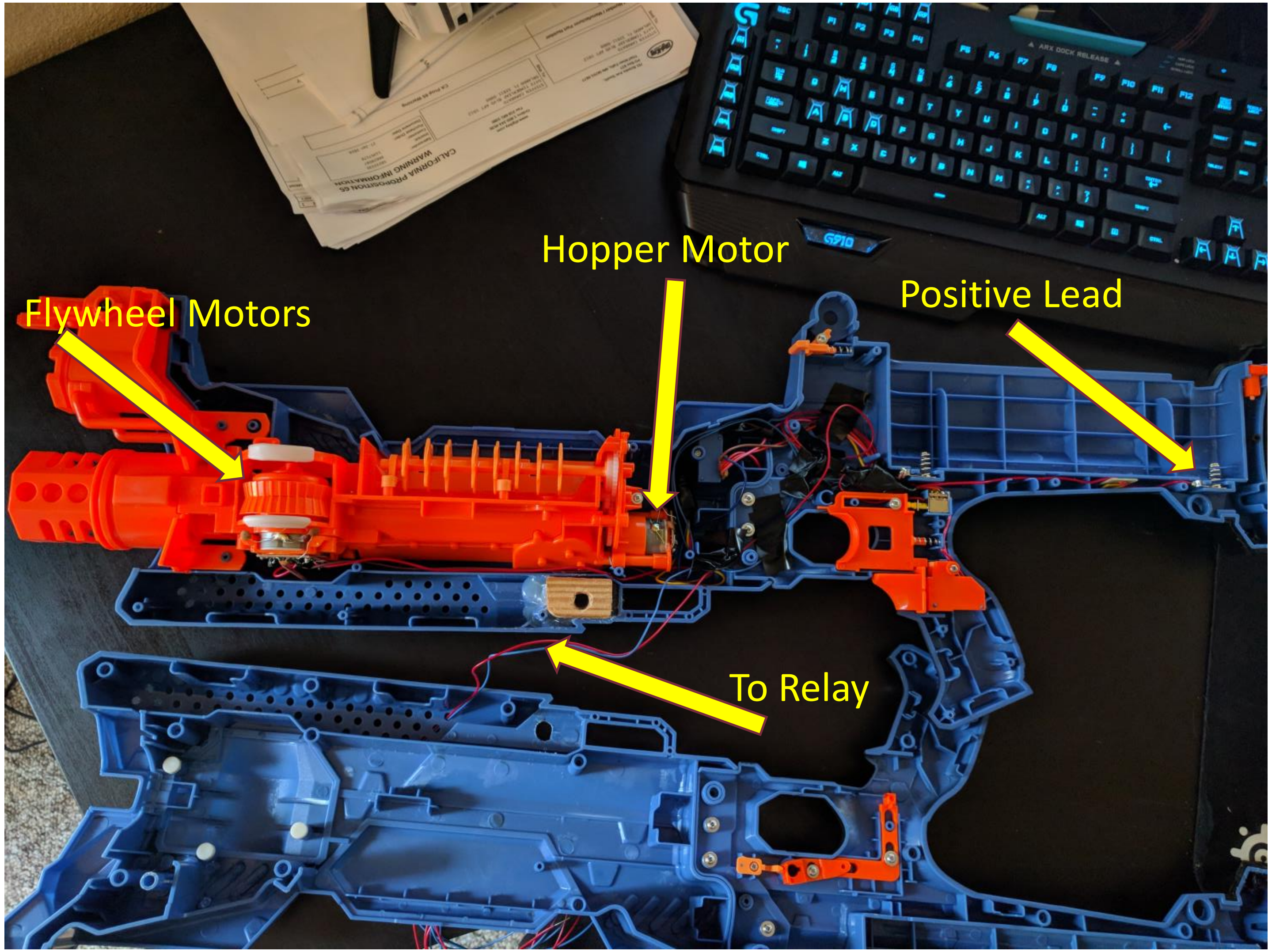
Camera Selection

Type	Logitech Pro/Brio
Resolution	4K UHD 2160p
Field of View	90
Frames Per Second	30
Digital Zoom	5x
Autofocus	Yes
Auto-light Correction	Yes
Lens	Glass
Weight	4.7oz
Dimension	2.5in x 1.4in x .73in

NERF Rival Nemesis

- NERF Rival Nemesis chosen as the onboard NERF gun
  - High Capacity Hopper holds 100 Rounds
  - High-Impact Spherical NERF Rounds
  - Fully Automatic Operation
  - Ease of Modification

NERF Rival Nemesis Cont.



- NERF gun is actuated with two separate triggers; one for bringing two fly-wheel motors up to speed, the other for actuating the hopper agitator motor.
- Triggers have been bypassed and all three motors' positive lead wires have been rerouted to a relay.
- Positive lead wire for NERF gun battery has been rerouted to the same relay.

Relay for Trigger Assembly

Specifications	Data
Operating Voltage for Actuation	5V
Current Ratings	10A at 250VAC, 10A at 30VDC
Line Side Contacts	Common, Normally Closed, Normally Open
Control Side Inputs	Ground, +5VDC, Control Signal
Dimensions	1.6” x 1.06” x 0.71”

- Relay receives control signal from a digital output pin of the ATmega328P-PU, giving full firing control of the NERF gun to the primary PCB.

Battery Packs- NERF Gun Battery

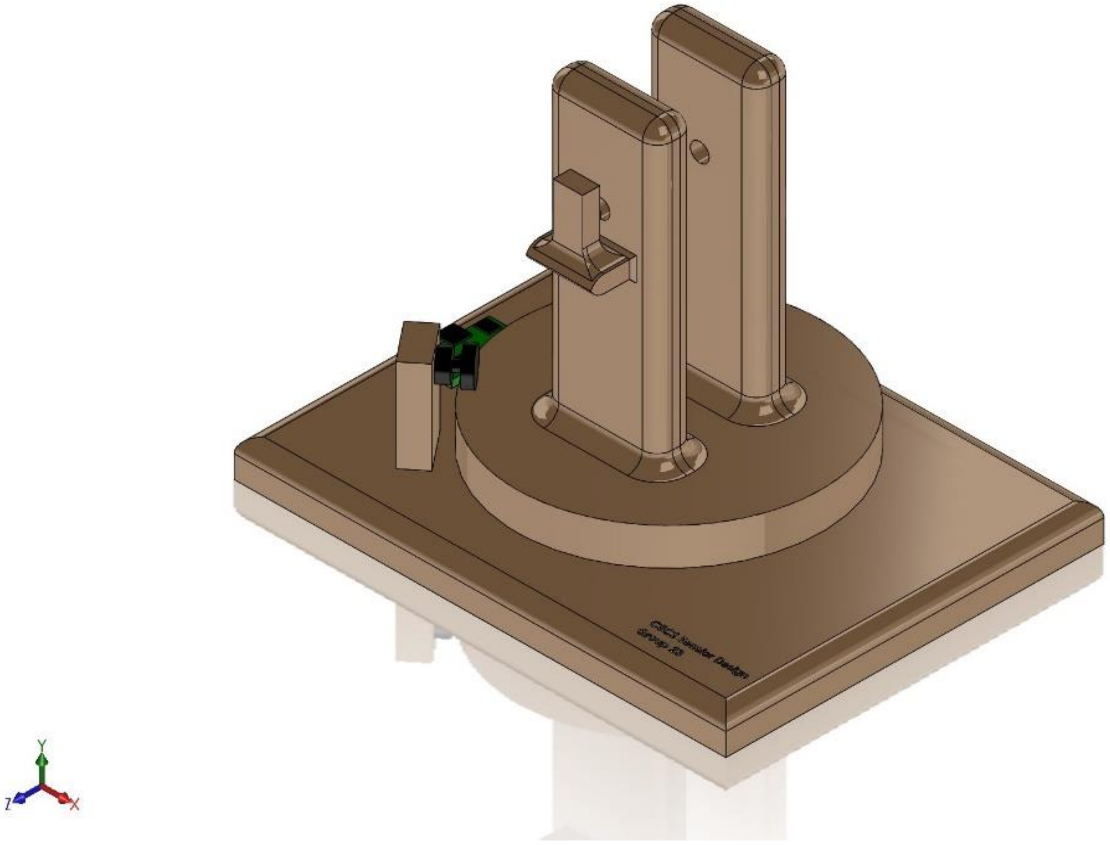
- NERF NiMH rechargeable battery pack will be used to increase modularity surrounding the NERF gun.
  - Chassis of the battery pack is designed to fit accurately within the stock of the NERF gun without movement/vibration.
- Nominal operating voltage of 7.2V at 1.5Ah capacity, powers the NERF gun without voltage regulation.

