ECE445

SENIOR DESIGN LABORATORY

DESIGN DOCUMENT

Intelligent Basketball Retrieval and Return Robot

Team #36

Linzhi Du [linzhid2]
Zichao Lin [zichaol3]
Libo Zhang [liboz2]
Jinghui Zheng [jz137]

Advisor: Timothy Haw-Yu Lee

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1. Introduction

1.1 Problem Statement

Basketball players often need a training partner to return the ball quickly and accurately during shooting practice. Traditional passing machines usually deliver the ball in a fixed direction, at a fixed speed, or only to a limited area, which makes training less flexible and less realistic. When the player changes position on the court, the machine may not be able to adjust the passing direction and ball speed in time, leading to inaccurate passes, interrupted practice rhythm, and reduced training efficiency.

The problem addressed in this project is how to design an intelligent basketball passing robot that can automatically locate the player and deliver the ball accurately under changing positions. The system must determine the relative position between the player and the machine in real time through a Bluetooth-based positioning method, then adjust the orientation of the launcher and control the initial ball speed so that the ball can be passed to the player with sufficient accuracy and consistency. The key challenge is to integrate sensing, position estimation, mechanical rotation, and launch control into one coordinated system that is reliable, responsive, and suitable for repeated basketball training.

1.2 Solution Overview & Visual Aid

The proposed solution is a basketball passing robot that can automatically detect the player's relative position and deliver the ball accurately for repetitive shooting practice. The system is designed around a Bluetooth-based positioning method, a rotating base, and a controlled ball launching mechanism. A wearable Bluetooth device carried by the player continuously provides location-related signals, while the robot uses these signals to estimate the player's position relative to the machine. Based on this information, the control unit determines the required horizontal orientation of the launcher and the appropriate initial launch speed needed to send the ball to the player.

Mechanically, the robot consists of a turntable structure for directional adjustment, a launching subsystem for ball delivery, a storage or feeding section for holding basketballs, and an electronic control subsystem that coordinates sensing and motion. The rotating base allows the robot to face the player as the player moves to different shooting spots. The launching subsystem then adjusts the wheel speed or equivalent power output so that the basketball can reach the intended receiving position with sufficient accuracy and consistency. In this way, the robot is able to provide passes to different locations without requiring manual repositioning of the machine.

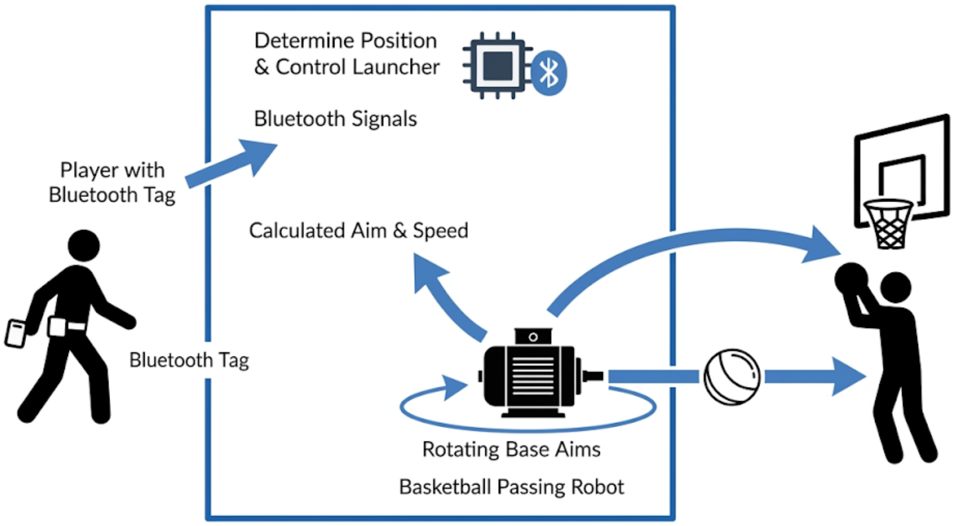

Figure 1: Visual aid of the basketball passing robot system and its operation *during shooting practice.*

Figure 1: Visual Aid of the whole system

In the context of the problem, the final solution is used as an automated training assistant. During practice, the player moves to a selected shooting position on the court while wearing or carrying the Bluetooth tag. The robot receives the signal, calculates the player's relative location, rotates toward the player, and launches the basketball with the required speed. After the player catches and shoots the ball, the process can be repeated as the player changes position. This creates a more continuous and efficient training flow than a fixed-direction passing machine, because the system can adapt to the player's movement in real time and support practice at multiple spots on the court.

