UCF

UNIVERSITY OF CENTRAL FLORIDA

Robot Basketball

Summer/Fall 2019

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Motivation

- Entertainment
- Robot Athleticism
- Technologies and skills

Goals and Objectives

- Arcade-style entertainment system
- Eye-catching, engaging, and fun
- Low-cost and scalable
- Exciting Robot Capabilities

Realistic Design Constraints

- $ Economic: Budget, Scalability, Affordable
- Health and Safety: Flying projectiles
- Manufacturability: Produced in high Volume
- Sustainability: Maintainable by technicians

Impact

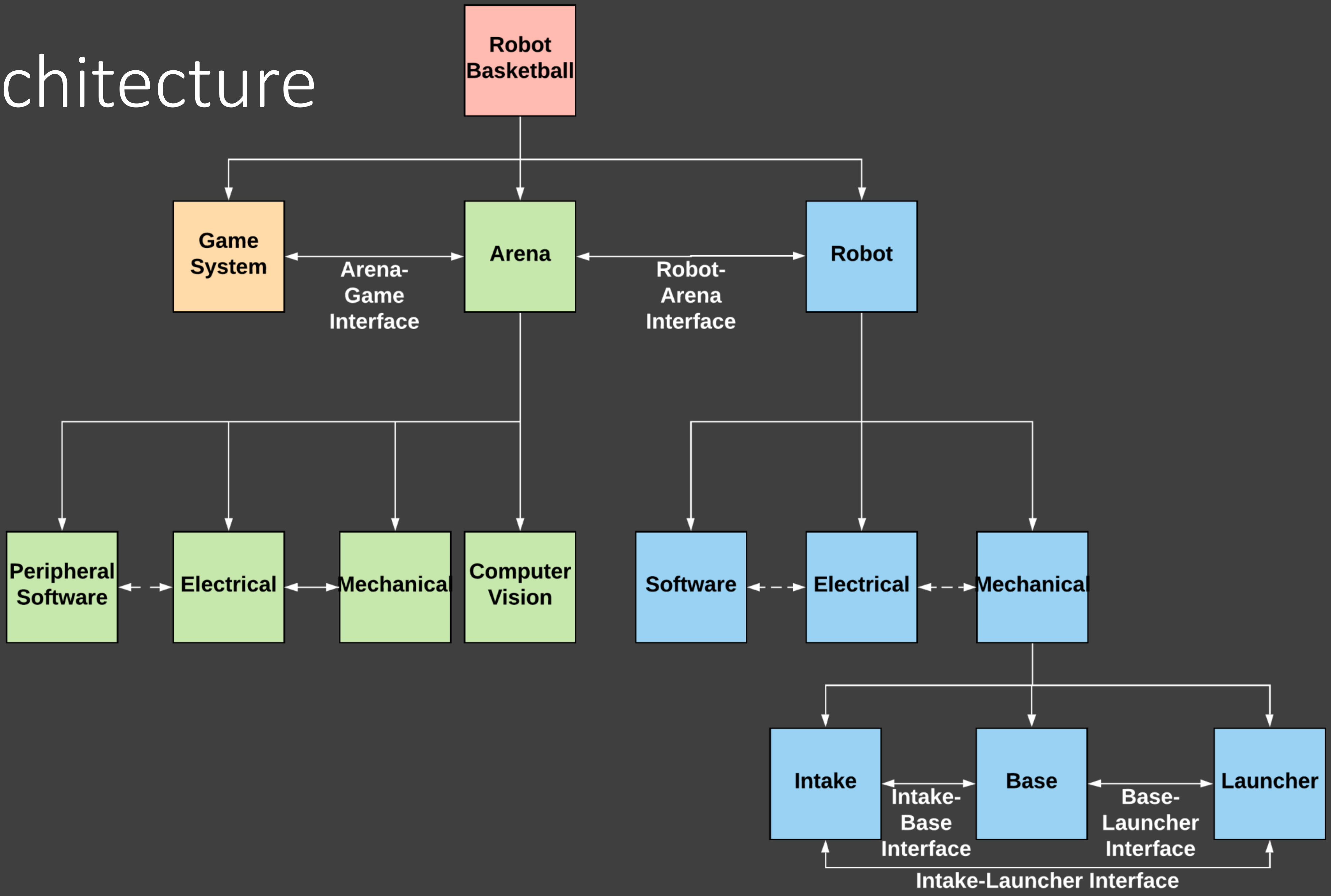
Entertainment industry

- Interactive displays
- New, unique experiences increases repeat-visits

Robotics Industry

- Platform to test new and unique software
- Expandable to a variety of sports and events

