Motion-Detecting Sentry

GROUP 33
FINAL PRESENTATION

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Computer Engineering

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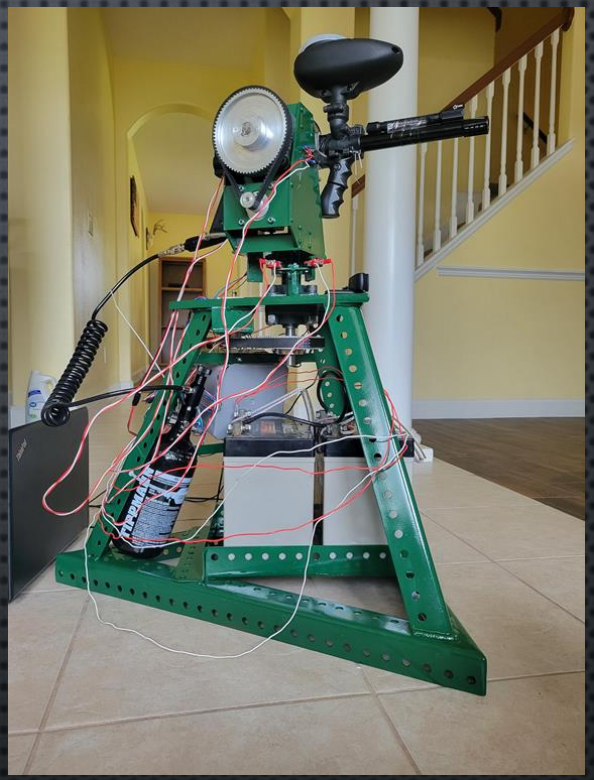
MOTIVATION

- ENTERTAINMENT/RECREATION
- PERSONAL/BUSINESS SECURITY
- MILITARY APPLICATIONS



Goals and Objectives

- Primary Goals:
  - Identification of targets through computer vision
  - Paintball gun capable of aiming at and hitting targets
  - Warning light
  - Non-lethal ammunition
  - Modifiable
  - Easily transportable
  - Sufficient Power Supply

KEY SPECIFICATIONS

Specification	Requirement
Accuracy (minimum)	70%
Traverse	180° horizontally, 45° vertically
Range	10 – 75 feet
Power Supply Duration	3 hours
Ammunition Capacity (minimum)	20 rounds
Weight (maximum)	40 pounds