1.3 High-Level Requirements List

The basketball passing robot system shall meet the following requirements:

- **Accuracy Requirement:** Detect and track a player carrying a Bluetooth tag within an operating range of 3–7 m in front of the robot. The system shall achieve at least 85% passing accuracy for a stationary player, where a successful pass is defined as the ball arriving within a 0.6 m radius of the intended receiving position. For a slowly moving player with a speed up to 1.5 m/s, the system shall maintain at least 70% passing accuracy while continuously updating the target position.
- **Speed Configuration Requirement:** The launcher shall provide a configurable ball release speed in the range of 4–8 m/s to support controlled basketball passing, including one-bounce passes to players near or beyond the three-point line. The system shall complete one full detect–aim–launch cycle within 3 s under normal operating conditions.

- **Mobility Performance Requirement:** The rotating base shall provide a horizontal aiming range of at least 180°. The robot shall be able to reorient the launcher toward a new target direction within 2 s, enabling responsive passing to players at different court positions.
- **Safety & Durability Requirement:** The system shall prevent ball launch when the player position signal is lost for more than 1 s or when the target location cannot be determined reliably. A protective cover shall be installed around the launching wheels and moving parts, and the emergency stop function shall stop launcher operation within 0.5 s. The prototype shall maintain stable operation for at least 100 consecutive launches without critical mechanical failure, loss of control, or major reduction in passing performance.

2. Design

2.1 Block Diagram

The Basketball Passing Machine consists of four primary subsystems: Power, Control, Sensing, and Actuation. Each subsystem performs specific functions and maintains necessary electrical and data connections with the others to ensure seamless operation. Here is the block diagram of the whole system.

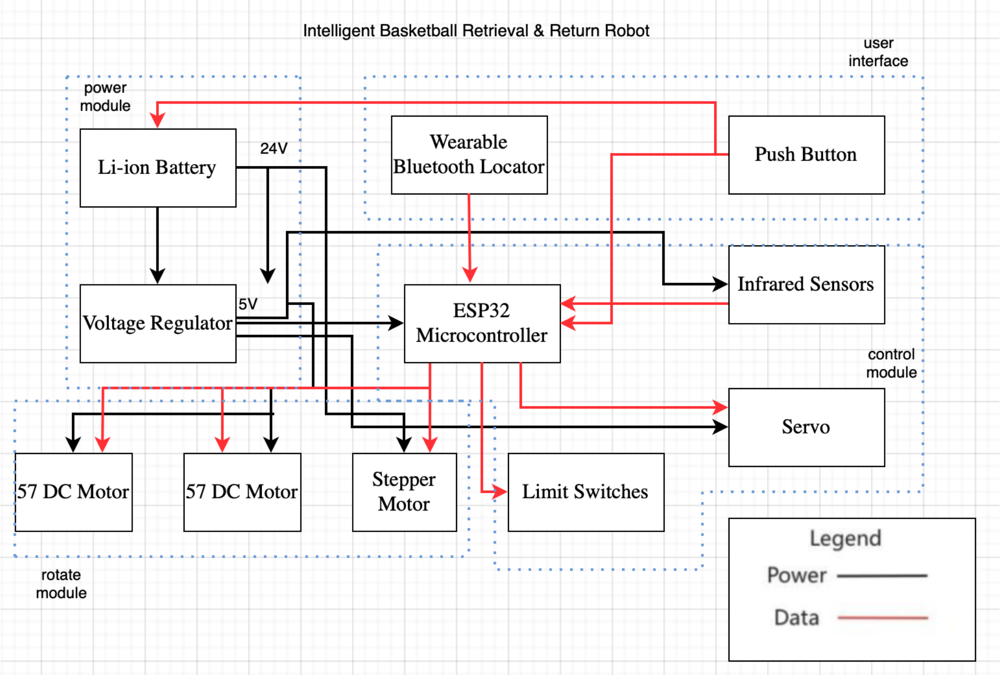

Figure 2: Basketball Passing Machine System Block Diagram

Brief Description of Subsystems:

- **Power Subsystem:** Utilizes a 24V Li-ion battery with a main push-button switch and a 5V voltage regulator to distribute power cleanly between high-power motors and low-power logic circuits.

- **Control Subsystem:** Centered around the ESP32 microcontroller to process positioning data and coordinate motor actions.
- **Sensing Subsystem:** Includes a wearable Bluetooth locator for user tracking, infrared sensors for ball detection, and limit switches for chassis calibration.
- **Actuation Subsystem:** Consists of 57DC motors for the launching mechanism, a 57 stepper motor for horizontal rotation, and a servo motor for the ball feeding mechanism.