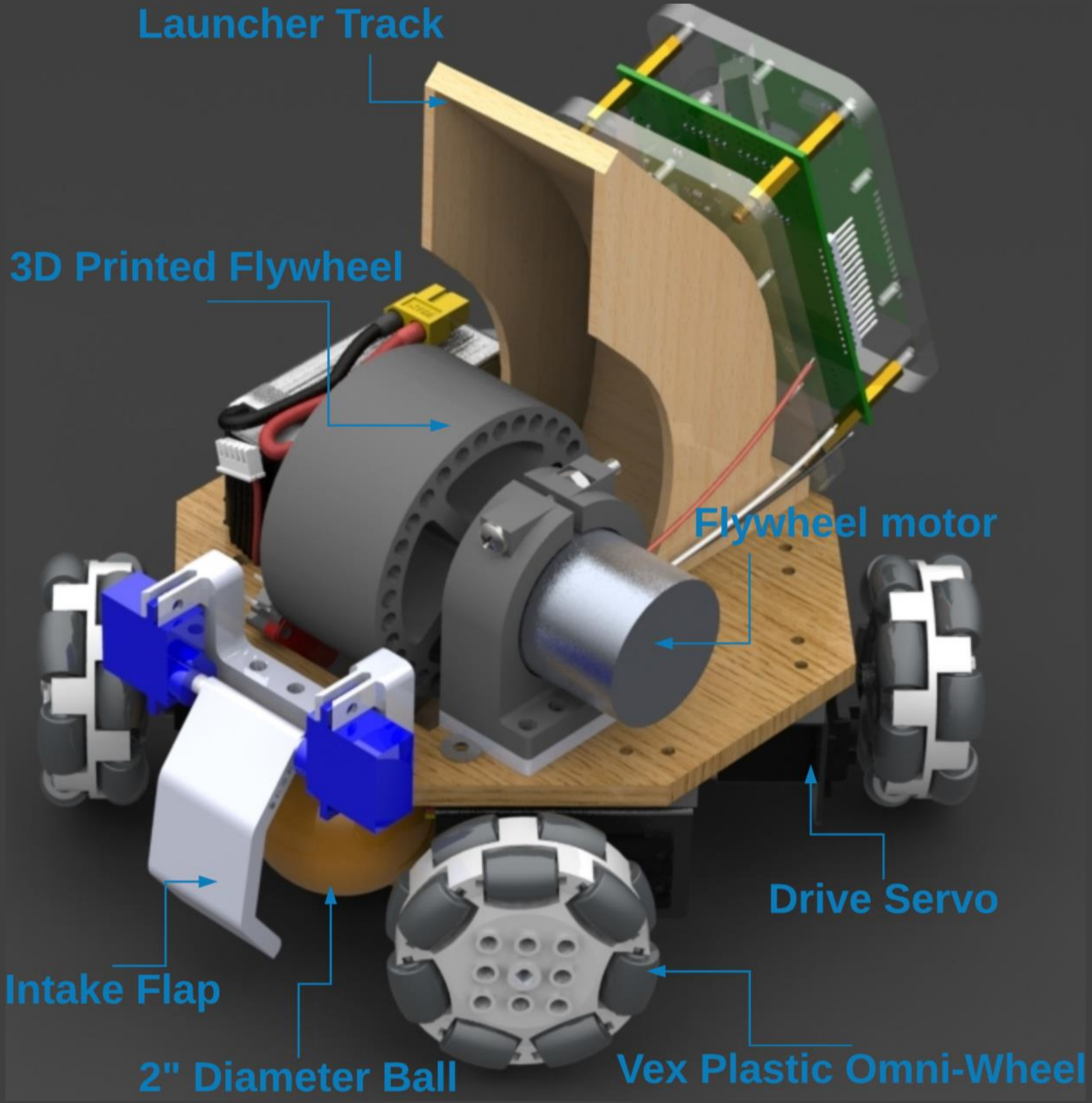
System Architecture

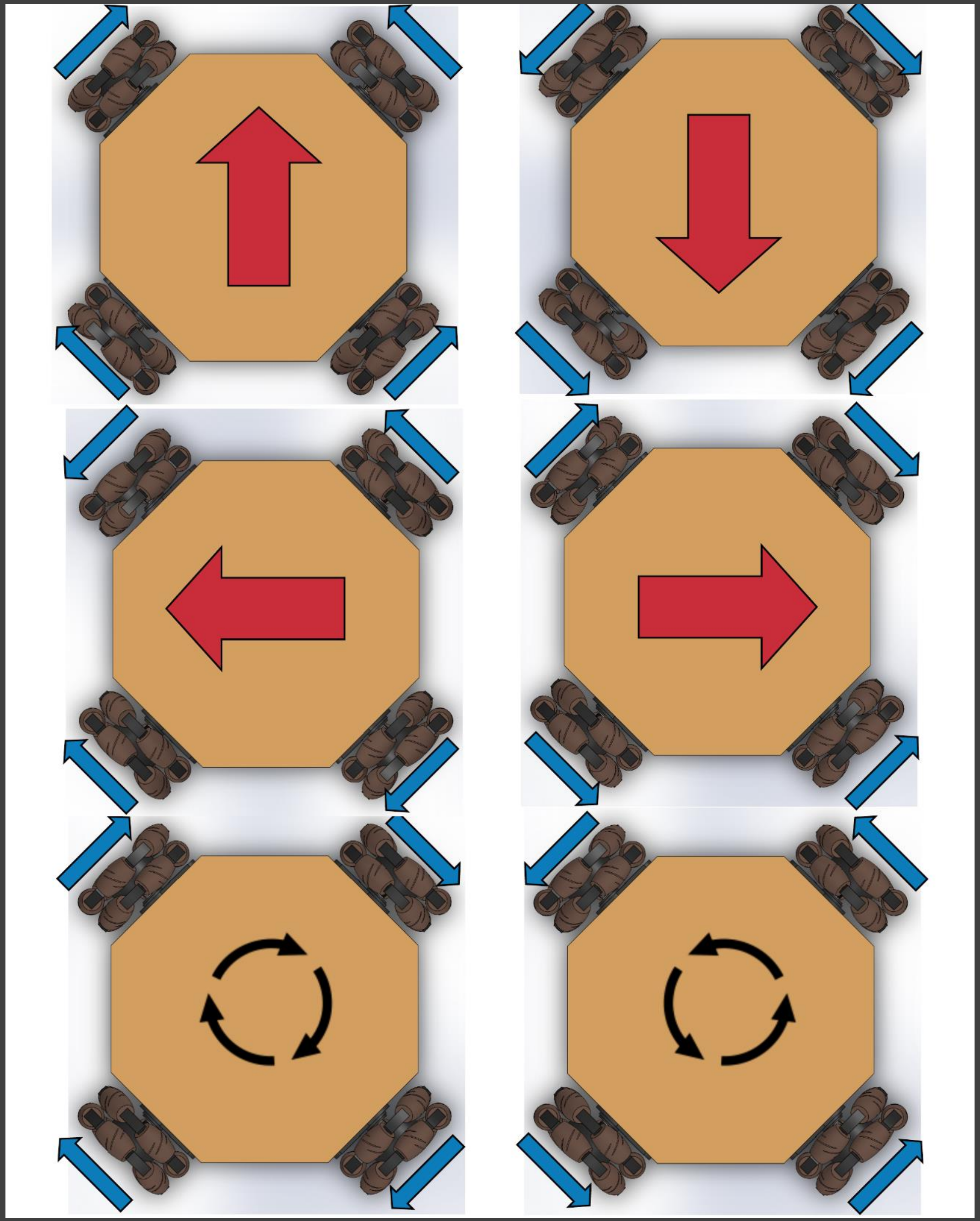


Requirement Specifications

Requirement #	System	Requirement	Value	Unit
1	Robot	The launcher shall launch a ball with a range of…	1-5	Feet
2	Robot	The robot shall drive in any direction at a minimum velocity of at least…	1.25	Feet/ second
3	Arena	The computer vision shall detect robot and ball position with an accuracy of at least…	0.5	Inches
4	Arena	The computer vision shall detect robot orientation with an accuracy of at least…	3	Degrees
5	Game	The game shall control the robot with a gamepad at a rate of at least…	5	Hz
6	Game	The game shall prevent the robot from driving within a distance to the wall at most…	1	Inch

Robot


Launcher Track
3D Printed Flywheel
Flywheel motor
Drive Servo
Intake Flap
2" Diameter Ball
Vex Plastic Omni-Wheel

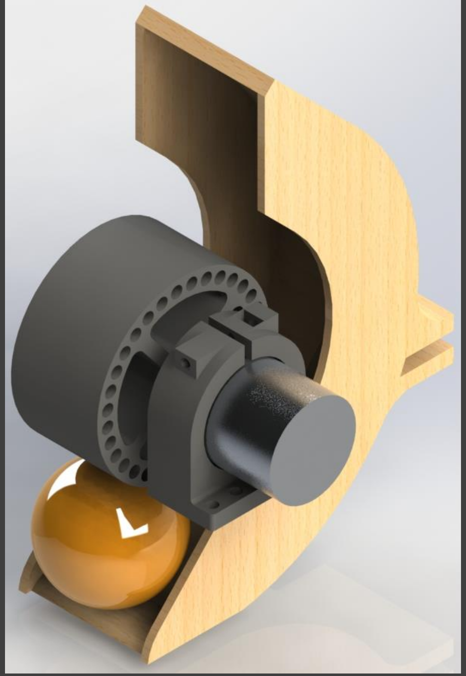


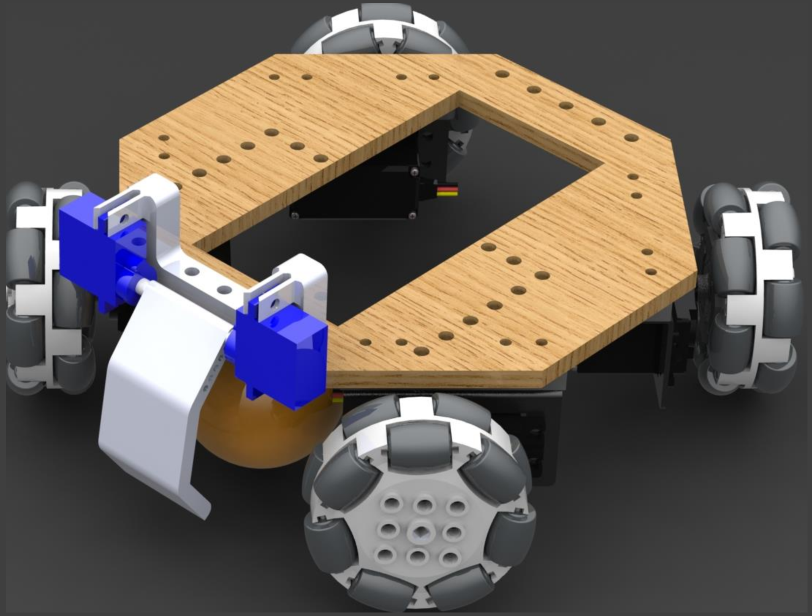
Mobile Base Design

- Holonomic Drive with 4 Omni-Wheels
  - Can maintain shot angle while traversing without turning
  - Slightly faster motion
  - Requires more torque
  - Vector addition of Wheel outputs

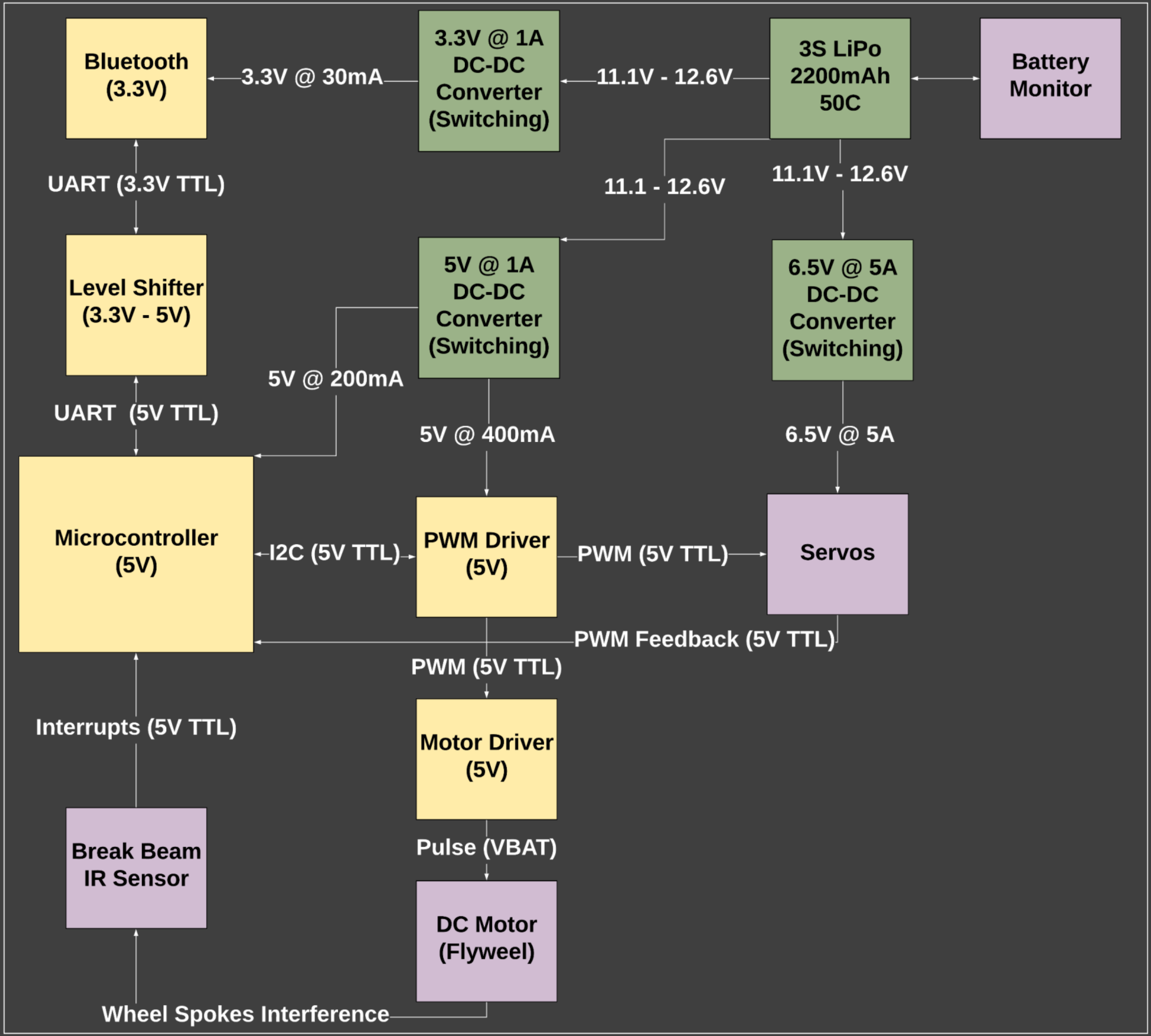
Robot Launcher/Intake Design

- Flipper mechanism to trap ball and feed it into intake
  - 2-Servo flap that acts grabs and engages the ball with the flywheel
- Flywheel to launch the ball from anywhere on the court
  - DC Motor with fast response, up to 3200 RPM





Robot PCB Overview



Bluetooth (3.3V)

3.3V @ 30mA

3.3V @ 1A DC-DC Converter (Switching)

11.1V - 12.6V

3S LiPo 2200mAh 50C

Battery Monitor

UART (3.3V TTL)

11.1 - 12.6V

11.1V - 12.6V

Level Shifter (3.3V - 5V)

5V @ 1A DC-DC Converter (Switching)

6.5V @ 5A DC-DC Converter (Switching)

5V @ 200mA

UART (5V TTL)

5V @ 400mA

6.5V @ 5A

Microcontroller (5V)

I2C (5V TTL)

PWM Driver (5V)

PWM (5V TTL)

Servos

PWM Feedback (5V TTL)

PWM (5V TTL)

Interrupts (5V TTL)

Motor Driver (5V)