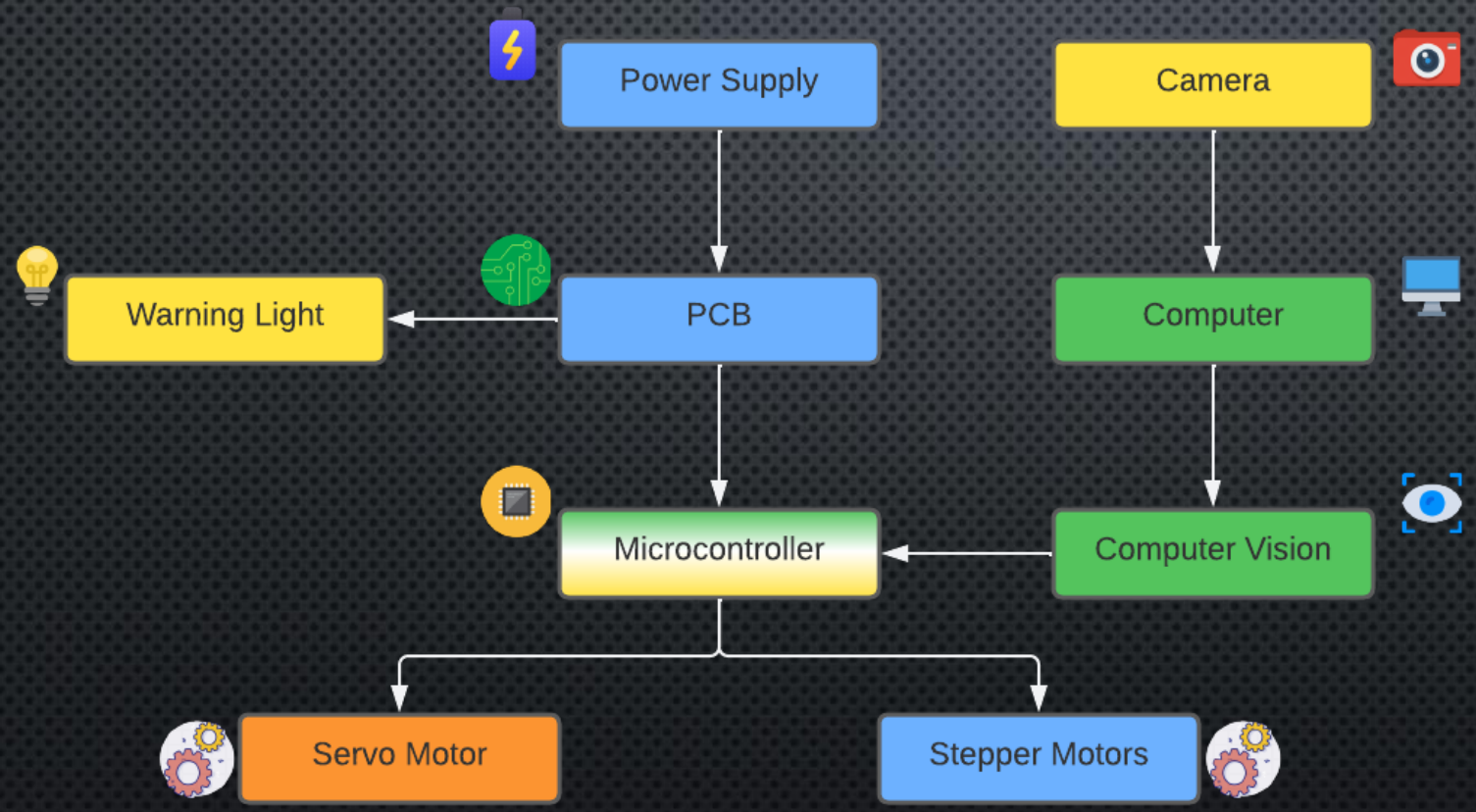
HARDWARE SPECIFICATIONS

- Turret should have a camera with high enough resolution such that human figures can be determined within a range of 10- 75 feet
- Warning system to indicate the turret is about to fire
- Fully automatic fire
- Magazine of at least 20 rounds
- Turret should be lightweight, roughly 40 pounds or less, enabling a single individual to safely lift and relocated the turret as desired
- Internal power supply lasting up to 3 hours
- Cost of no more than $600

SOFTWARE SPECIFICATIONS

- SHOULD USE COMPUTER VISION TO IDENTIFY TARGETS WITHIN RANGE OF 30 FEET
- MOTION SENSOR ACTIVATES THE CAMERA TO CHECK FOR TARGETS WITHIN 30 FEET
- WARNING LIGHT WHEN A TARGET ENTERS THE FIRING RANGE
- SHOULD STOP FIRING WHEN THE TARGET LEAVES 30-FOOT RANGE
- SHOULD ADJUST TURRET'S AIM AS TARGET MOVES TO MAINTAIN ACCURACY

OVERALL BLOCK DIAGRAM



Liderma Guerry

Kaitlyn Martin

Michael MacAllister

Quintin Jimenez

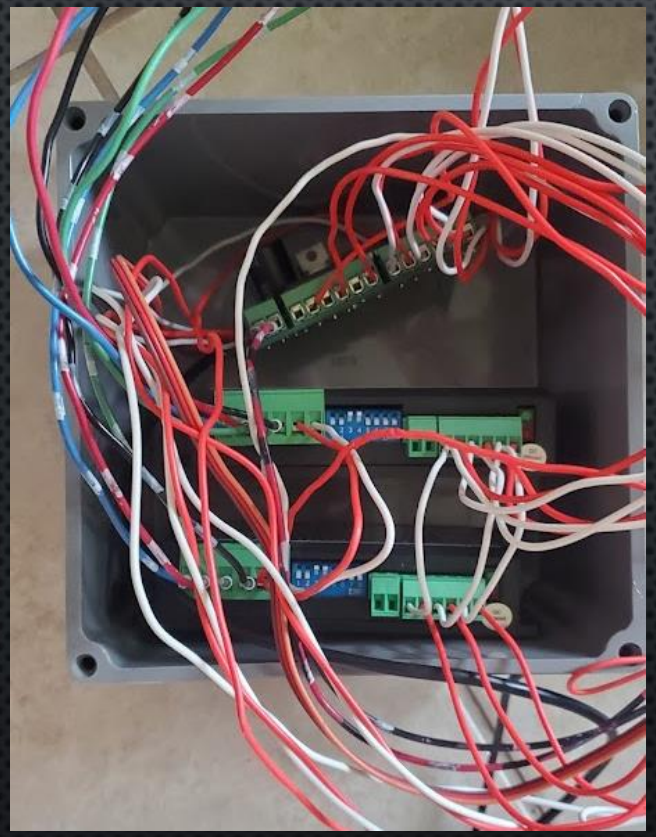
STRUCTURE DESIGN

STRUCTURE MATERIAL SELECTION

Material	Cost
Pine Wood	~$20
Medium-Density Fiberboard	~$30
Aluminum	~$60
Steel	$58.89

BASE DESIGN

FINAL DESIGN



HARDWARE

MICROCONTROLLER SELECTION

- Originally thought we could do both turret control and computer vision using a Single Board Computer (SBC)
- Concerns over performance & price restrictions changed strategy
- Considered Arduino Microcontroller + Laptop
- Eventually used the ATMEGA MCU from the Arduino on a custom PCB instead
  - ATmega 328 is compatible with Arduino IDE, easier to program
  - Sufficient Input/Output pins
- Laptop has processing power, but limits portability & self sufficiency

MICROCONTROLLER SELECTION

Arduino	CPU	Memory	I/O Pins	Operating Voltage	Price
Uno	16MHz ATmega328P	32KB SRAM, 32KB flash memory	14 digital I/O pins (6 PWM); 6 analog input pins	5V	$23.00
Leonardo	16MHz ATmega32u4	2.5KB SRAM, 32KB flash memory	20 digital I/O pins (7 PWM); 12 analog input pins	5V	$20.70
Due	84MHz AT91SAM3X8E	96KB SRAM, 512KB flash memory	54 digital I/O pins (12 PWM); 12 analog input pins; 2 analog output pins	3.3V	$40.30
Mega	16MHz ATmega2560	8KB SRAM, 256KB flash memory	54 digital I/O pins (15 PWM); 16 analog input pins	5V	$40.30