Battery Packs - Servo Battery

Specifications	
Li-Ion Nominal Voltage	11.1V
Capacity	6.6Ah
Maximum Discharge Current	5.7A
Overcharge Protection	>12.6V
Over-Discharge Protection	<9.0V

- Battery pack comes with a built in protection circuit board to shield it from over-discharge and overcharge.
- High maximum discharge current will accommodate in-rush current from servos and allow the switching regulator to run at its maximum rated current of 3 amps.

Turret Framing



Initial Framing Design in SolidWorks

Current Framing

Servo Specifications

Model	HSR-2645CRH	HS-5645MG
Voltage Range	4.8V - 7.4V	4.8V - 6.0V
Speed (6.0V)	58 RPM	0.18sec/60deg
Torque (6.0V)	138.87 oz-in	168 oz-in
PWM Increase	Clockwise	Clockwise

- Yaw Rotation - HSR-2645CRH
  - Continuous Rotation along the turn table is controlled with Pulse Width Modulation which is time dependent for relative position.
- Pitch Rotation - HS-5645MG
  - Encoded Rotation along the horizontal rod is controlled with Pulse Width Modulation with values mapped to absolute position.

Motor Control

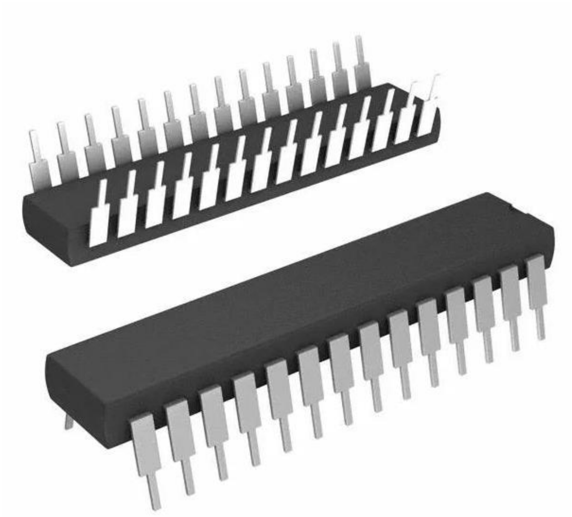
Encoded Directions

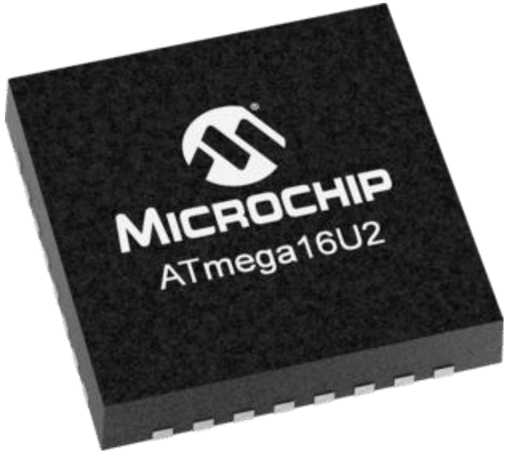
Type	Yaw Rotation	Pitch Rotation
Movement	Relative	Absolute
HIGH 0	Right	Up
HIGH 1	Left	Down
2-bit 00	Delay 0ms	0.50
2-bit 01	Delay 2000ms	0.50 +- 0.12
2-bit 10	Delay 5000ms	0.50 +- 0.25
2-bit 11	Delay 7000ms	0.50 +- 0.38

- Encoded instructions with the target's relative position is sent from ATmega16U2-MU.
- Instruction set decoded by ATmega328P-PU, arithmetic and logical processes are used to determine pulse width modulation and delay times.
- Implement integrity check to detect bit error, sending interrupt if encountered.

Microcontroller Specifications

Model	ATmega328P-PU	ATmega16U2-MU
Operating Voltage	1.8V - 5.5V	2.7V - 5.5V
Memory	16kB Flash	32kB Flash
CPU Speed	20MHz	16MHz
Architecture	8-Bit	8-Bit
Language	AVR Atmel	AVR Atmel
I/O Pins	23	32
Casing	DIP	VFQFN





Embedded Systems

ATmega16U2-MU

- USB-Serial Interface.
- Receives the 5V, GND, Rx and Tx lines from USB 2.0 Type B and converts the serial information into USART format, which is then sent to ATmega328P-PU.

ATmega328P-PU

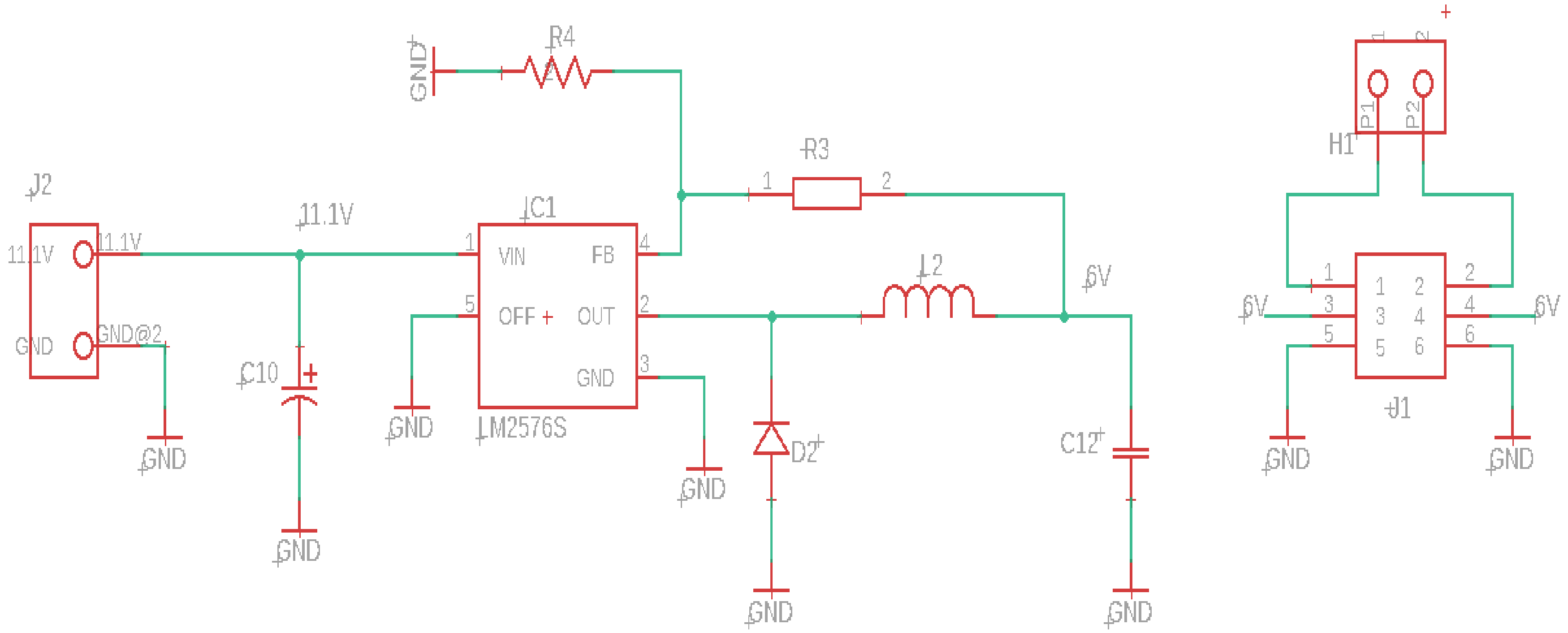
- Serves as the central processing unit, providing digital and analog I/O control, Pulse Width Modulation signals, and arithmetic and logical calculations.
- The 328P will also decode system inputs and interrupts, giving the appropriate response.