Break Beam IR Sensor

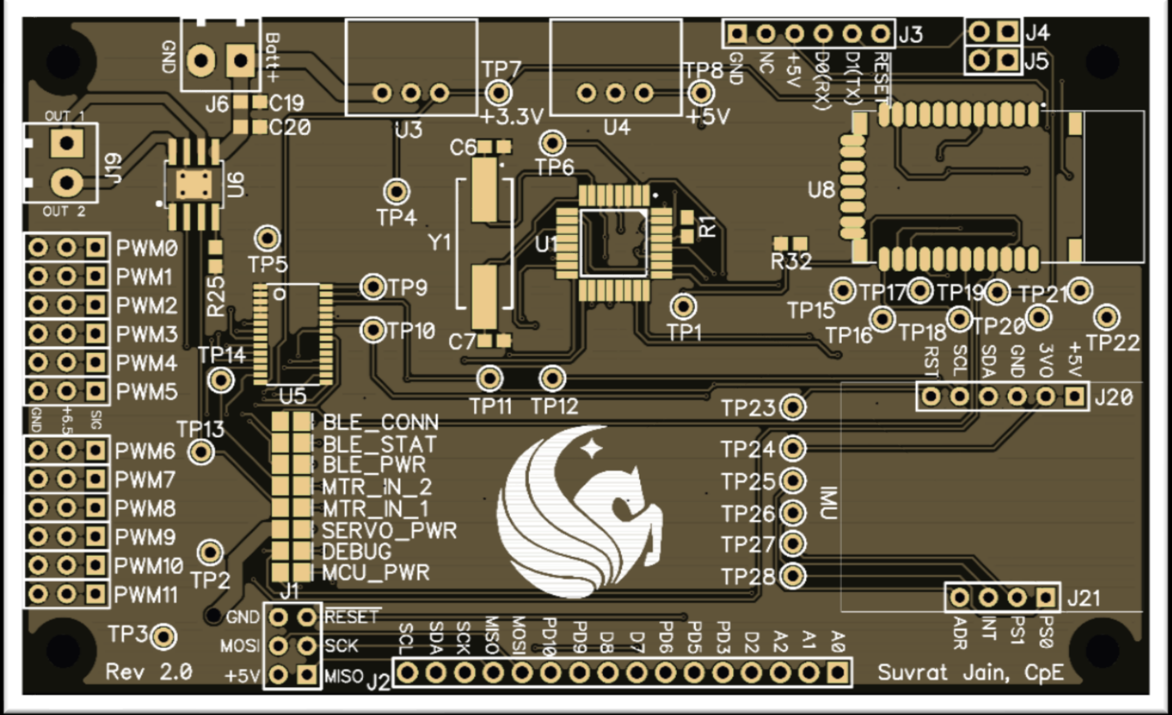
Pulse (VBAT)

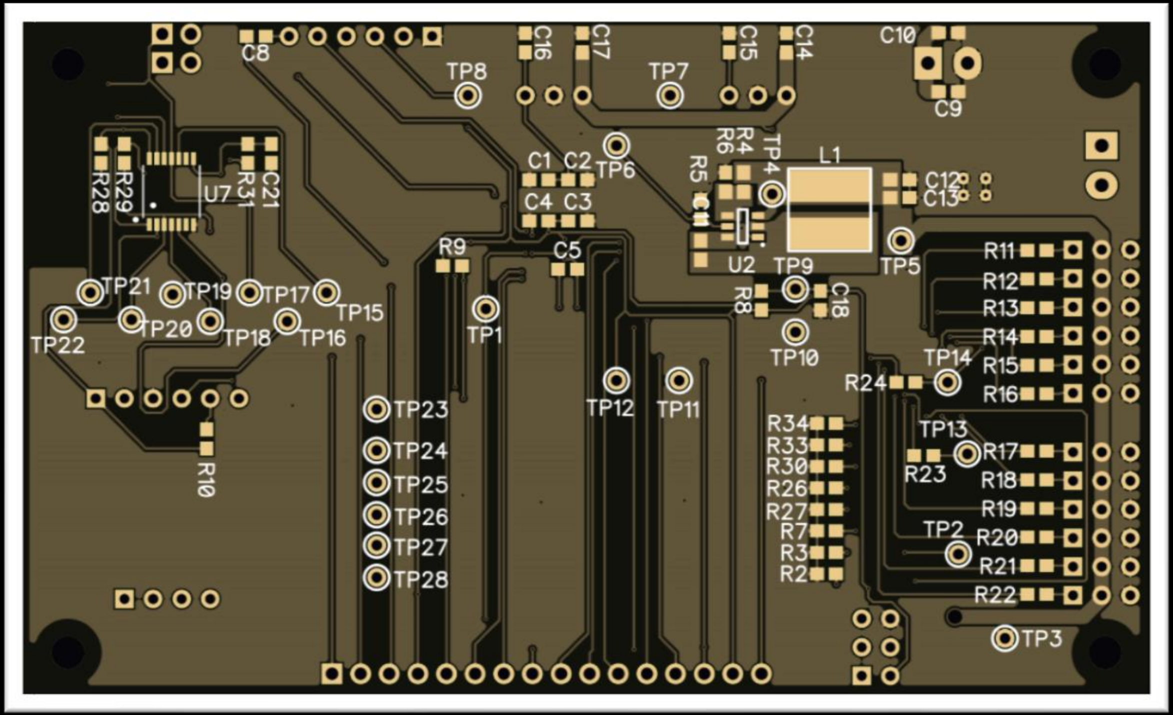
DC Motor (Flyweel)

Wheel Spokes Interference

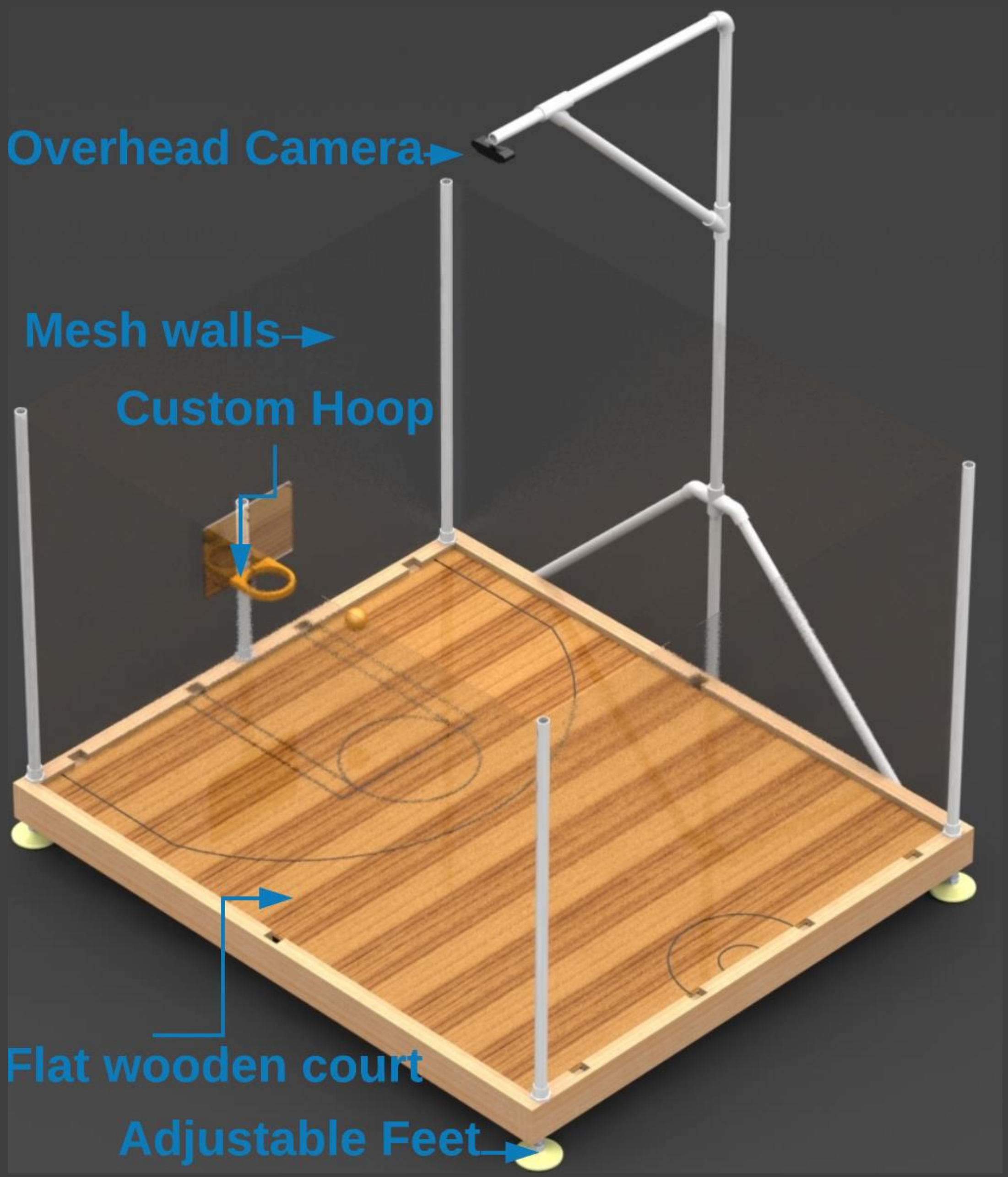
ICs	Peripherals	Power

PCB Layout


GND
Batt+
J6
C19
C20
OUT 1
OUT 2
J19
U6
U3
U4
TP7
+3.3V
TP8
+5V
J3
GND
NC
+5V
D0(RX)
D1(TX)
RESET
J4
J5
C6
TP6
TP4
Y1
U1
R1
U8
R32
TP5
R25
TP9
TP10
C7
TP1
TP15
TP16
TP17
TP18
TP19
TP20
TP21
TP22
RST
SCL
SDA
GND
3V0
+5V
J20
PWM0
PWM1
PWM2
PWM3
PWM4
PWM5
TP14
U5
GND
+6.5
SIG
TP13
TP11
TP12
BLE_CONN
BLE_STAT
BLE_PWR
MTR_IN_2
MTR_IN_1
SERVO_PWR
DEBUG
MCU_PWR
PWM6
PWM7
PWM8
PWM9
PWM10
PWM11
TP2
TP23
TP24
TP25
TP26
TP27
TP28
IMU
J21
J1
GND
RESET
MOSI
SCK
+5V
MISO
J2
TP3
Rev 2.0
SCL
SDA
SCK
MISO
MOSI
PD10
PD9
D8
D7
PD6
PD5
PD3
D2
A2
A1
A0
ADR
INT
PS1
PS0
Suvrat Jain, CpE