LIGHTING SELECTION

Warning Light	Voltage used	Features	Wire Installation	LEDs contained	Cost
AgriEyes Amber Beacon Light	12 – 24 V	Seven different flashing modes	Red, black, yellow	30	$26.99
Industrial Warning Safety Flashing Beacon	12 –24 V	4 different flashing/strobing modes Plays an audio warning	Red, black, yellow, green	15	$29.99
Bolt Beam 12mm LED Light	9 – 14.5 V	None	Red and black	3	$2.95

CAMERA TYPE

Camera module	Webcam
Soldered on and interfaced	Connected via USB
Lower resolution	Better quality resolution
Lower cost	Higher cost
Lower Megapixels	Higher Megapixels

WEBCAM

Logitech	Microsoft
Large selection	Very limited
Well known for webcam quality	Webcams are not well known

CAMERA SELECTION

Camera	Resolution	Frames Per Second	Field of View	Lens Type	Weight (ounces)	Cost
Logitech C270	720p	30	60°	Plastic	2.65	$27.99
Logitech C920s	1080p/720p	30	78°	Glass	5.71	$59.99
Logitech C922	1080p/720p	30/60	78°	Glass	5.71	$99.99

MOTOR SELECTION

Motor Type	Advantages	Disadvantages
Stepper	• Precise positioning • Precise speed control • Excellent torque at low speed • Excellent torque to maintain position	• Limited torque at high speed • Low efficiency • More complex to control
DC	• Efficient • Reliable • Simple control	• Some brushless motors require a specialized regulator to control • Imprecise
Servo	• Consistent torque at varying speeds • Excellent torque at high speed • High variety in size and torque ratings • Direct control over positioning	• Limited range of motion, usually 180 degrees • Small adjustments while attempting to hold a steady position

STEPPER MOTOR SELECTION

Frame size	Diameter (mm)	Typical torque range (Nm)	Typical speed range (RPM)
NEMA 17	42	0.2 - 1	0 - 1000
NEMA 23	57	0.5 - 3	0 - 1000
NEMA 24	60	1.2 - 4.6	0 - 1000

Motor	E-Series Nema 23	P-Series Nema 23 x76	Nema 17
Dimensions	57x57x56mm	57x57x76mm	42x42x34mm
Step Angle	1.8 degree	1.8 degree	1.8 degree
Holding Torque	1.26Nm (178.4oz.in)	1.9Nm (269oz.in)	0.26Nm (36.8oz.in)
Rated Current / Phase	2.8A	2.8A	0.4A
Number of Leads	4	4	4
Lead length	300mm	500mm	1000mm
Price	$26.78	$32.05	$22.89

STEPPER MOTOR DRIVERS

Driver	Operational Voltage	Continuous current/ phase	Max current/ phase	Micro-steps	Price
DRV 8825	8V - 45V	1.5 A	2.2 A	Full, ½, ¼, 1/8, 1/16, 1/32	$11.95
DRV 8880	6.5V - 45V	1.0 A	1.6 A	Full, non-circular ½, ½, ¼, 1/8, 1/16	$8.95
A4988 (Black)	8V - 35V	1.2 A	2.0 A	Full, ½, ¼, 1/8, 1/16	$7.49
TB67S128FTG	6.5V - 44V	2.1 A	5.0 A	Full, ½, ¼, 1/8, 1/16, 1/32, 1/64, 1/128	$13.95
DM542T	20V - 50V	1-4.5A	4.5 A	Full, ½, ¼, 1/8, 1/16, 1/32, 1/64, 1/128	$28.99

POWER SUPPLY

Power Supply	Type	Voltage (V)	Capacity (Ah)	Weight (lbs)	Size (in)	Price
Tmezon Power Adapter	Power Adapter	12	N/A	N/A	N/A	$8.99
Universal Battery UB1280	Rechargeable Battery	12	8	4.96	5.94 x 2.56 x 3.94	$20.89
TalentCell PB240A1	Rechargeable Battery	24	22.4	1.43	0.94x2.48x 4.13	$72.79
Duracell Ultra DURDC12-55P	Battery	12	55	42.26	8.98x 5.39x 9.06	$174.99 (FREE)

POWER SYSTEM IMPLEMENTATION

Load on the 24-Volt Source	
Microcontroller	5V
Stepper Motors (2)	24V
Servo Motor	5V
Warning Light	12V
Stepper Motor Drivers	5V