2.2 Aim System

The Aim System autonomously aligns the robot with the player and determines the optimal launch velocity in real time. As illustrated in Figure 3, the ESP32 processes advertising packets (UUID, RSSI, AoA) from the wearable Bluetooth beacon. The calculated angular error is fed into a PID control loop to drive the 30W DC gear motor for yaw-axis rotation. Concurrently, the estimated distance is mapped to a speed command for the dual brushless motors. The ball is launched only after final alignment is verified.

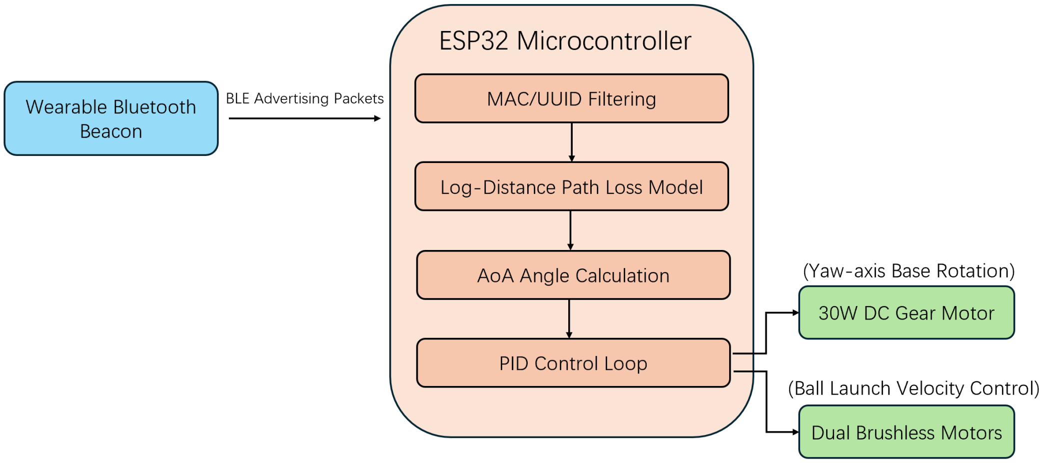

Figure 3: aim system overview

2.2.1 Hardware Support

Location Sensor: Integrated Bluetooth 5.0 (BLE) module on ESP32, supporting RSSI and AoA tracking.

Processing Unit: ESP32 Dual-Core Microcontroller (240MHz) executing PID and localization algorithms.

Communication Interface: UART Serial interface for debugging and internal module communication.

Actuator: 30W DC Gear Motor (1:90 reduction ratio, metal gearbox) for base azimuth rotation.

Requirements	Verification
1. The Bluetooth localization system shall maintain a reliable tracking range of ≥ 7m (standard 3-point line) with an angular error of ≤ ±5°. 2. The ESP32 processing unit shall execute the PID control loop and target tracking algorithm at a refresh rate of ≥ 20Hz. 3. The rotation system shall initiate motor movement within 40ms after the MCU receives a valid coordinate update from the Bluetooth beacon.	1. Position the beacon at 7m distance at various angles; record 100 data points and calculate the mean absolute error to ensure it is within ±5°. 2. Use internal hardware timers to benchmark the software execution loop; verify that the total processing cycle time is ≤ 50ms. 3. Use a logic analyzer to measure the latency between the UART signal arrival and the first PWM pulse sent to the motor driver; ensure ≤ 40ms.

2.2.2 Human Detection

Unlike vision-based systems that rely on cameras and image processing, our system detects the player's presence using Bluetooth Low Energy (BLE) scanning. The ESP32 microcontroller continuously scans for advertising packets from the specific wearable Bluetooth locator. The target is identified by filtering for a predefined MAC address or UUID. The received signal strength indicator (RSSI) is also monitored to ensure the player is within the effective passing range (3-7 meters). By removing the need for a camera, this method avoids line-of-sight occlusion issues and reduces computational overhead.

Requirements	Verification
1. The ESP32 shall successfully identify and filter the predefined Bluetooth UUID among multiple BLE signals. 2. The system shall detect the beacon within the 3-7m operating range with a ≥ 95% detection rate.	1. Introduce 3 different Bluetooth beacons in the room; verify the serial monitor only outputs data for the targeted UUID. 2. Place the paired beacon at distances of 3m, 5m, and 7m; record 100 ping attempts at each location and verify at least 95 packets are received successfully.