Power PCB Voltage Regulator

LM2576 Specifications	
V_{IN} Range	4V-40V
V_{OUT} Range	3.3V-37V
I_{OUT} Max	3A
I_Q	5mA

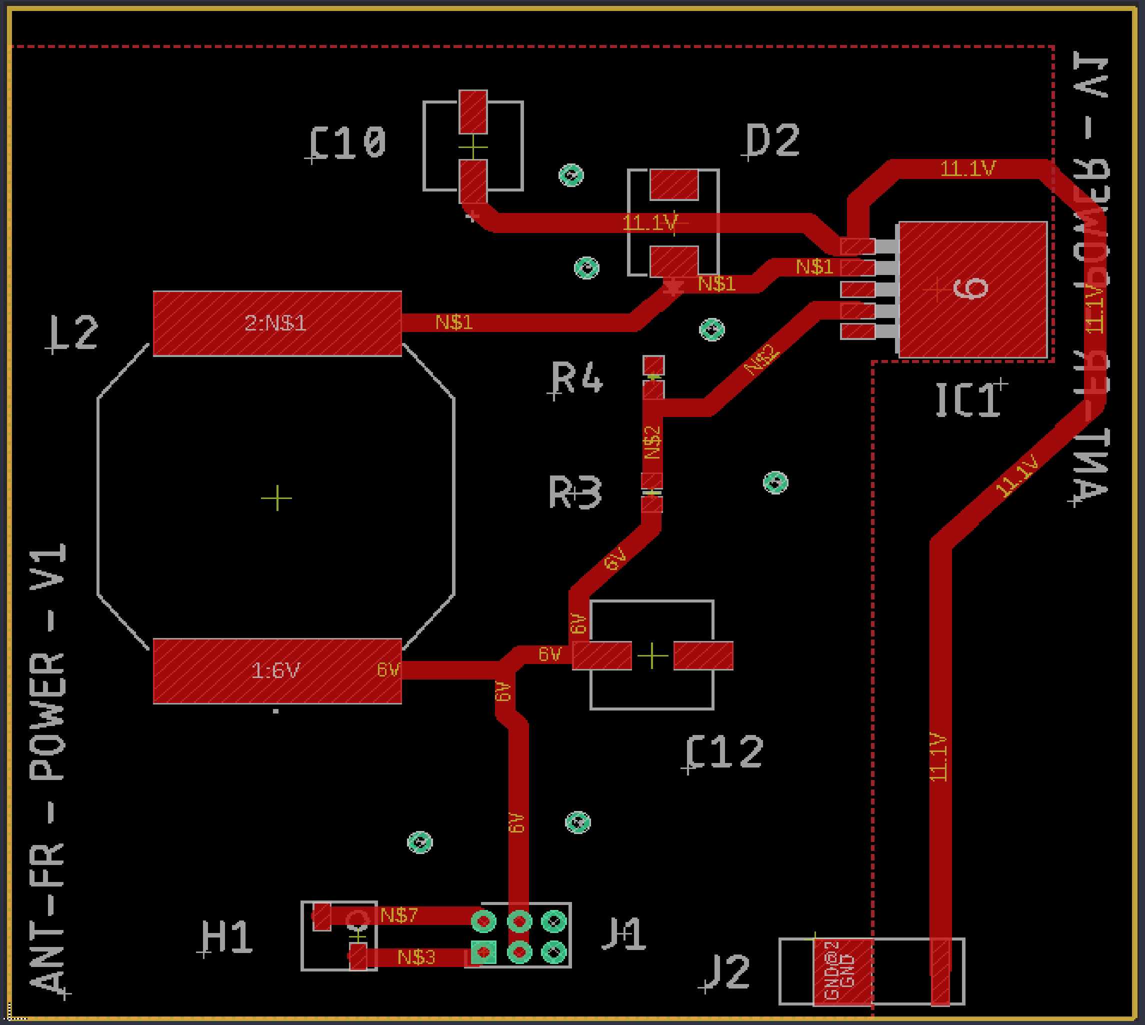
- The adjustable version of the LM2576 was chosen to produce a final output voltage of 6 volts, which is the nominal operating voltage of the servos.