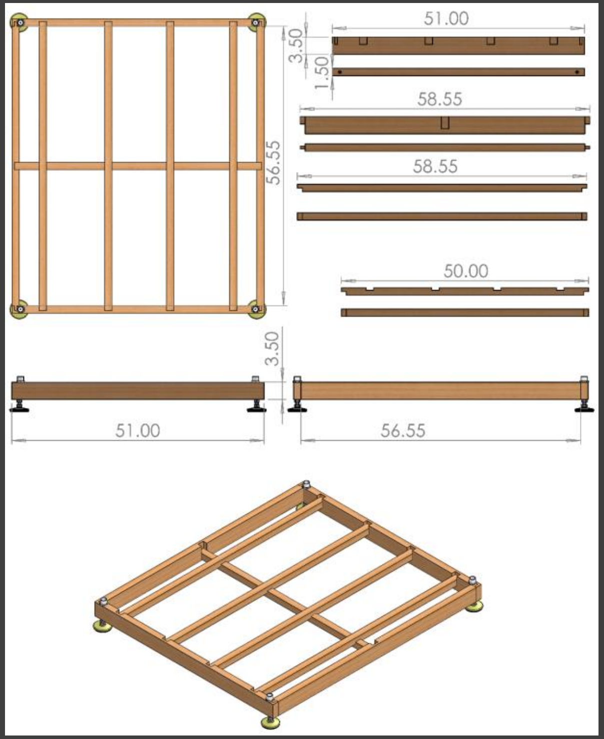

C8
C16
C17
C15
C14
C10
C9
TP8
TP7
R28
R29
U7
R31
C21
C1
C2
TP6
C4
C3
R4
R6
R5
TP4
L1
C12
C13
R9
C5
C11
U2
TP9
TP5
TP21
TP19
TP17
TP15
TP22
TP20
TP18
TP16
TP1
R8
C18
TP10
R11
R12
R13
R14
R15
R16
TP14
R24
R10
TP23
TP24
TP25
TP26
TP27
TP28
TP12
TP11
R34
R33
R30
R26
R27
R7
R3
R2
TP13
R23
R17
R18
R19
TP2
R20
R21
R22
TP3

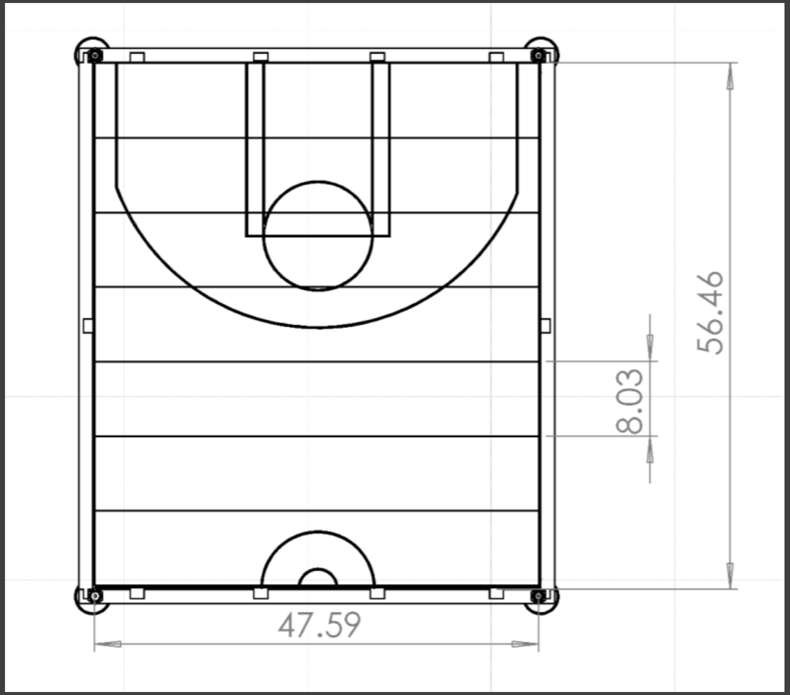
Arena


Overhead Camera
Mesh walls
Custom Hoop
Flat wooden court
Adjustable Feet

Arena - Frame & Court Design

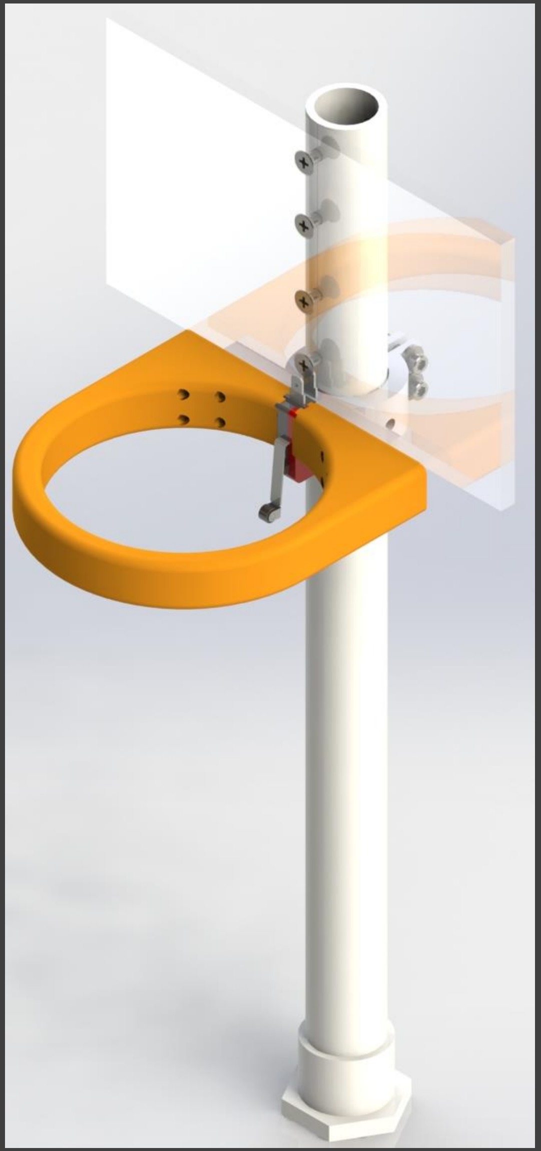
- Arena is 5' length by 4' Width by 3' height (Minus camera mount)
- Broken into several locking pieces without tools or hardware
- Frame mounted on adjustable feet to level the floor
- Wall mesh included to prevent projectiles flying outside the Arena

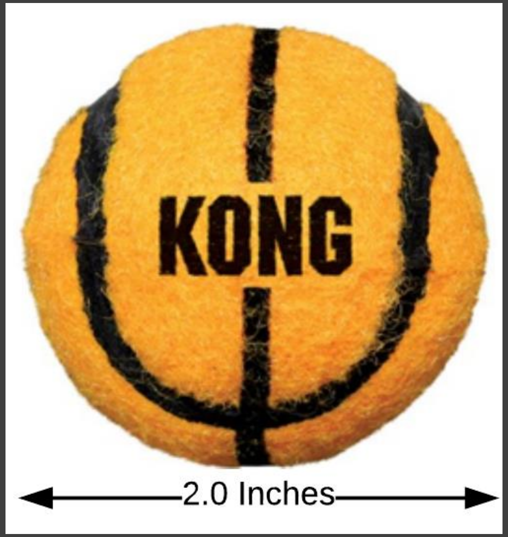




Arena - Ball & Hoop Design

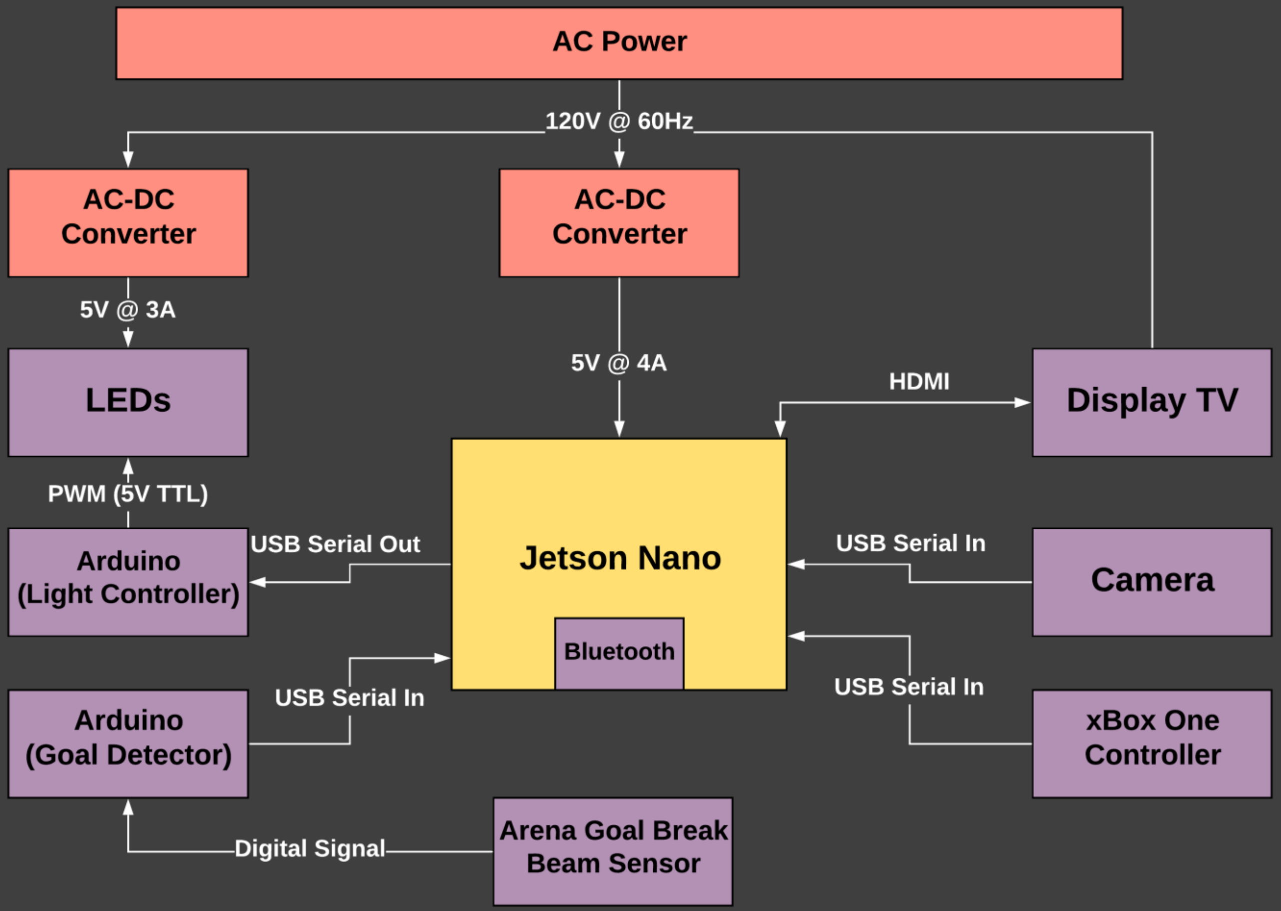
- Ball is a small-scale tennis ball with a basketball appearance
  - Chosen because of size, appearance, and higher weight than a ping-pong ball
- 3D-Printed hoop and mount attached to a PVC post and an ABS backboard
- IR Break Beam Sensor to capture when baskets are made





Arena - Electrical Design

- The Arena is AC Powered
- A 120V to 5V AC-DC converter is used to power the Nano
- Another 5V AC-DC converter is used to power the LEDs
- Nano does most of the processing for CV and Game System onboard
- The XBox Controller inputs are taken in serially via USB and sent to the Robot via Bluetooth
- The TV/Display is powered from an AC outlet as well