SERVO SELECTION

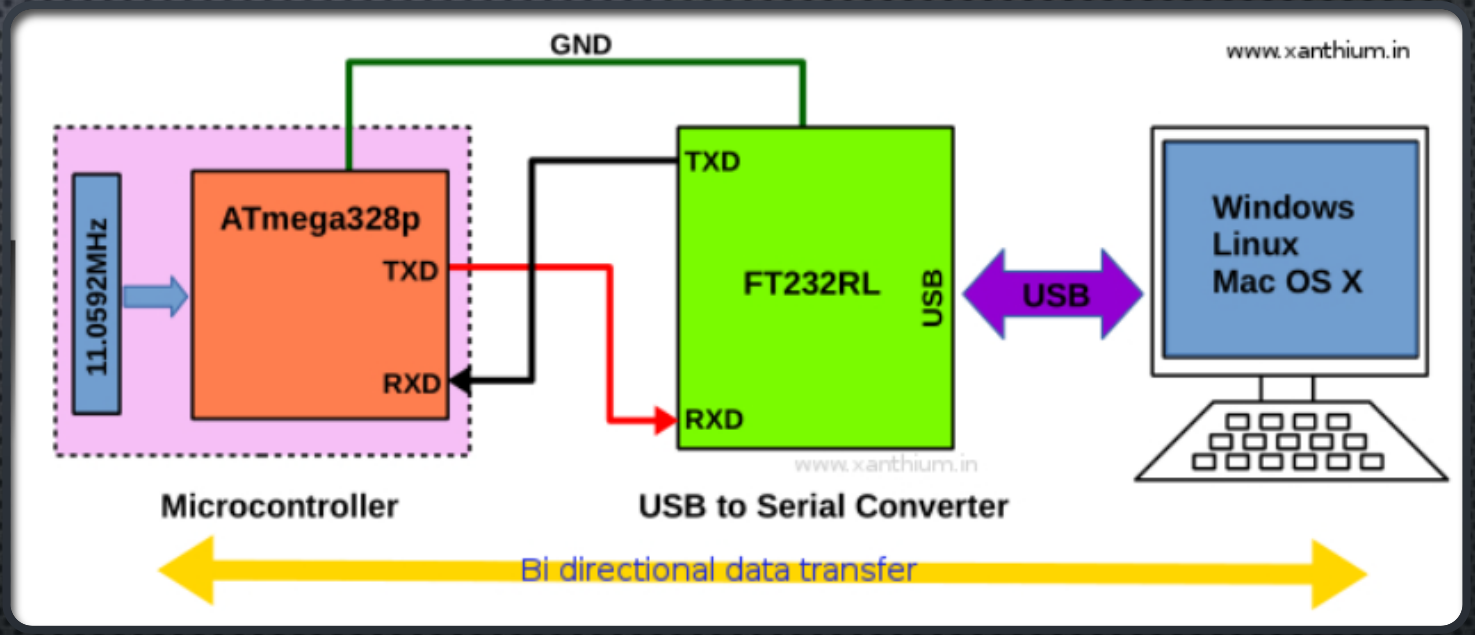
Servo	Power	Speed	Torque	Rotation Angle	Size (L x W x H)	Price
Tower Pro MG995	4.8V - 6.0V DC	60 deg in 0.2 sec	8.5 kg-cm	120 deg	40.7mm x 19.7mm x 42.9mm	$11.99
Tower Pro MG995R	4.8V - 6.0V DC	60 deg in 0.20 sec	9.4 kg-cm	120 deg	40.7mm x 19.7mm x 42.9mm	$19.95
Hitec HS-311	4.8V - 6.0V DC	60 deg in 0.19 sec	3.0 kg-cm	96 deg; 202 deg with travel turner	40.0mm x 20.0mm x 36.5mm	$13.49
Hitec HS-645 MG	4.8V - 6.0V DC	60 deg in 0.24 sec	7.7 kg-cm	90 deg; 197 deg with travel turner	40.2mm x 19.8mm x 39.0mm	$35.99

TRIGGERING SERVO (TOWER PRO MG995)