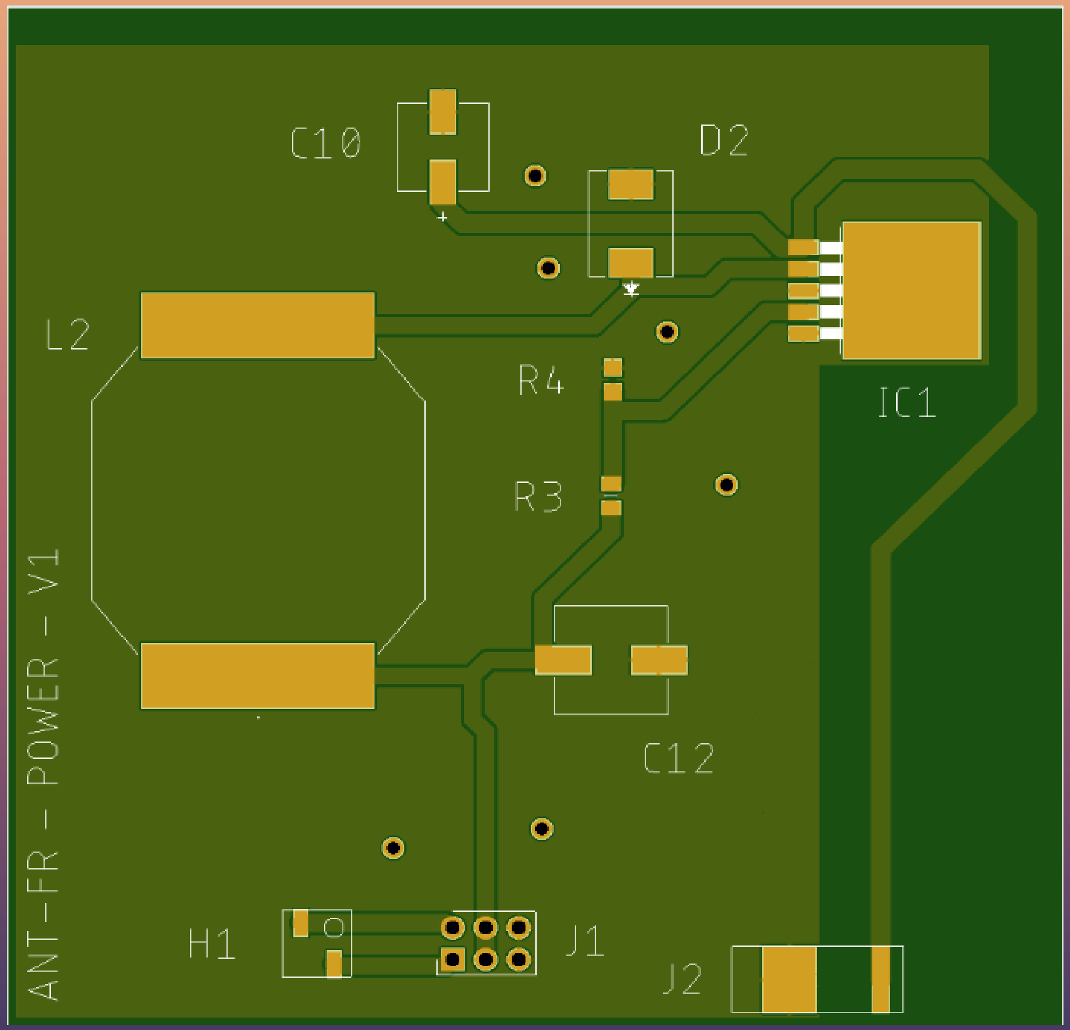
Power PCB Schematic



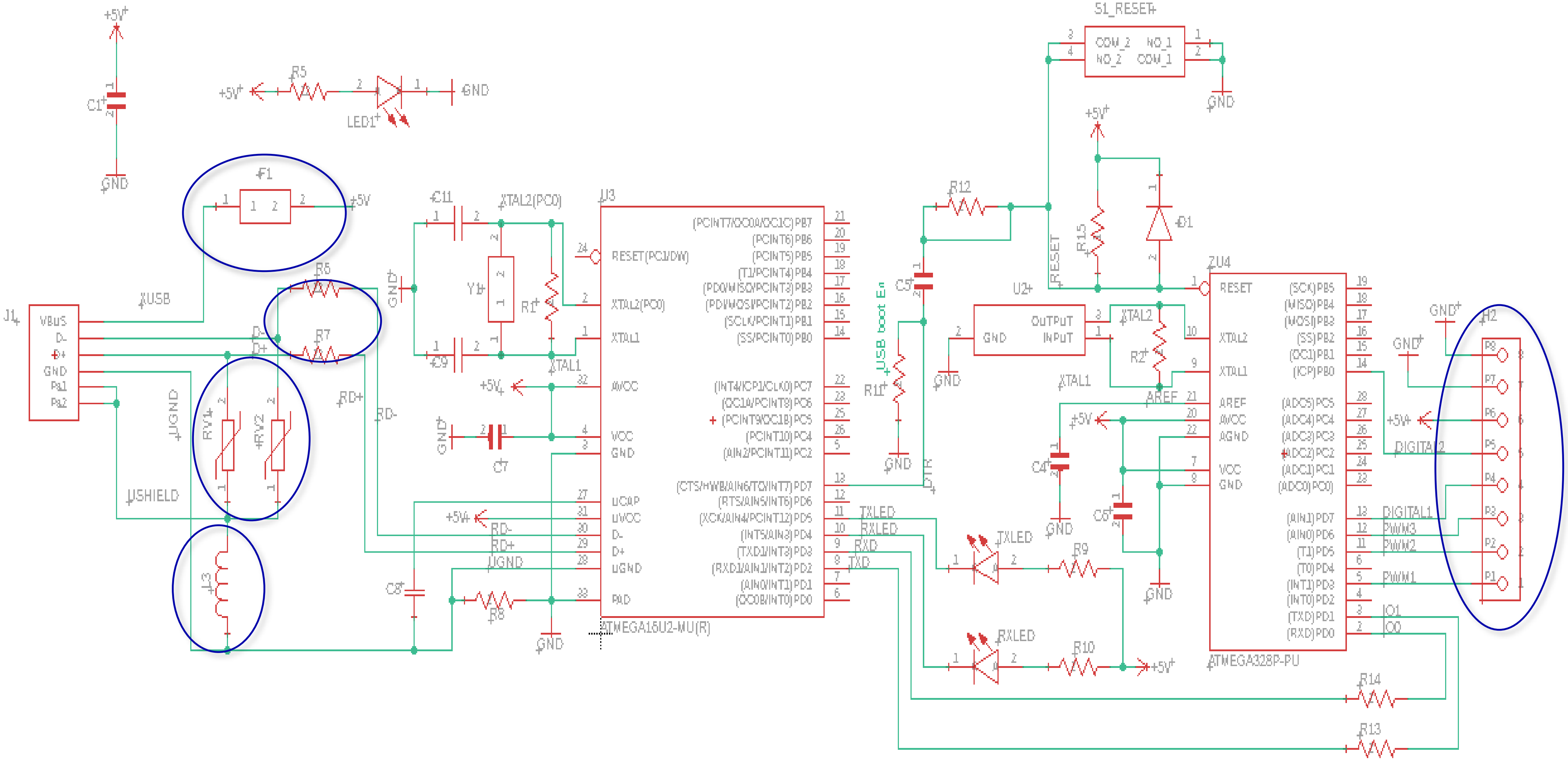
- Power PCB regulates 11.1V down to 6V to allow for optimal servo operation.