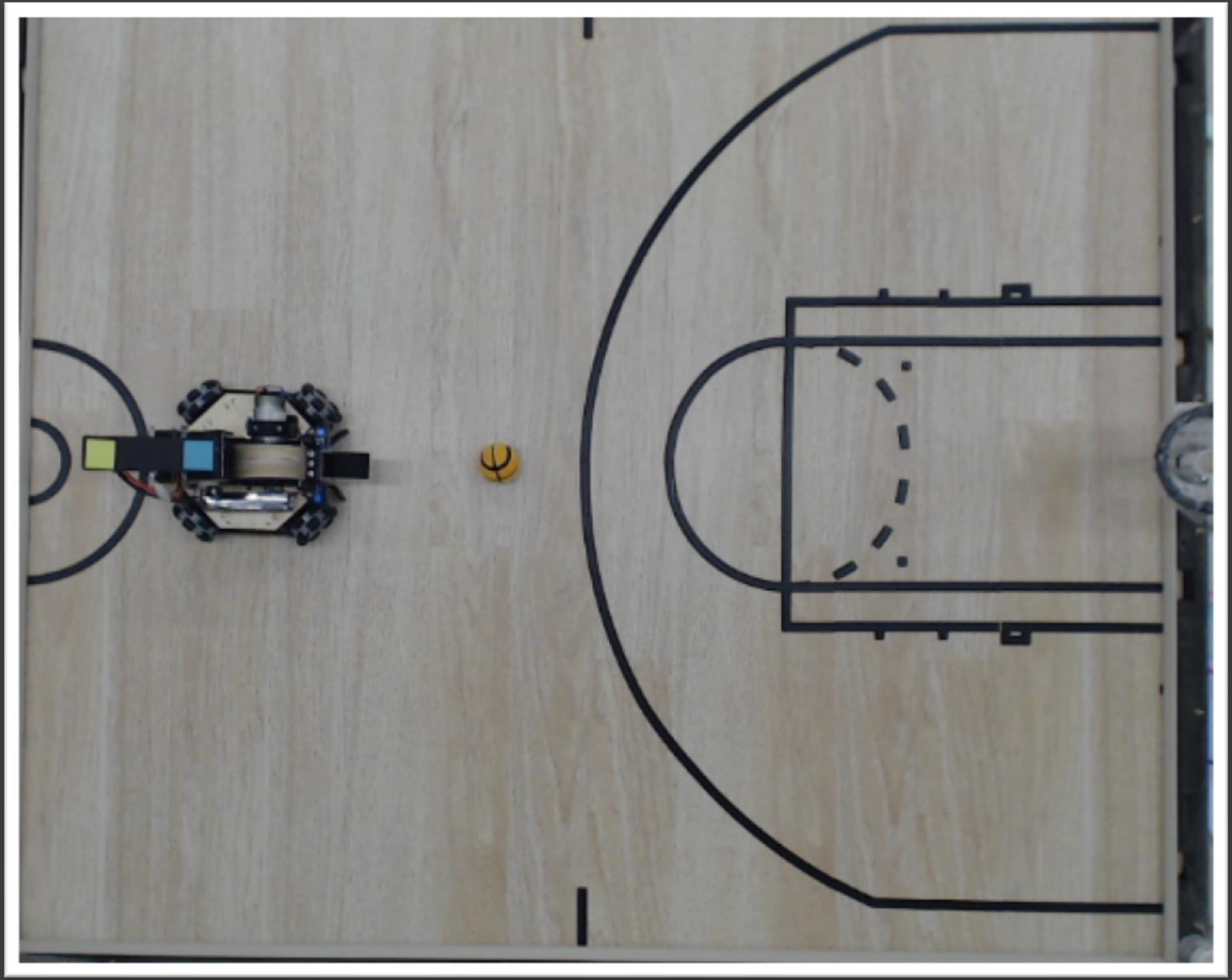


Arena Computer Vision System

- Position & Orientation of Robot required for automatic control
- Position of ball displayed in the game
- Overhead camera used to be able to easily scale to more robots and objects