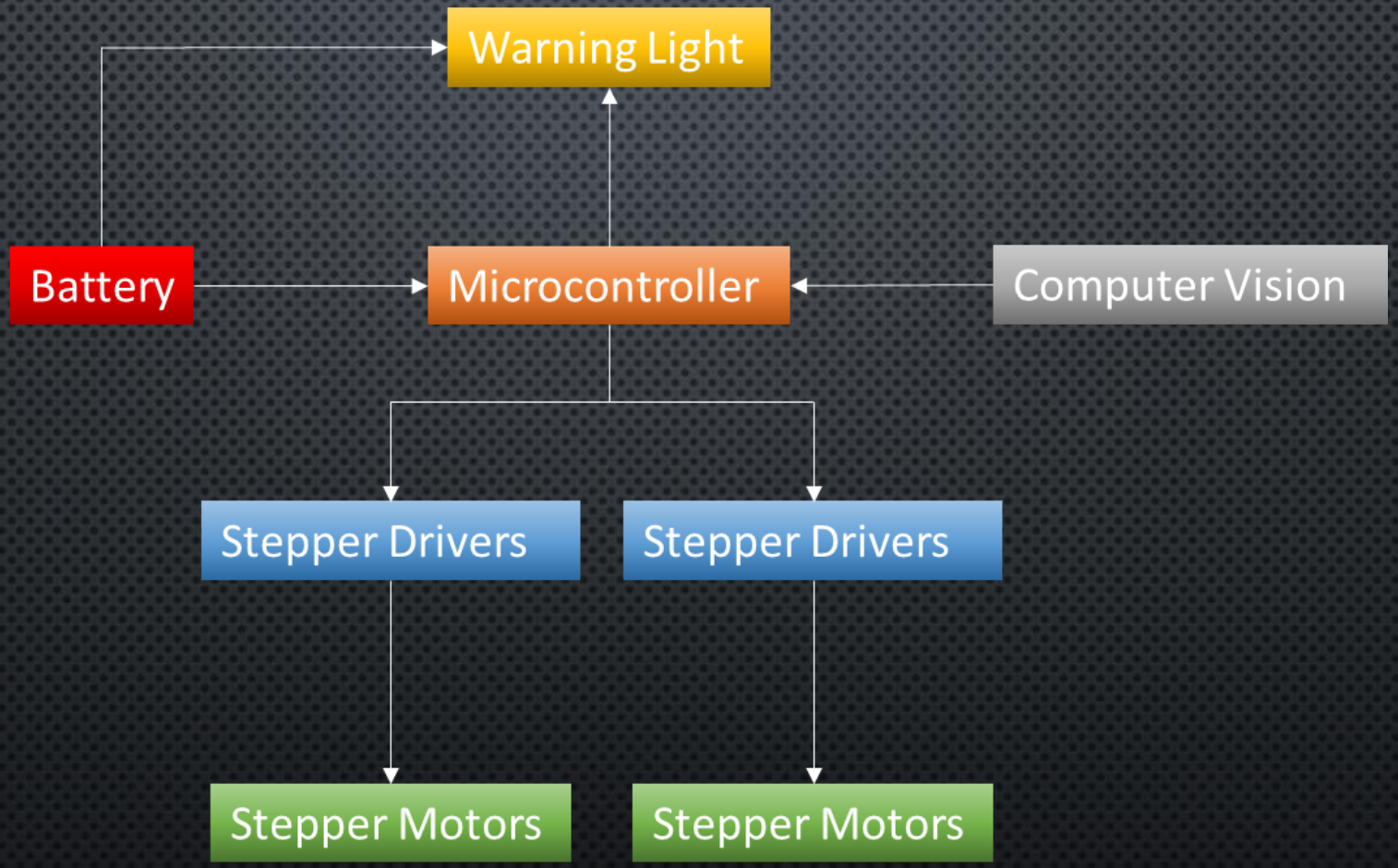
- Speed & position feedback
- Consistent torque at varying speeds (8.5 kg-cm)
- Direct control over positioning (rotation angle: 120 degrees)
- Low power consumption (4.8 V – 6.0 V DC)