Power PCB Layout

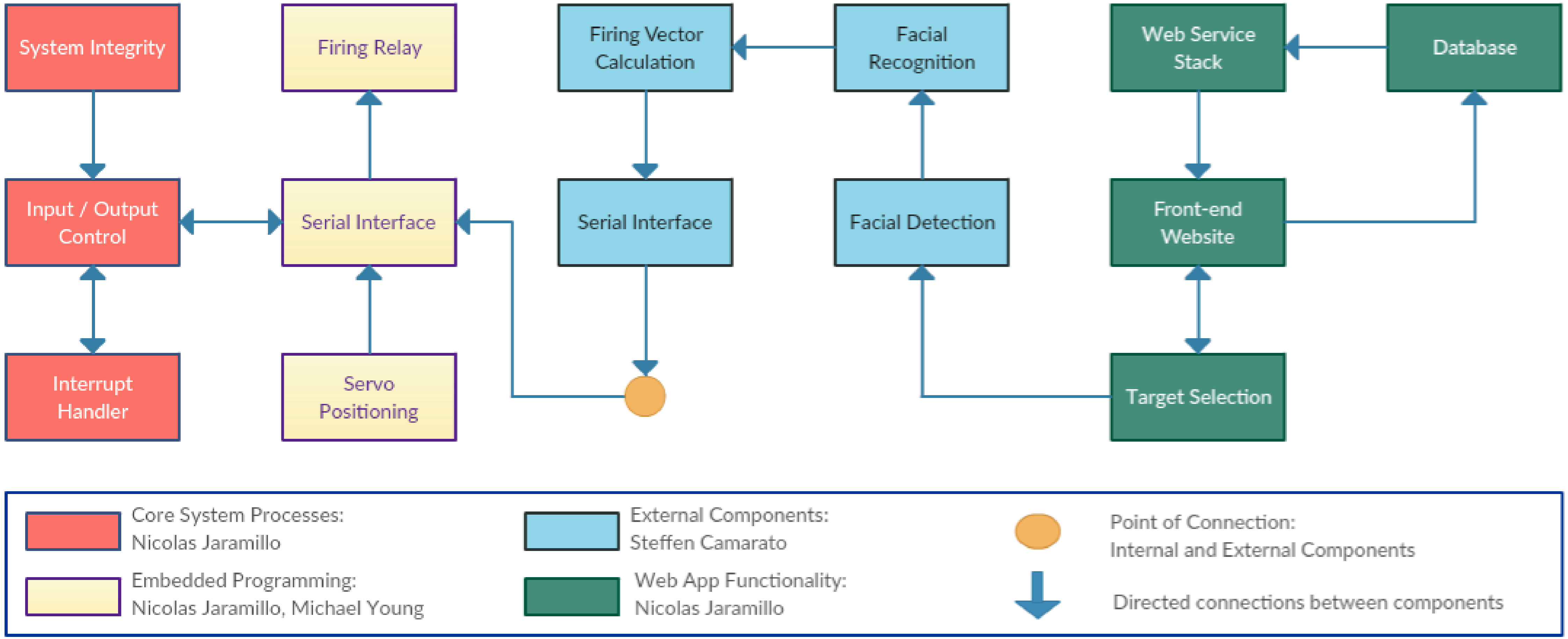


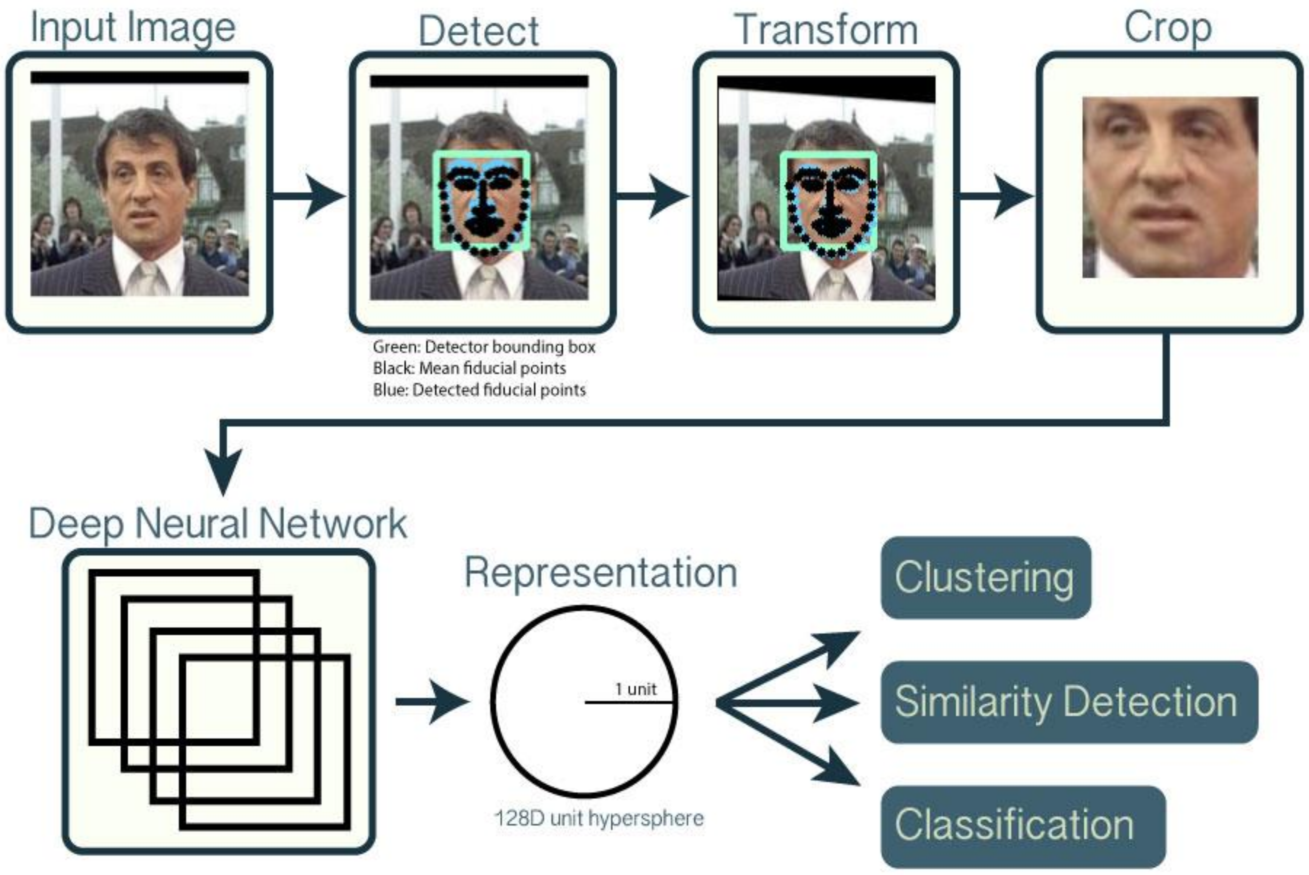


Primary PCB Schematic



Software Block Diagram





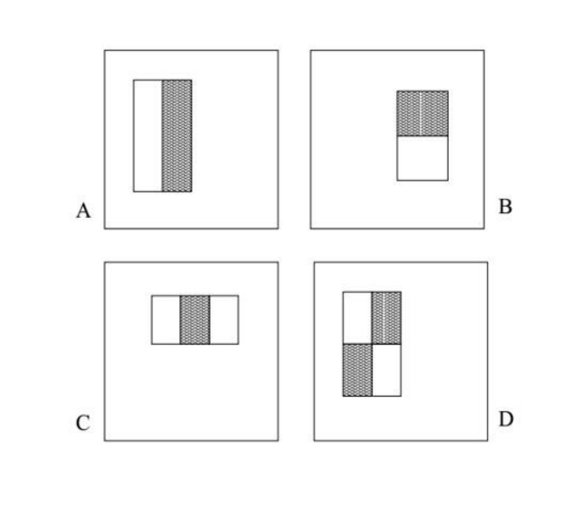
OpenFace

Project Overview

- The facial recognition software is one of the main components of this project which will be used to identify the targets in the field of vision of the turret.
- OpenFace, which is a free and open source face recognition with deep neural networks, will be used for implementation of the facial recognition portion of this project.
- This section is divided into four main categories:
  - Face Detection
  - Face Landmark Estimation
  - Embedded 128-D Unit Hypersphere
  - Similarity Detection

Face Detection

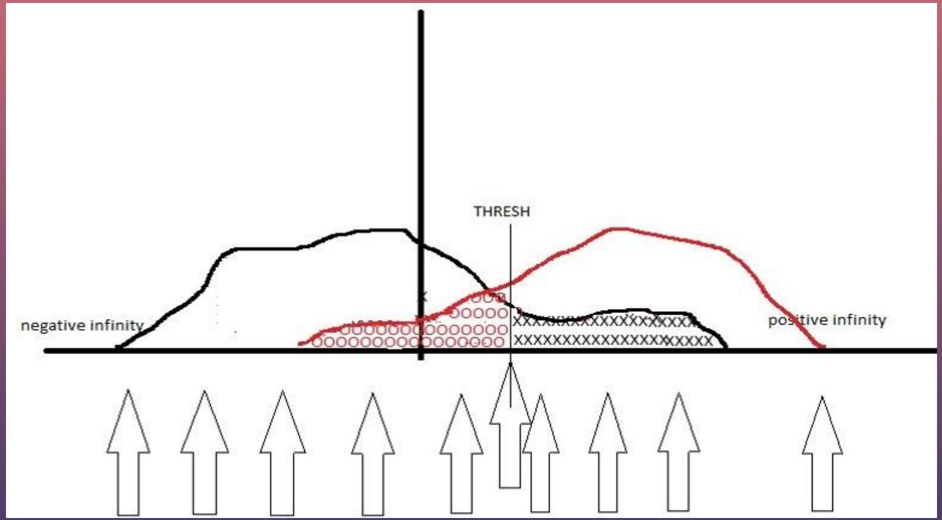
Pattern Convolution



- By convolving the pattern with the training image, each classifier can determine if a face is there or not.

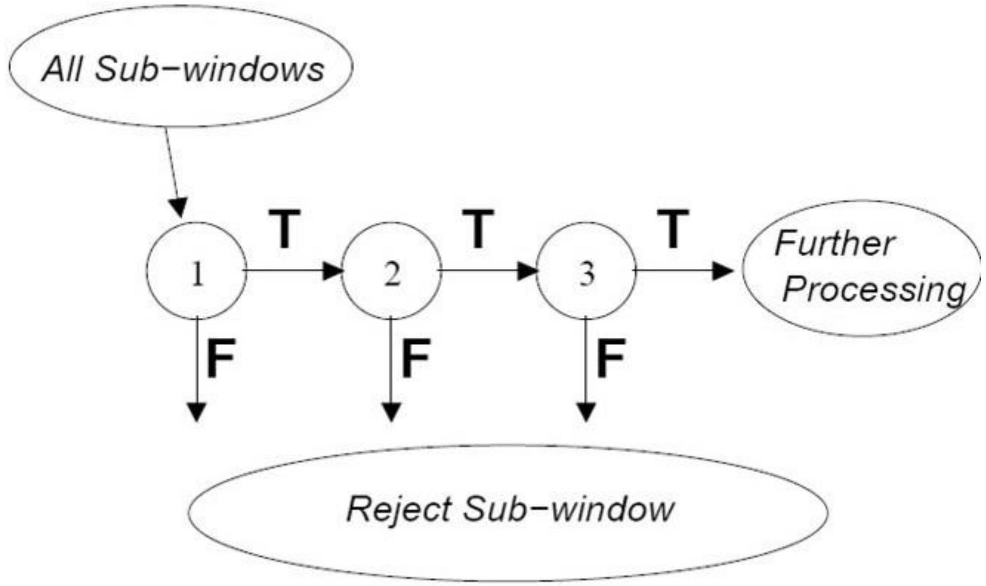
Thresholding

- By plotting all the correct and incorrect selections for a face and performing the same method for non-faces, a number line plot can be used to determine the threshold needed for a classifier.



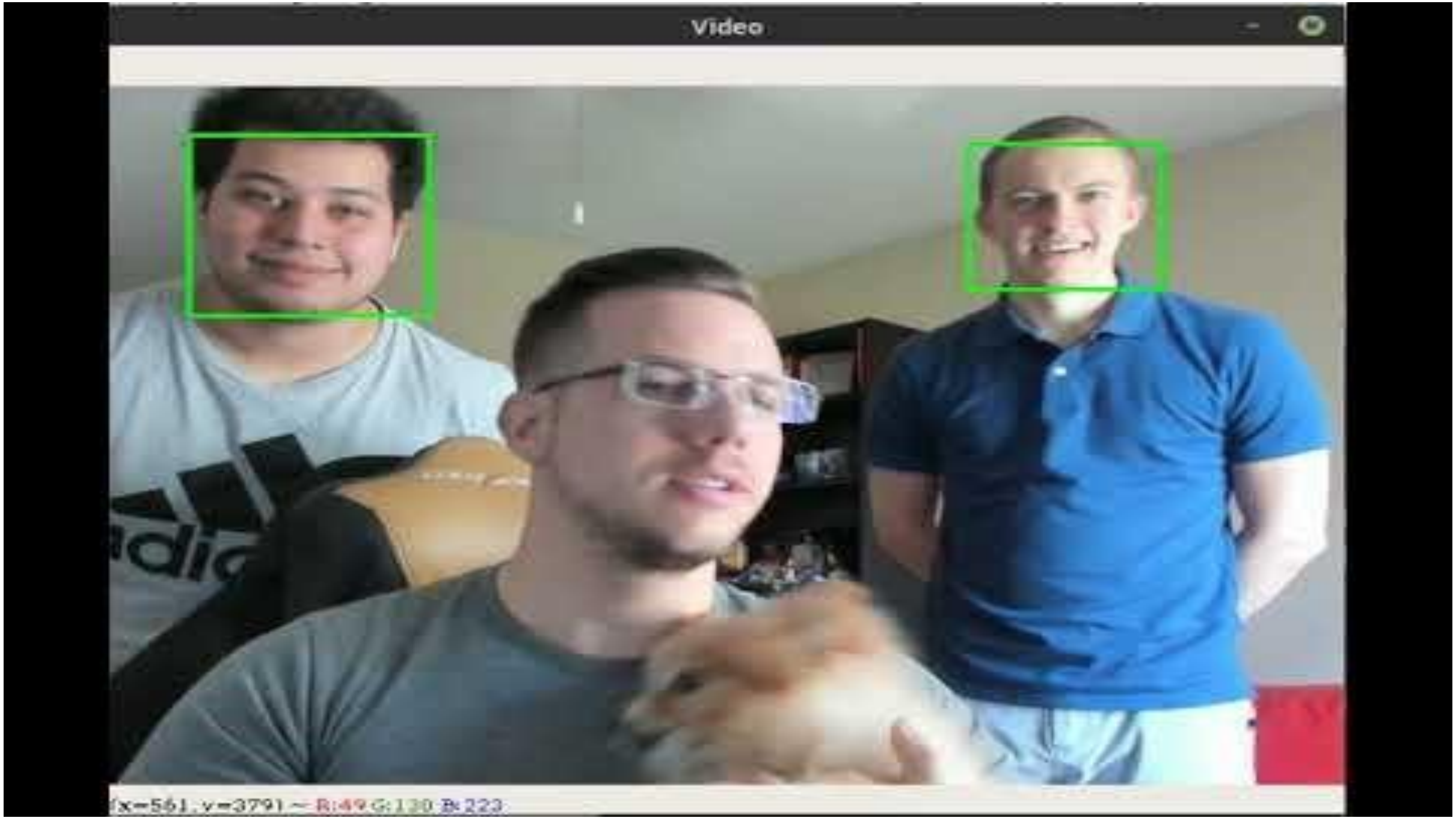
Face Detection Cont.