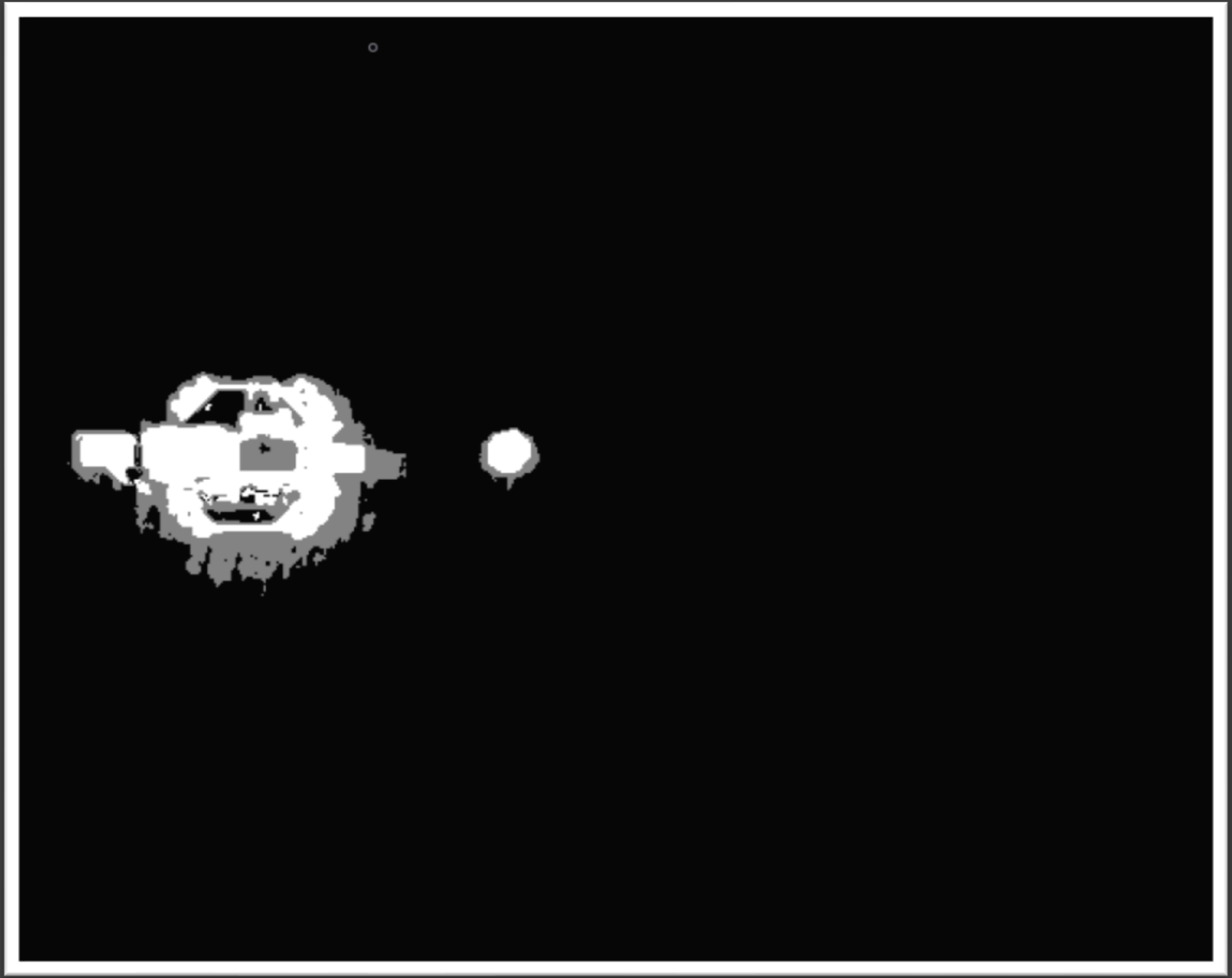
Step 1 – Collect the Frame

- Capture and build a background model
- Add objects to the court



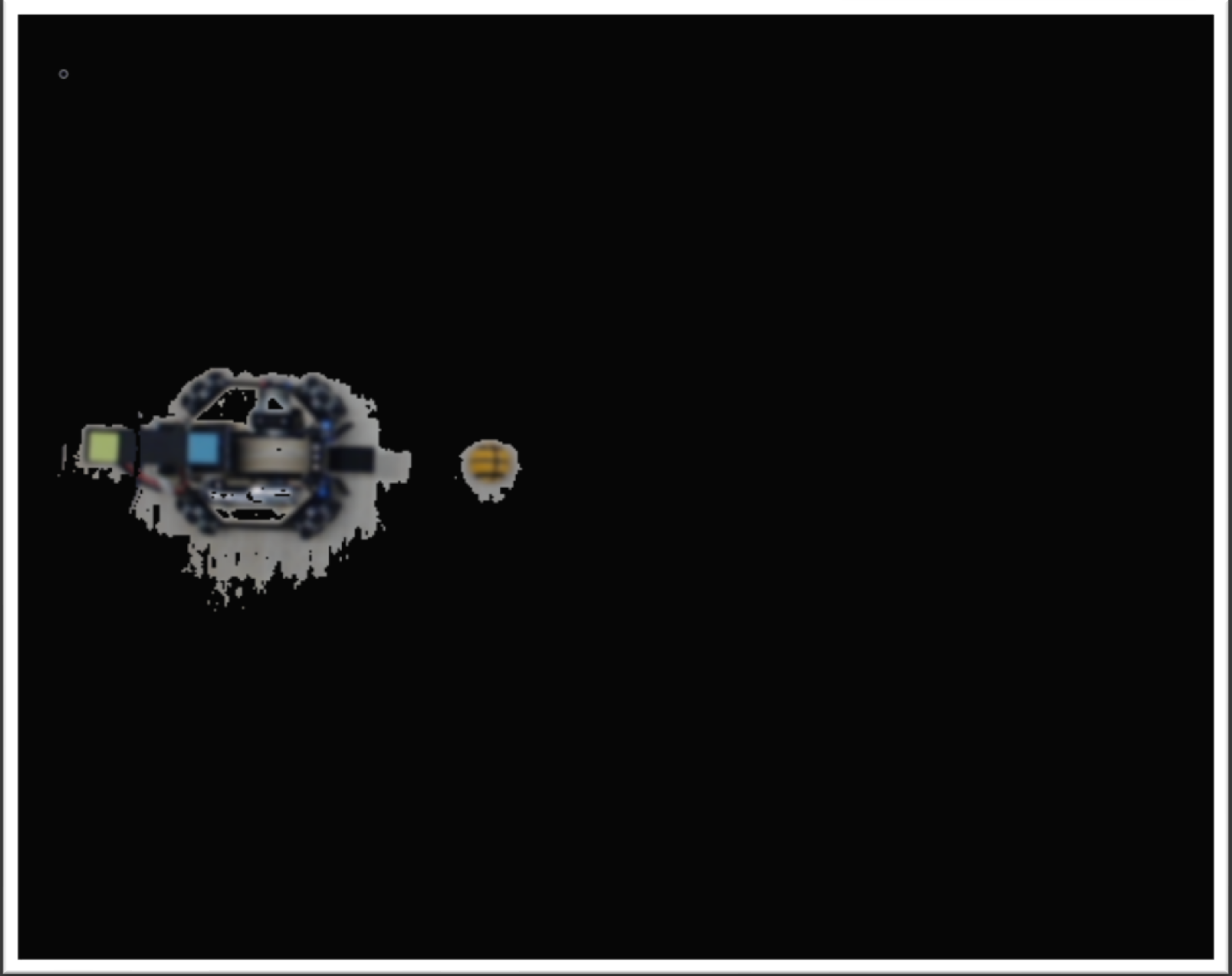
Step 2 – Foreground Mask

- Apply background subtraction to get a foreground mask



Step 3 – Background Mask 'AND' Frame

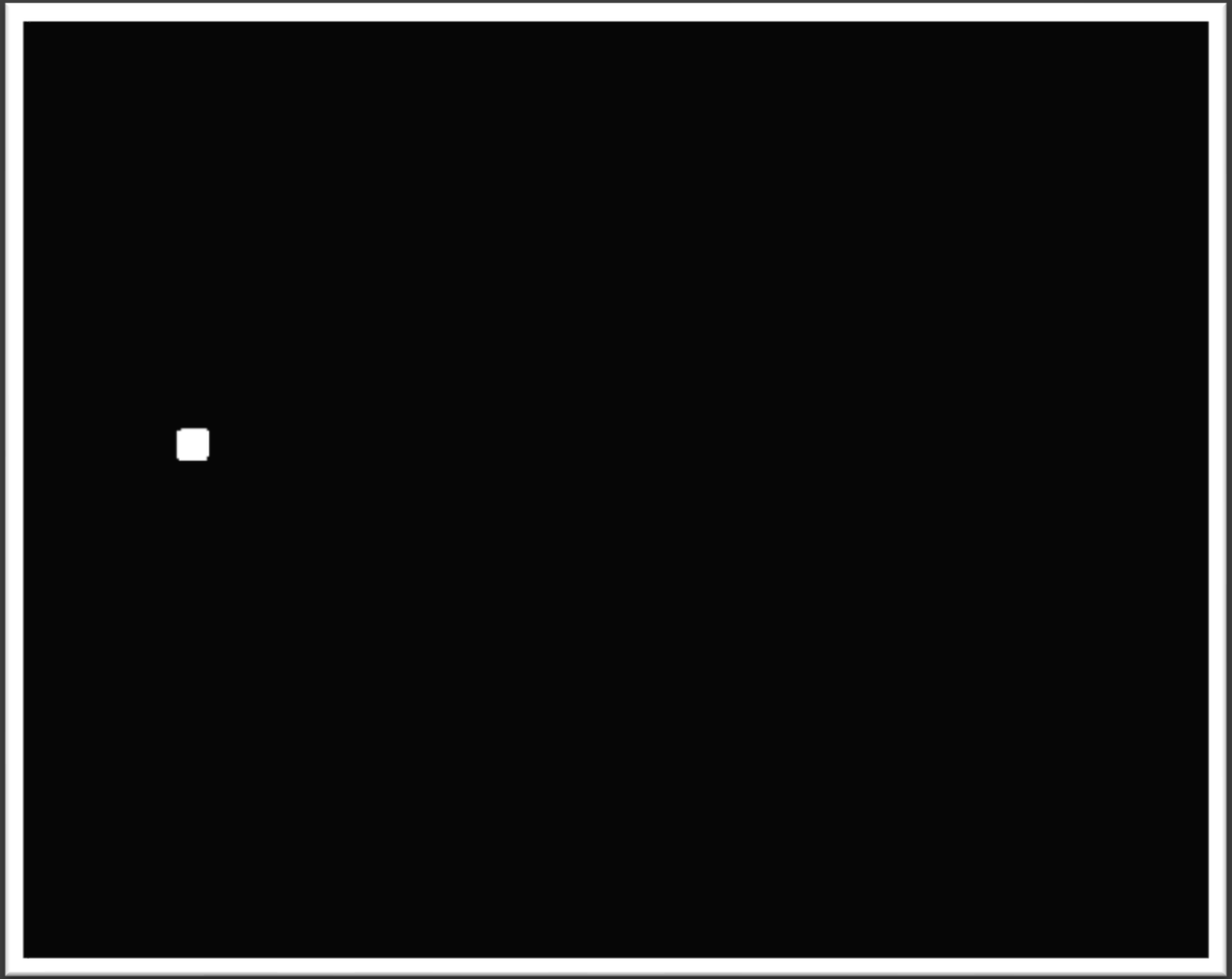
- Perform bitwise 'AND' on the blurred frame and foreground mask to get a color image from the results of background subtraction



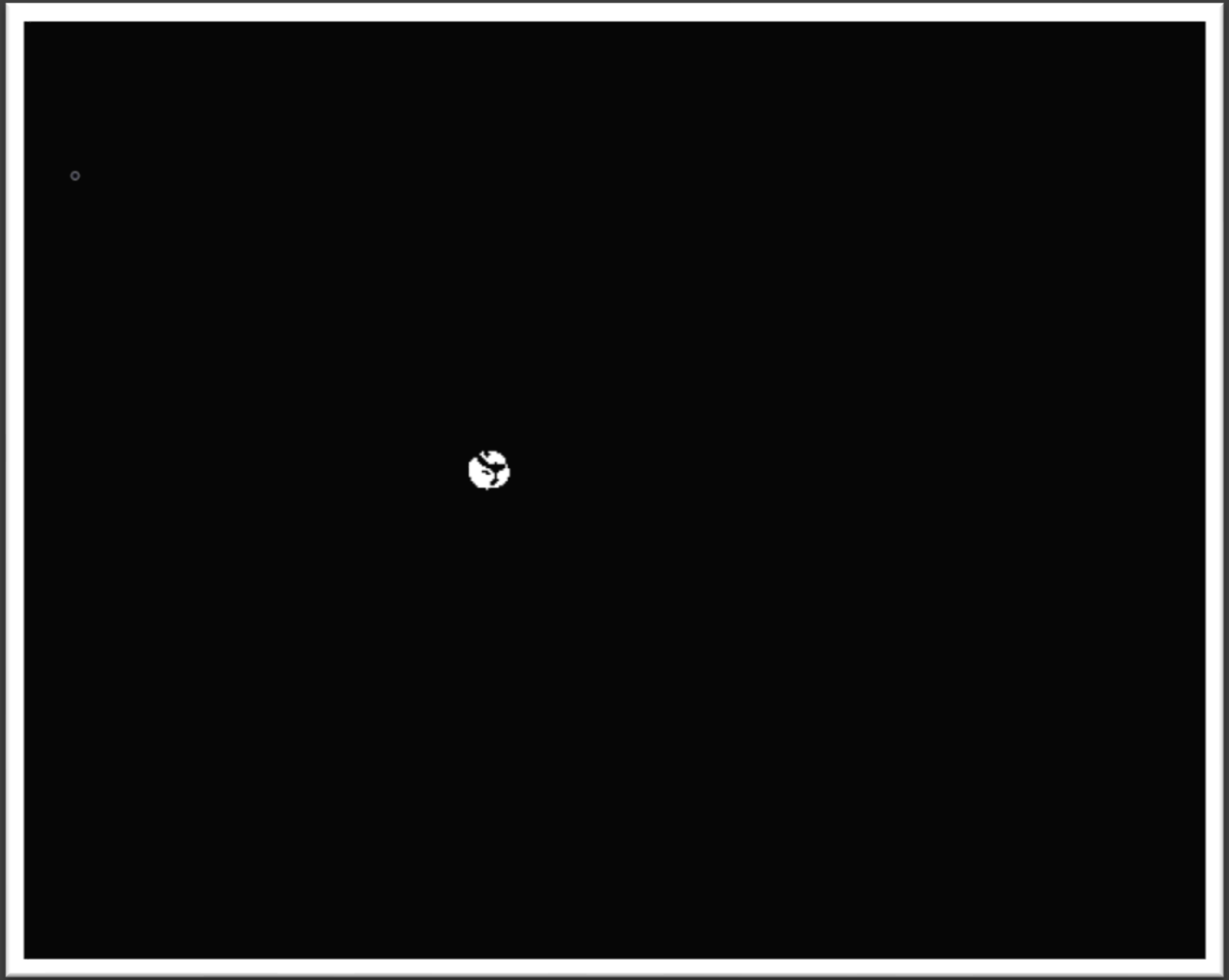
Step 4 – Color Filtering

- Lower and Upper bounds for each color are created using the HSV color scale
- An inRange() function is applied and a mask for each color is created