SERIAL COMMUNICATION

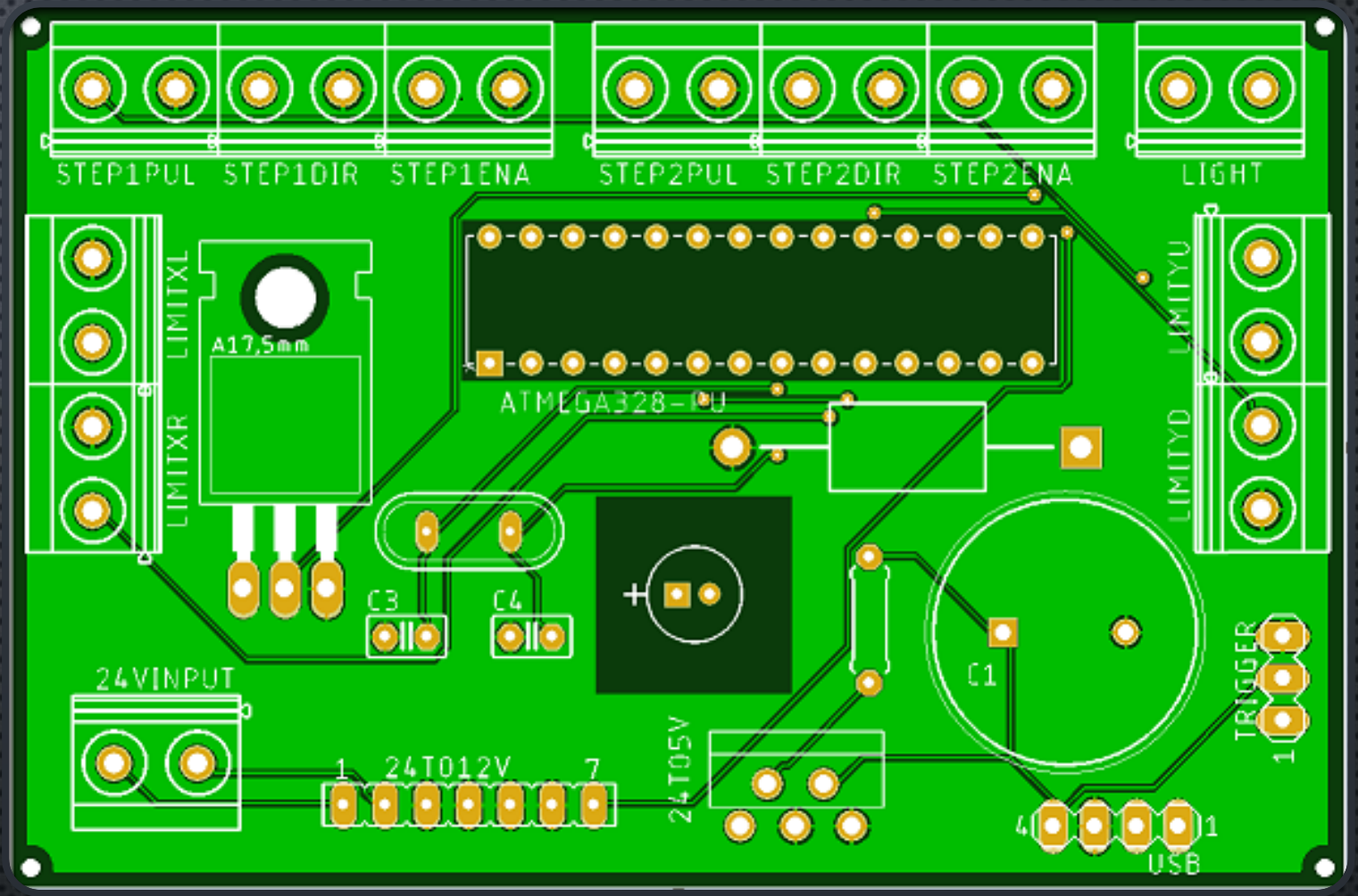
- FT232RL
- ALLOWS COMMUNICATION BETWEEN MCU & PC
  - SERIAL - USB



PCB BLOCK DIAGRAM

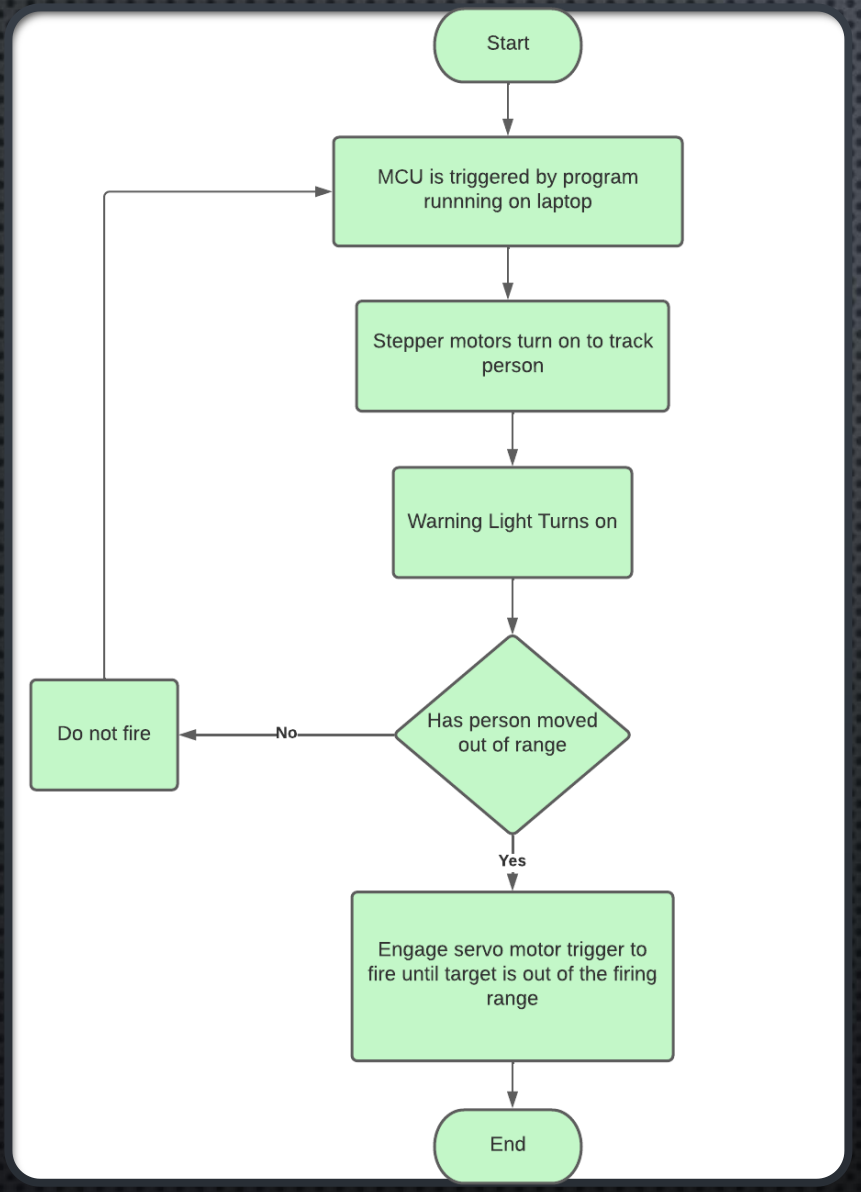


PCB LAYOUT

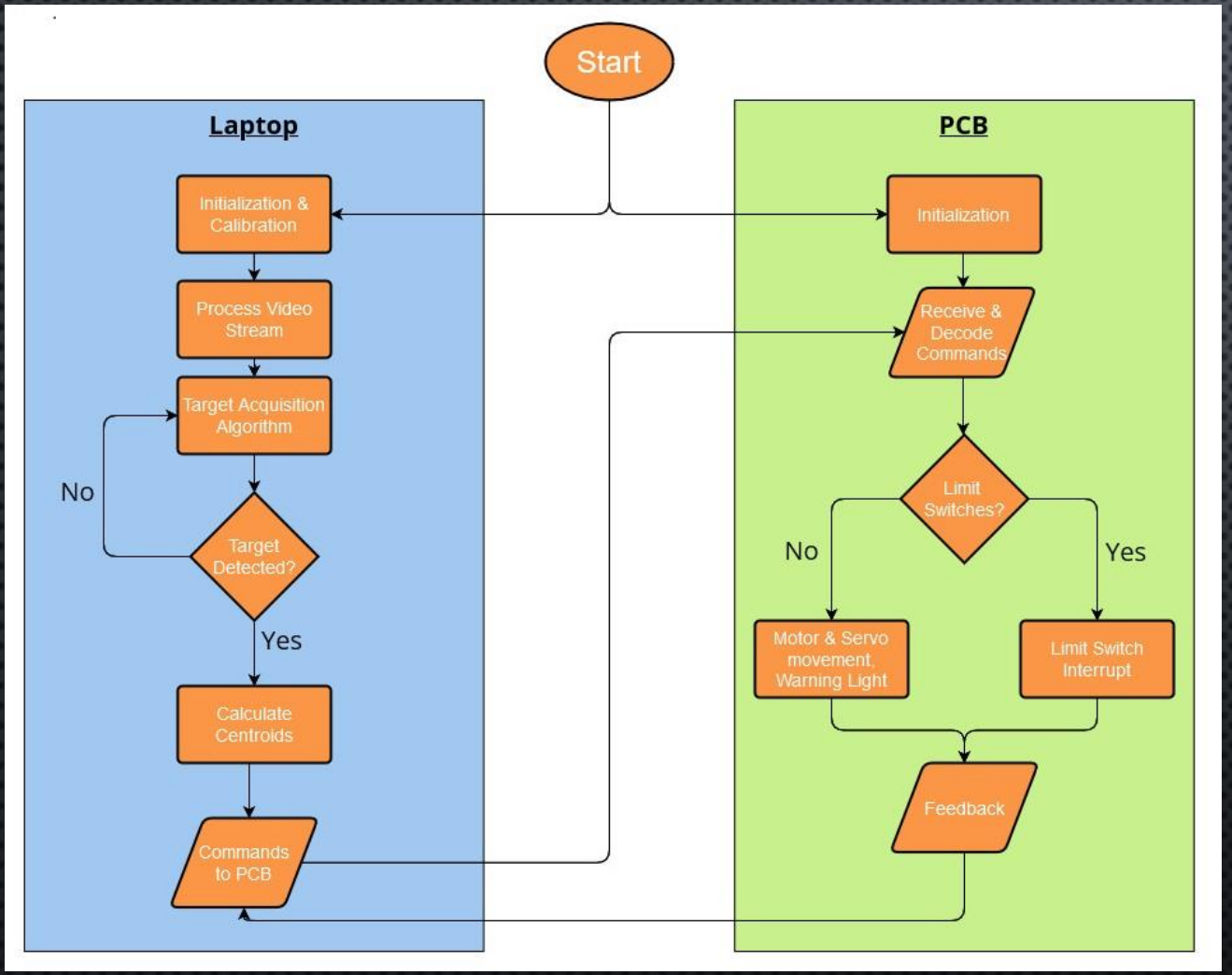


OLD PCB PROBLEMATIC FOOTPRINT

FUNCTIONAL FLOWCHART

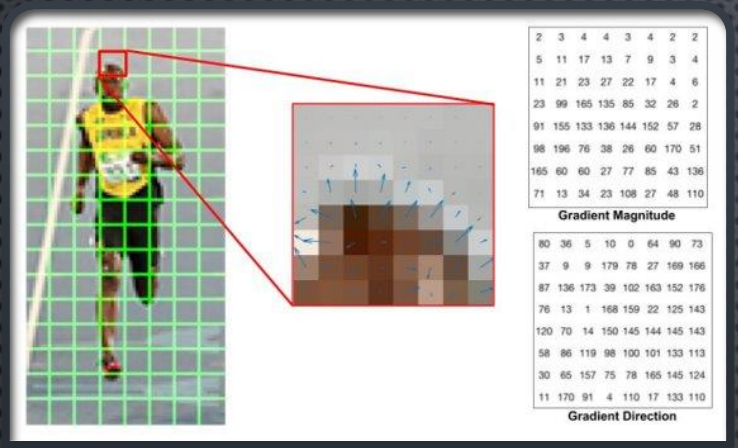


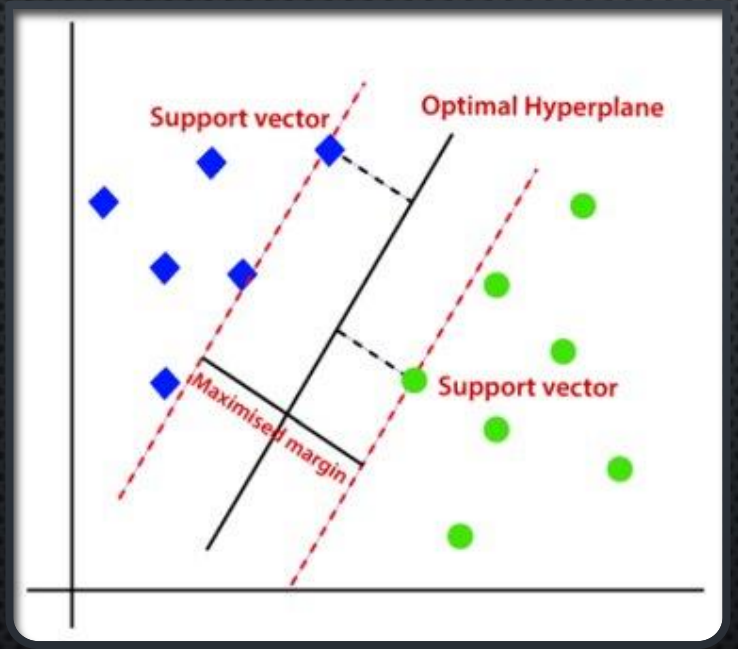
SOFTWARE



SOFTWARE OVERVIEW

- LAPTOP
  - HANDLES COMPUTER VISION ASPECT OF PROJECT
  - WAITS FOR RESPONSE BEFORE SENDING NEXT COMMAND
- PCB
  - RECEIVES INSTRUCTIONS FROM LAPTOP
  - COMMANDS MOTORS & LIGHTS ACCORDINGLY





LAPTOP SOFTWARE

- OpenCV
  - Acquiring & processing video stream from camera
  - Histogram of Oriented Gradients
    - Feature Detection
  - Linear Support Vector Machine
    - Feature Classification
- Python
  - Faster to write, easier to debug
  - PySerial communication
- Calculations
  - Calculate target steps
  - Formulate & Send instructions

SOFTWARE COMPARISON

OpenCV	TensorFlow
Computer Vision	Machine Learning
Image processing and detection	Pattern Detection
Uses C++, Python, Java and MATLAB	Uses C, C++, Java, and Python