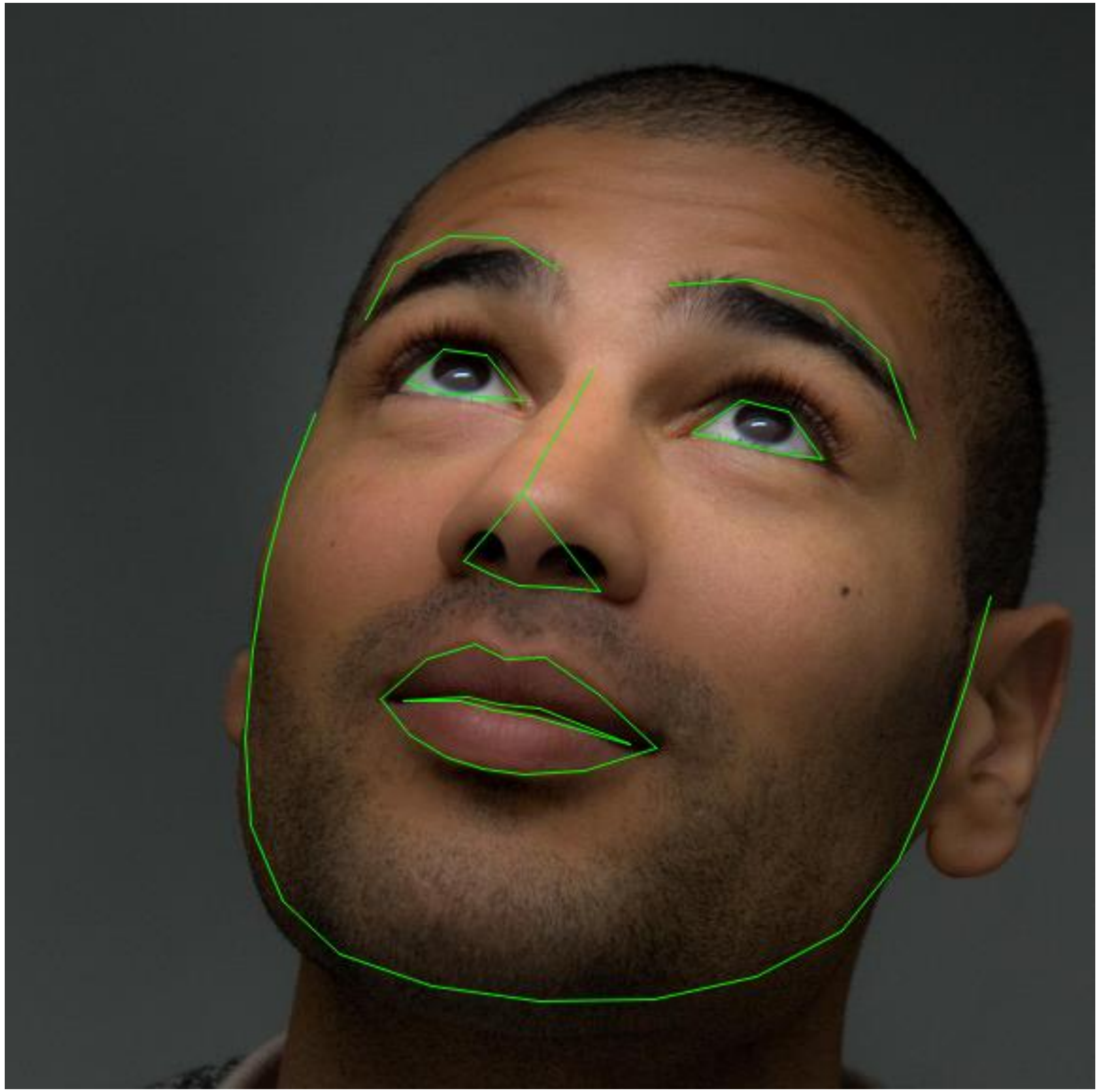
Viola-Jones Cascade Method



- With adaptive boosting, we can exploit the fact that faces are rare. The Viola-Jones method can be used, which uses a cascade system to speed up the process greatly.
- More classifiers are added to a team until a desired missed detection and false positive rate, approximately 30%, is achieved, which is generally 15-30 classifiers.
- With this design, each team will pass 99.9% faces and 30% non-faces.
- This means that approximately 91% of "failure" are rejected with only 50 experts used.