Colored Square

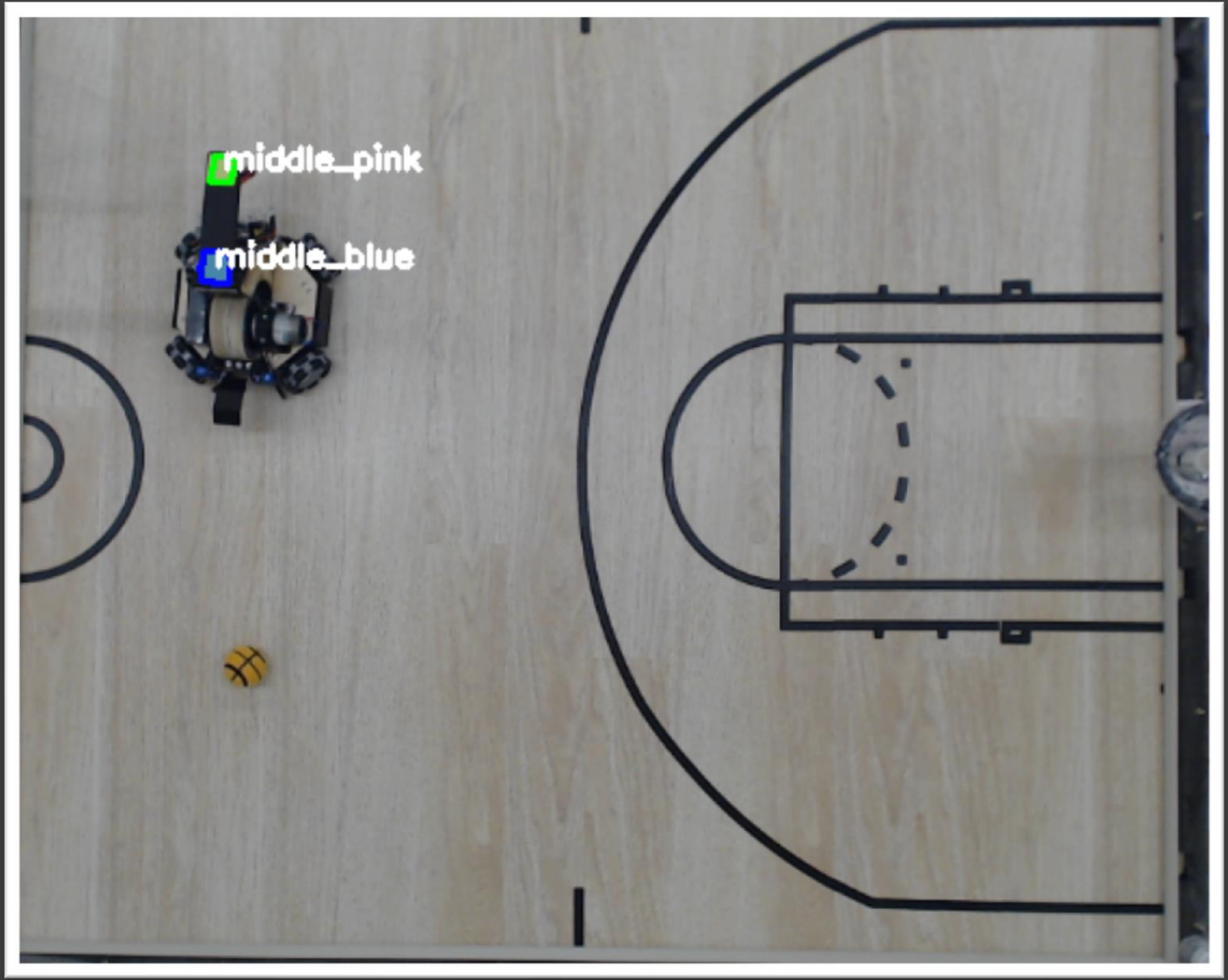


Orange Ball



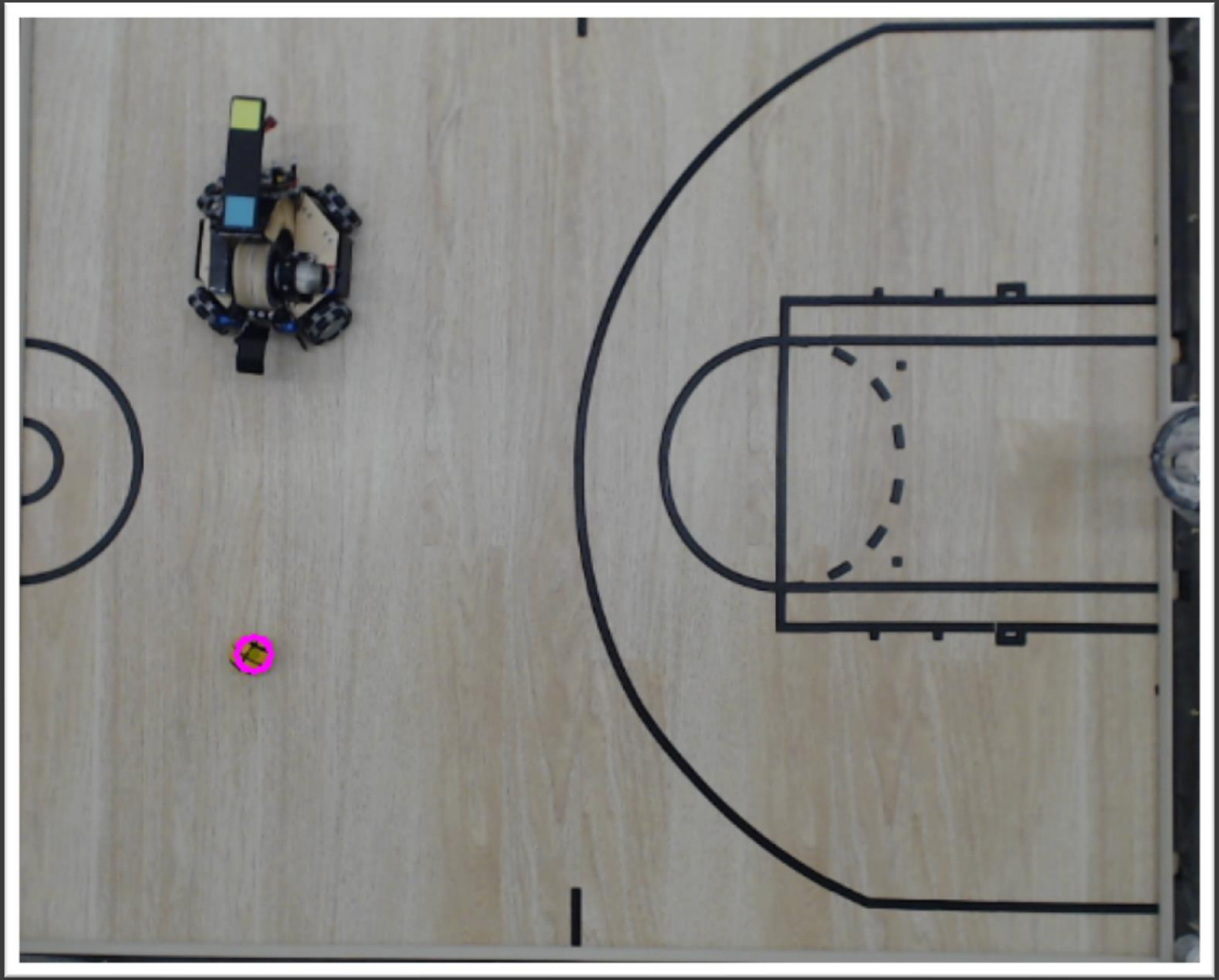
Step 5 – Contour Detection and Midpoint

- Find the contours of the squares
- Filter the list of contours by perimeter and number of sides
- Use moments to find the midpoint of each square



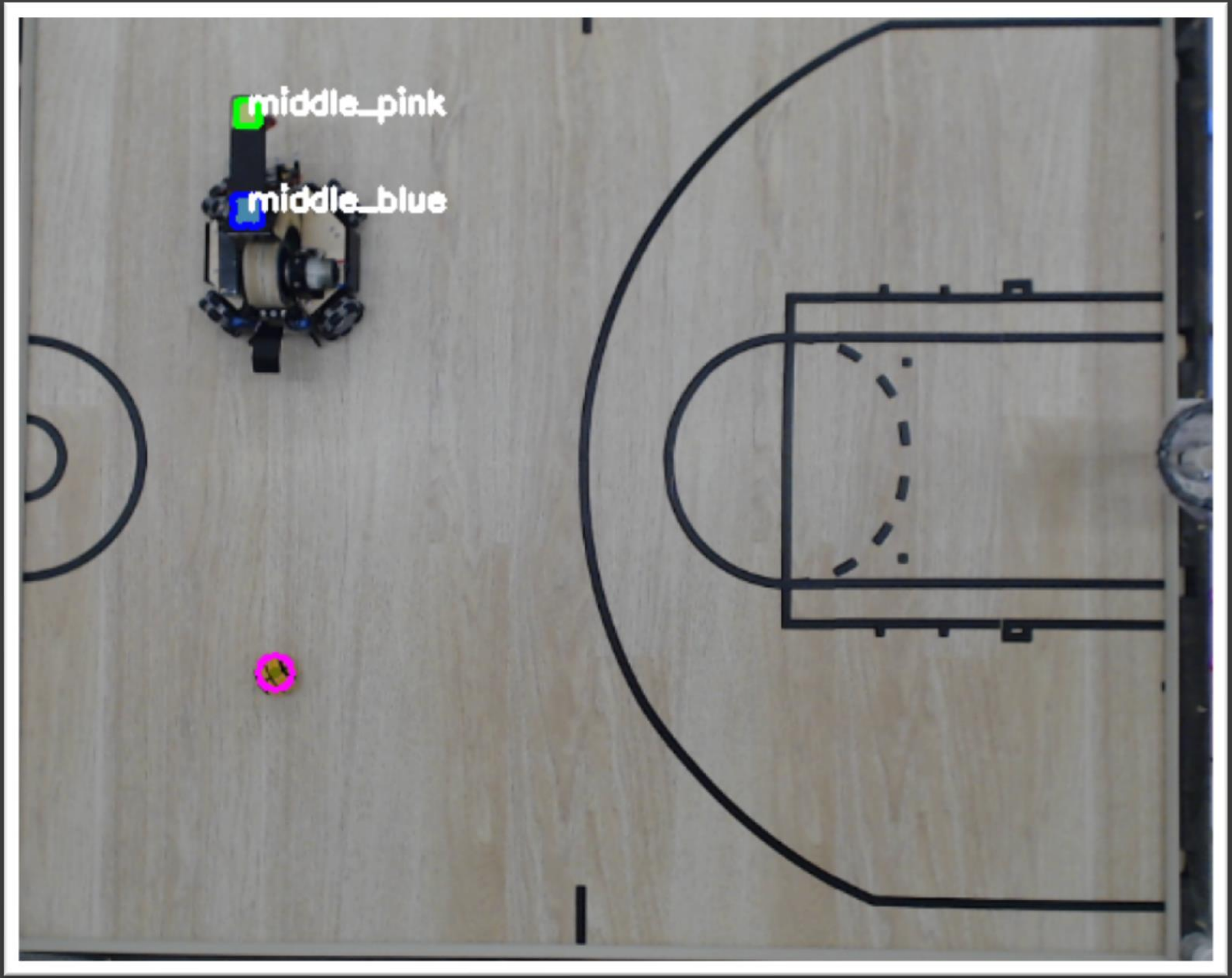
Step 6 – Canny Edge Detection & Hough Transform

- A Canny Edge filter is applied to the orange mask
- A Circle Hough Transform is applied, and the center is found