Operates on Windows, Linux, Android and Mac OS.	Operates on Windows, Ubuntu, macOS, and Python 3.7-3.9.
Efficiency of real-time applications	Mathematical solutions using dataflow charts

CODING LANGUAGE COMPARISON

C++ (will be used for microcontroller)	Python (OpenCV)
Object-Oriented	Object-Oriented
Harder to use	Easier to use
Has predefined syntaxes and structure	Syntax is easier to remember
Dynamically typed	Statically Typed
Pre-compiled	Uses Interpreter
Faster speed	Slower Speed
More lines of code	Less lines of code
Manages memory through pointers	Uses a garbage collector to manage memory

EMBEDDED SOFTWARE

- ATMEGA 328 - ARDUINO IDE CAN BE USED
- RECEIVES INSTRUCTIONS FROM LAPTOP AS BINARY
  - TRANSLATES THESE BINARY NUMBERS INTO INSTRUCTIONS FOR FUNCTIONS
  - PAN & TILT STEPPER MOTORS
  - TRIGGER SERVO
  - WARNING LIGHT

DEMO RESULTS

ACTUAL RESULTS

Key Specifications	Predicted	Actual
Accuracy (minimum)	70%	50%
Traverse	180° horizontally, 45° vertically	Success
Range	10-75 feet	10-30 feet

ADMINISTRATION

PROJECT TIMELINE

Senior Design II		
Number	Milestone	Planned Completion Week
1	Finish ordering parts	1/17/2022
2	Start building	2/7/2022
3	Start Initial Testing	2/14/2022
4	CDR Presentation	2/25/2022