Face Detection Demonstration

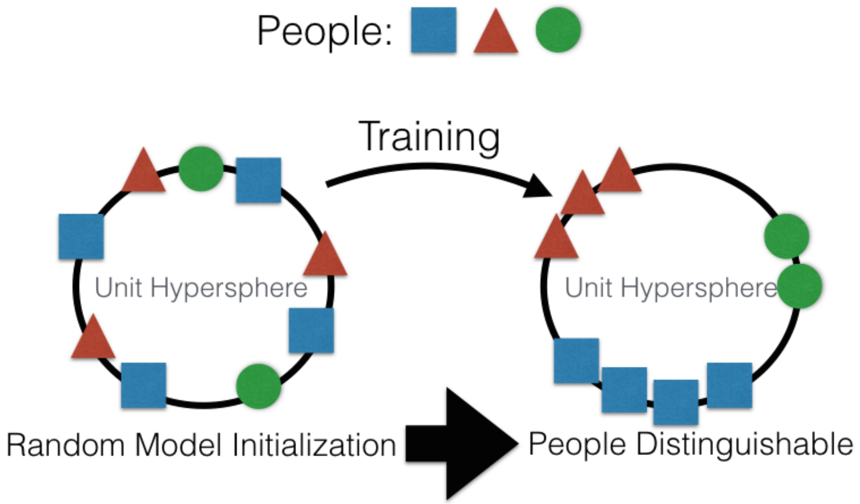


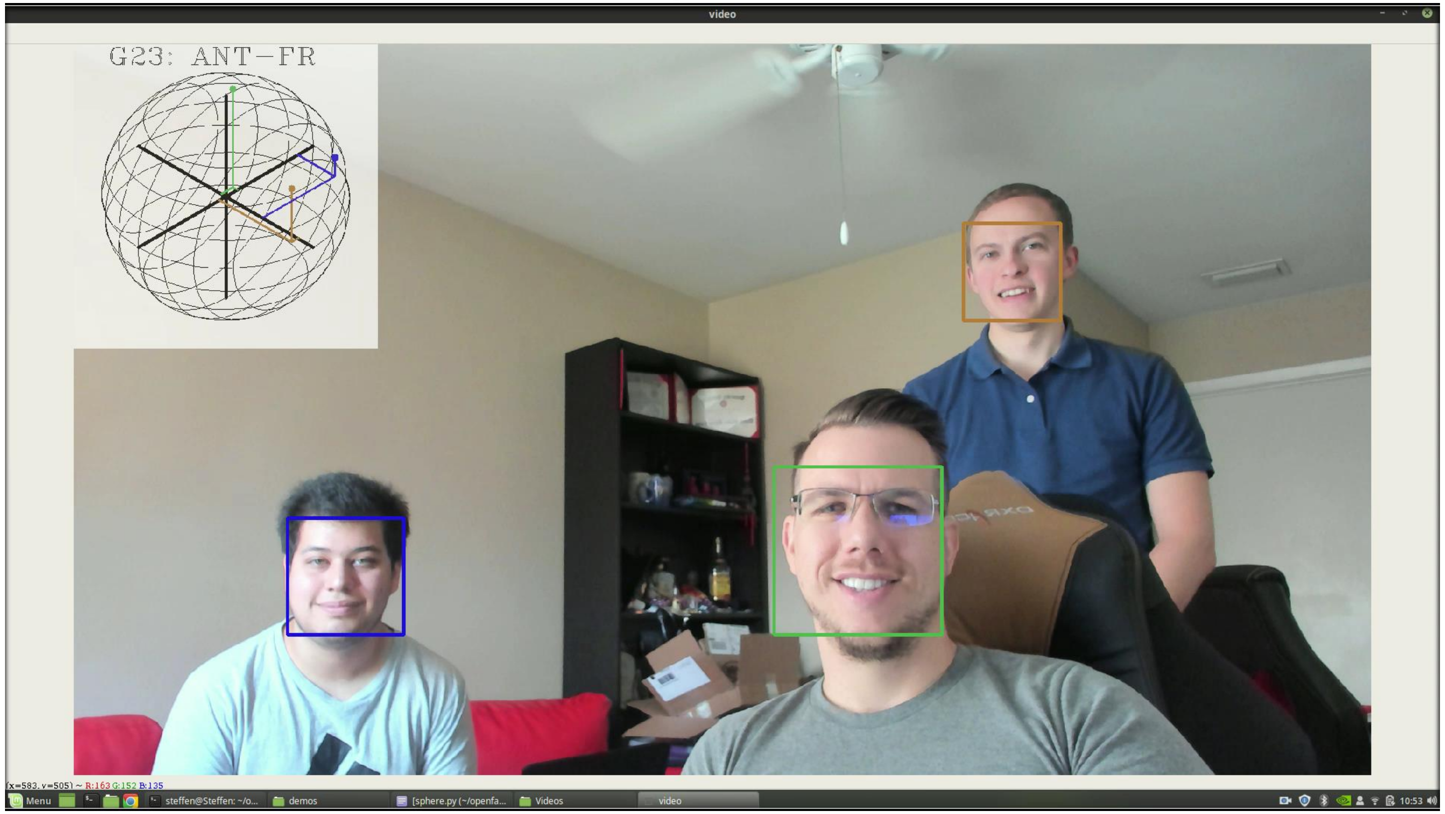


Face Landmark Estimation

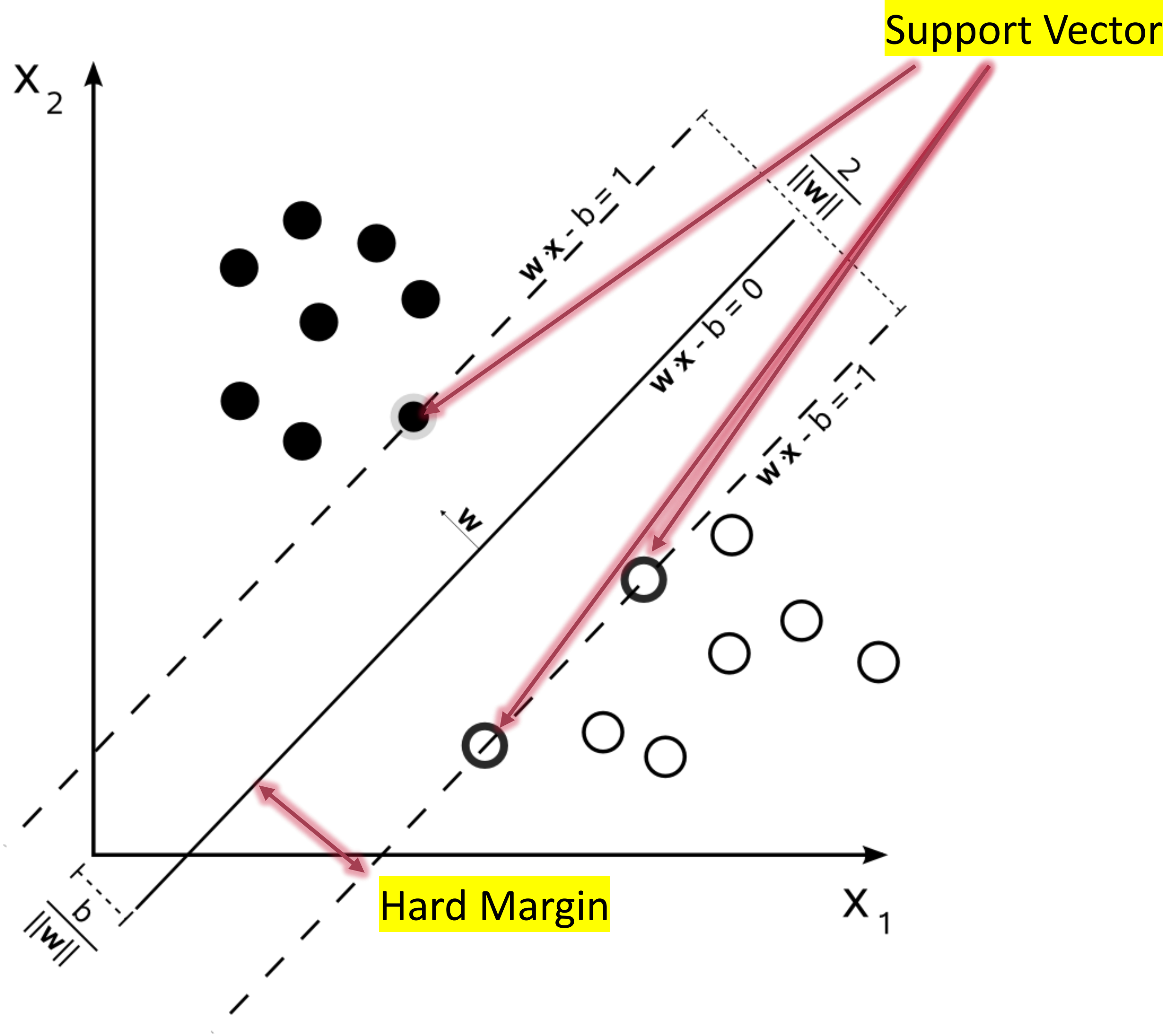
- The second process is the face landmark estimation which will be useful because faces can be warped and turned in different angles.
- Using homogenous coordinates will allow any number of affine transformations into one image.
- Adds an annotation around the key features of a face with 68 points of reference.
- Performing these techniques will make the eyes and bottom lip appear in the same location for each image.

Embedded 128-D Unit Hypersphere





- The points are randomly distributed because the initialization of the system is completely random for the neural networks.
- Through iterations of the network, the images are grouped together and will be fully optimized.
- The 3-dimensional embedding doesn't have the same accuracy as the 128-dimensional embedding, but it's sufficient to illustrate how the embedding space distinguishes between different people.



Similarity Detection

Support Vector Machines

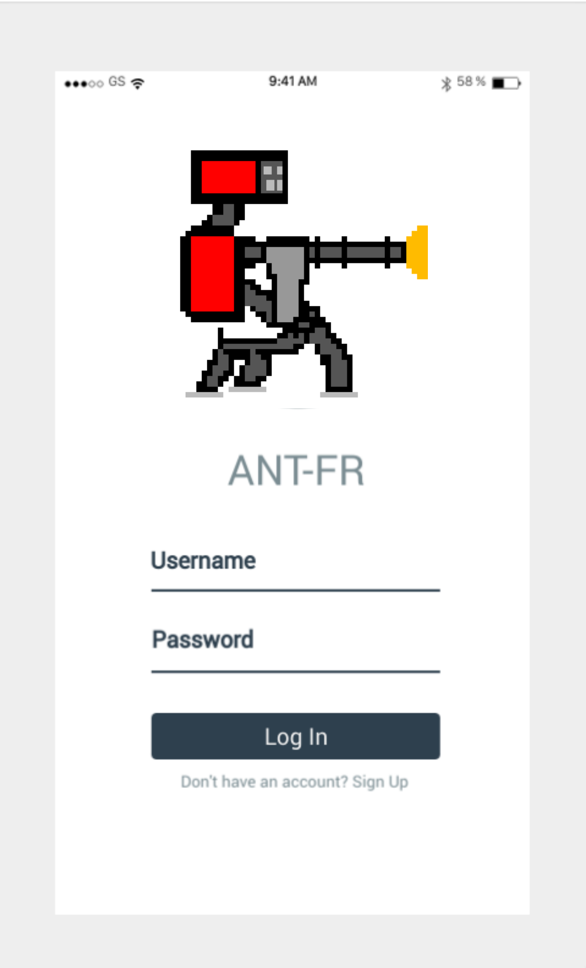
- The last step is to apply a similarity technique to match the image with another image.
- A support vector is simply finding the correct hyperplane that encompasses all the coordinates of a given system and separates the two classes via that hyperplane.
- The goal is to find the best hyperplane that will separate the two classes with the highest margin.