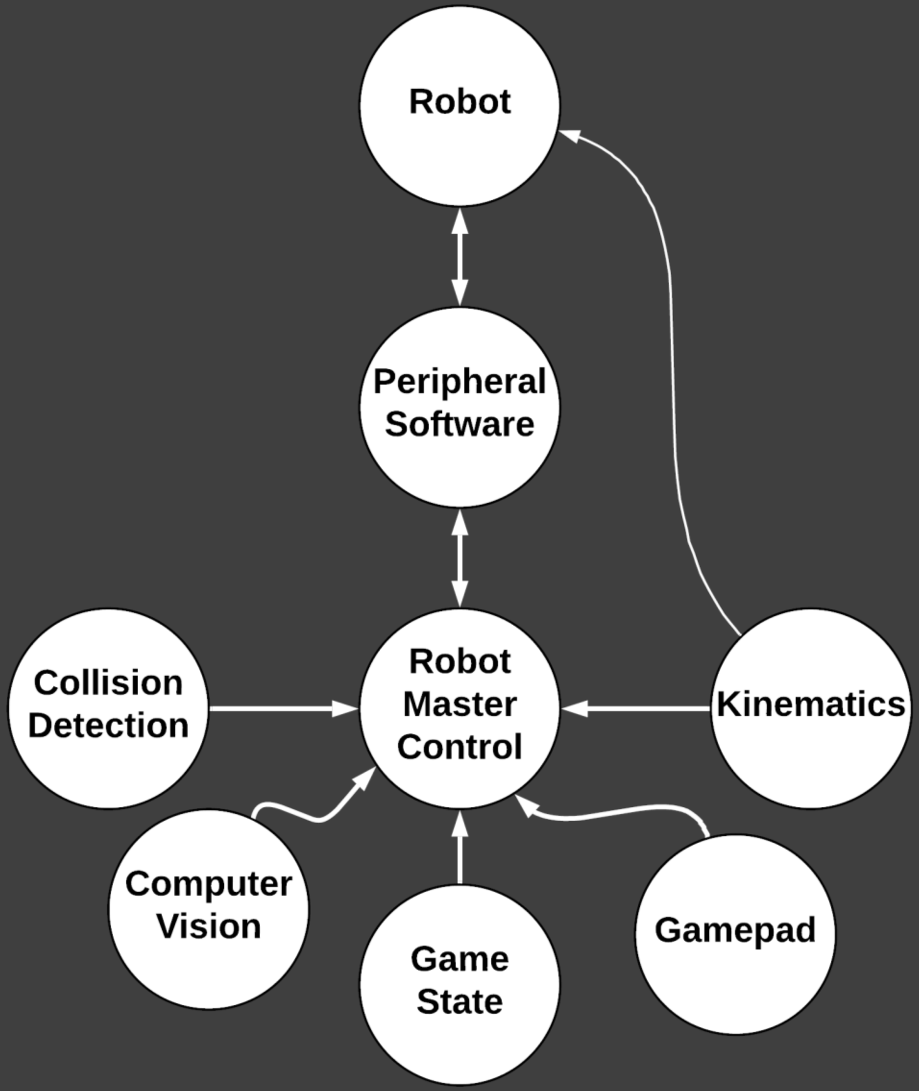


Final Output

- A unit vector is created using the x,y center values of each square
- The center of the robot is blue
- The unit vector, center point of the robot, and center point of the ball is sent to the game

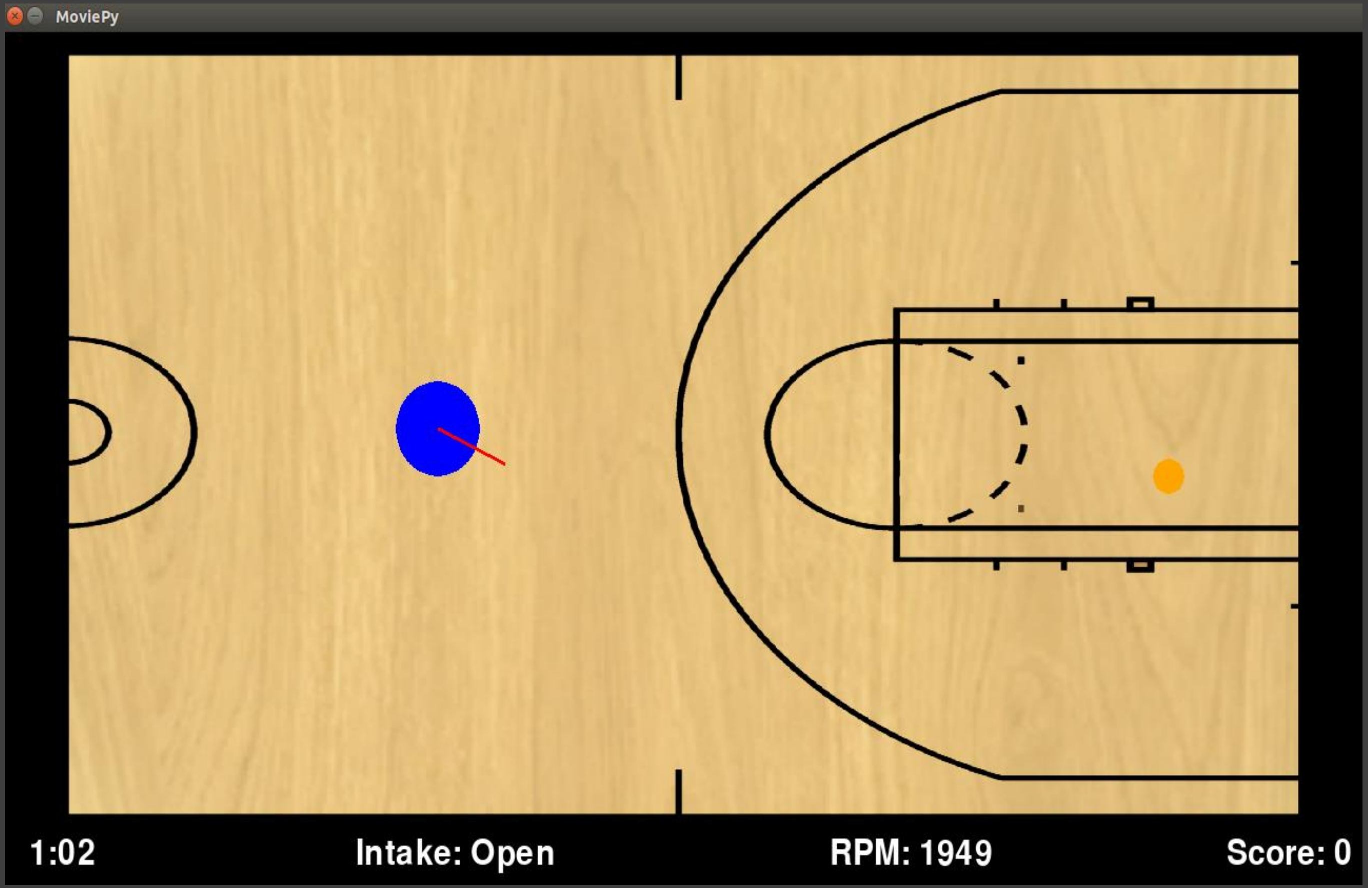


Game Overview



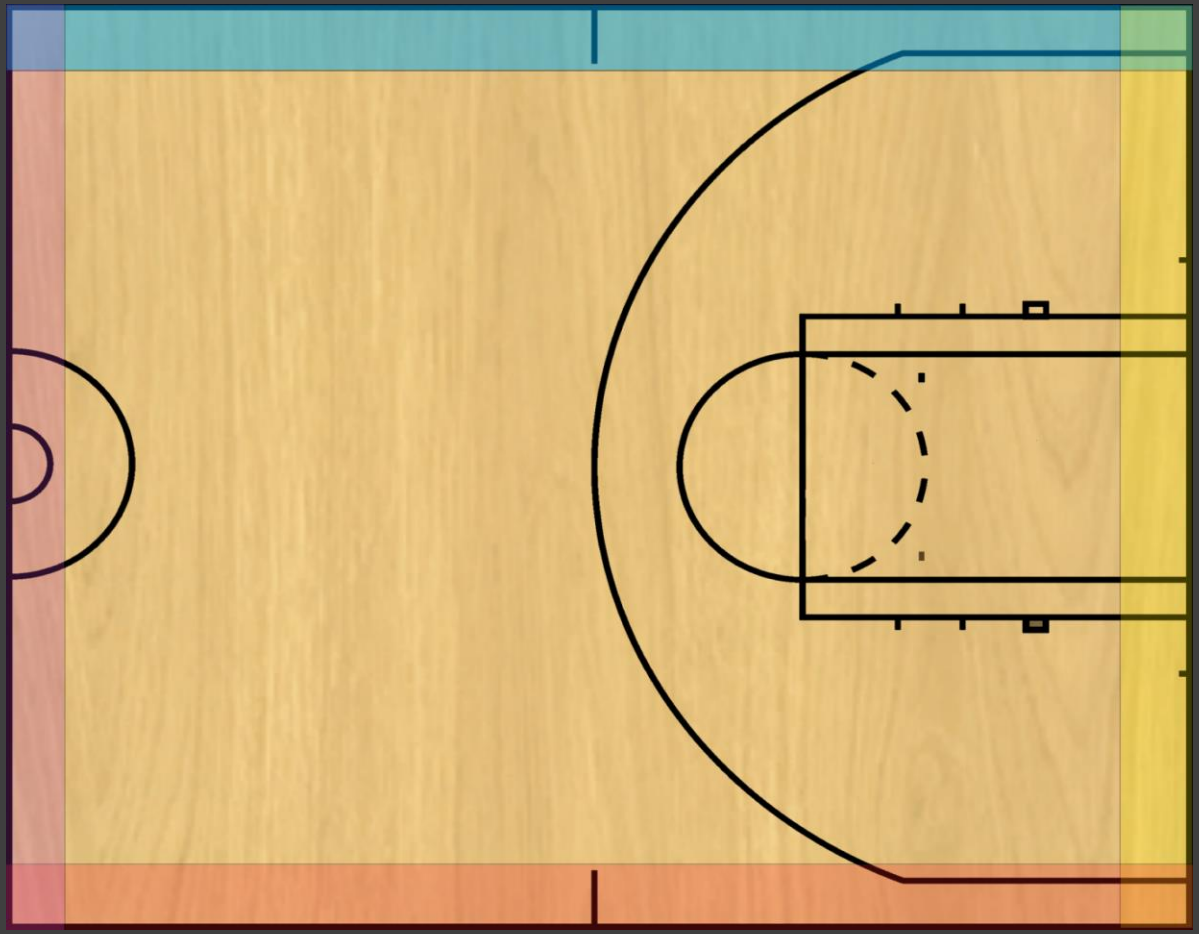
Autonomous Control in Easy Mode

- Alignment
  - Proportional Control minimizes angle to hoop
- Flywheel Speed
  - Linear Function
  - Positional Data from computer vision



Collision Detection

- Prevents robot from being driven off arena
- Transform Robot Space to Task Space
  - Check if components would take robot off arena, if so, remove component from vector
  - Rotate new vector back to Robot frame



Testing

- Design Verification (Subsystem Requirement Validation)
  - Verify Robot Drive, Intake, and Launching capabilities
  - Verify Computer Vision Accuracy
  - Verify Game communication and control
- Production Test (System Requirement Validation)
  - Verify the final PCB meets specifications and performs appropriately
  - Verify Game can fully control the robot and other peripherals
  - Ensure all critical interfaces are functional and the final product functions appropriately
- Focus Group (Market Requirement Validation)
  - Ensure high-level market requirements are met by allowing players to test the final product and implement feedback as necessary

Feedback incorporation

- Collision detection and avoidance added after walls found to be too small to stop robot from driving off the table
- Reduced speed of the robot to maximize controllability
- Added additional light animations to tell player when game is ending