5	Mid-Term Demo	3/21/2022
6	Final Demo	4/18/2022
7	Final Documentation	4/26/2022

PROTOTYPING

PHASE I

- SOFTWARE PROTOTYPING WITH ARDUINO DEVELOPMENT BOARDS
- COMPUTER VISION PROTOTYPING WITH LAPTOP & ITS INBUILT CAMERA

PHASE II

- BUILDING THE PHYSICAL UNIT
- TESTING THE CODE WITH PCB TO ENSURE ALL PARTS OF UNIT IS FUNCTIONING
- MAKING NECESSARY CHANGES

PHASE III

- ENSURE THE UNIT IS FUNCTIONING AS INTENDED AND READY TO DEMO

BUDGET

Item	Quantity	Price Estimate
Camera	1	$60
PCB	1	$30
Power Cord	1	$10
Internal Power Supply	1	$(175) Free
Paintball Gun	1	$92
Paintballs	1	$35
Air Tank	1	$30
Motors	3	$60
Microcontroller	1	$30
Jumper Wires	1	$5
Paint	1	$10
Screws and Washers	2	$20
Adhesive	1	$12
Red Warning Light	1	$13
Materials for Structure	1	$100
Total	-	$507

INDIVIDUAL RESPONSIBILITIES & WORK DISTRIBUTION

Team Member	Warning Light	Mounting & Casing Design	Camera Selection	Computer Vision Processing / Coding	Power System/ PCB Design	Arduino Coding	Validation and Checking	Servo Mechanism
Kaitlyn		P			P			
Quintin							P	S
Michael				P		P		
Liderma	P	S	P			S		P

DESIGNS CONSTRAINTS

- MONEY
- SCHEDULES
- DURABILITY
- ENERGY
- DETECTION
- COMMUNICATION (MCU)

THANK YOU!

ANY QUESTIONS?