Web Stack

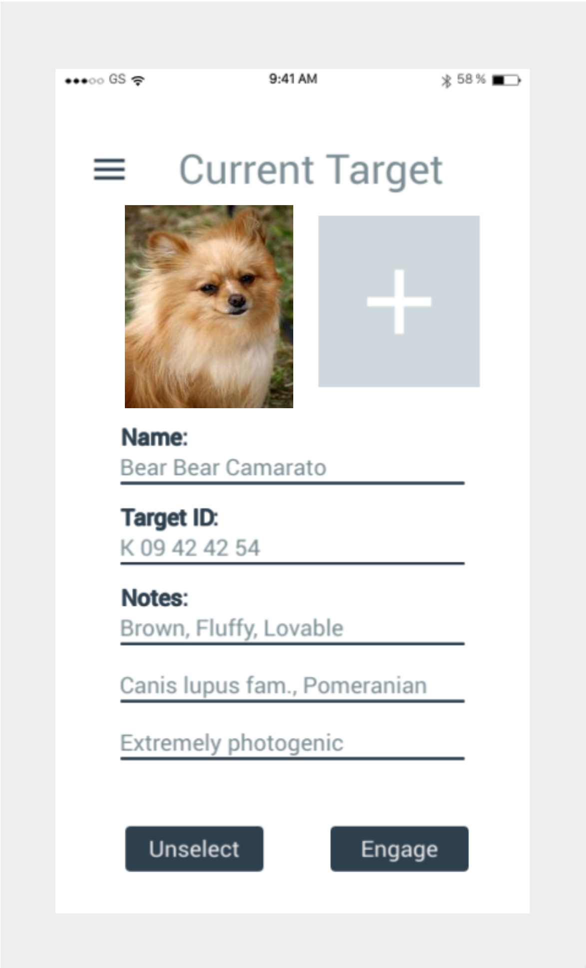
Backend Development

- Allow users to interface with the turret by enabling communications between the mobile application and the host computer running the facial recognition software.
    - Hosted SQL server and database
    - LAMP web service stack
    - SFTP (SSH File Transfer Protocol)
- Users will be able to retrieve, display, and manipulate database information from a mobile app designed for Android devices.

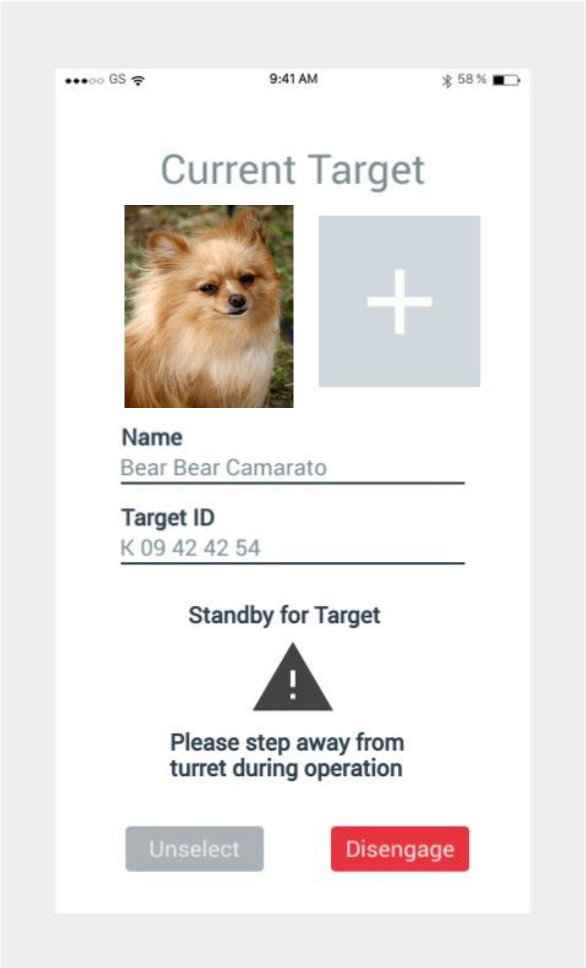
Mobile



Login



Profile



Target Engaged

Encountered Issues

- Trying to connect different software modules together
    - Using OpenFace to output a similarity score and sending a signal to the PCB to activate the NERF gun.

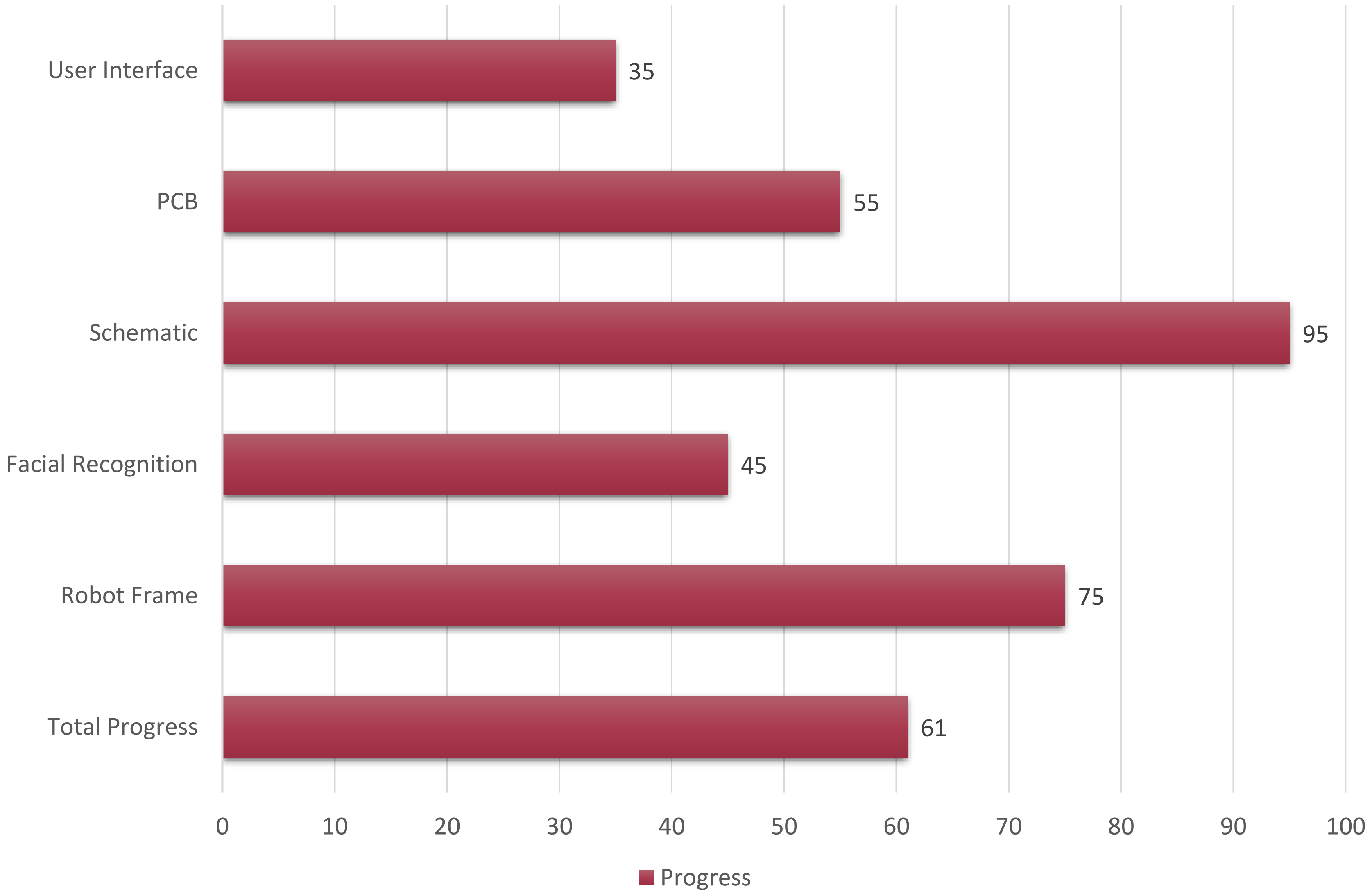
- Optimization of video stream and frames because there are too many faces on the screen, which slows down the processes.

Budget

- Sponsorships are provided by
  - Soar Technology, Inc. (SoarTech)
  - Valencia College Division of Engineering and Built Environments

Company	Part	Price
Digikey	PCB Components	$109.50
All-Battery	PCB Power Supply	$89.98
ServoCity	Servos	$89.40
Jameco	Relay	$15.40
Logitech	Camera	$159.74
Amazon	NERF Gun	$133.87
JLCPCB	PCB Manufacturing	$19.95
Lowes	Robot Frame	$65.71
Amazon	Miscellaneous	$38.14
Available: $1500	Total Spent:	$721.69

Current Progression



Copyright

Slide 25. OpenFace Workflow.
(Reprinted with permission from OpenFace 2015).

Slide 27. Viola-Jones Cascade Method.
(Reprinted with permission from Robot Vision 2018).

Slide 29. Landmarked Face.
(Reprinted with permission from Dlib C++ Library 2014).

Slide 30. Optimization Sphere.
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Questions?