2.2.3 Target Locking Logic

Unlike visual tracking that may accidentally switch to other people in the frame, our Bluetooth-based locking logic relies on unique device pairing. The robot initially locks onto the player's specific Bluetooth locator UUID. The lock is maintained as long as valid data packets are received. To ensure safety, if the signal is completely lost or the location cannot be determined reliably for more than 1 second, the system will disengage the lock and trigger a halt state until the signal is reacquired.

Requirements	Verification
1. The system shall exclusively lock onto the paired target and ignore other moving individuals. 2. The system shall safely disengage the lock and prevent ball launch if the beacon signal is lost for > 1s.	1. Have a secondary person walk between the robot and the player; verify the robot continues tracking the player's beacon without switching targets. 2. Turn off the wearable Bluetooth locator while the robot is tracking; use a hardware timer to verify the system enters the halt state within 1 second.

2.2.4 Distance Estimation

Distance estimation is performed using the Received Signal Strength Indicator (RSSI) of the Bluetooth packets. Since radio signal strength decays logarithmically with distance, the system estimates the range using the standard log-distance path loss model:

$$RSSI = -10n \log_{10}(d) + A \tag{1}$$

where A is the reference RSSI measured at a 1-meter distance, n is the path loss exponent (typically 2.0 to 3.0 in indoor environments), and d is the estimated distance. This calculated distance is then used by the control system to configure the ball release speed ($4 - 8$ m/s).

Requirements	Verification
1. The system shall calculate the player's distance within a ±0.5m accuracy in the 3-7m operating range. 2. The RSSI readings shall be filtered to prevent abrupt distance fluctuations caused by multi-path fading.	1. Place the locator at 3m, 5m, and 7m. Compare the ESP32 estimated distance output with a laser rangefinder; ensure the error is ≤ 0.5m. 2. Apply a moving average filter to the raw RSSI data and plot the output; verify that the standard deviation of stationary readings is significantly reduced.

2.2.5 Dynamic Tracking

Once the target is locked, the system uses Bluetooth Angle of Arrival (AoA) technology to determine the player's horizontal bearing. The ESP32 calculates the angular offset between the robot's current facing direction and the beacon. This offset is fed into a PID control algorithm, which outputs a PWM signal to the 57 DC gear motor to rotate the base. When the angular offset falls within an acceptable tolerance ($\leq \pm 5^\circ$), the robot is aligned, and the launch sequence can be triggered.

Requirements	**Verification**
1. The robot shall reorient its base toward a new target direction within 2 seconds for a 180° range. 2. The tracking system shall maintain alignment with a player moving at speeds up to 1.5 m/s.	1. Command the robot to rotate 180°; use a stopwatch and motor encoder data to verify completion within 2.0s without excessive overshoot. 2. Have the player walk laterally at 1.5 m/s at a 5m distance; measure the average angular tracking error to ensure it stays within passing tolerance.

2.3 Rotate System

The Rotate System is responsible for controlling the horizontal direction of the ball launching machine so that the launcher can aim at different target positions. In our design, the rotating function is implemented by a motor-driven base. The upper launching body is mounted concentrically on the rotating base, so that the center of the launcher remains aligned with the center of the base during operation. This structure improves rotational stability, reduces eccentric loading, and makes control more accurate.

The main function of this subsystem is to provide smooth and controllable left-right rotation for the launcher body. The system must be able to rotate to a commanded angle, stop at the desired position, and maintain that position during launching. Since the launcher body has a certain weight and may generate vibration during operation, the rotating subsystem must also provide sufficient torque and structural support.

The rotating subsystem consists of a DC geared motor, a transmission mechanism, a rotating plate, a central shaft, bearings, and a supporting base frame. The motor provides the driving torque, and the transmission mechanism transfers the torque to the rotating platform. A reduction mechanism is used to increase output torque and improve position control. The central shaft and bearing structure are used to ensure that the upper body rotates around the center axis of the base. This arrangement helps the launcher maintain balance and prevents excessive wobble during movement.

To improve reliability, the Rotate System is designed with the following considerations. First, the motor should provide enough torque to overcome the inertia of the launcher body and the friction in the rotating mechanism. Second, the rotating range should satisfy the aiming requirement of the machine. Third, the structure should be strong enough to support repeated motion without loosening or deformation. Finally, the rotational speed should not be too high, because excessive speed may reduce aiming accuracy and create safety risks.

Subsystem Requirements The Rotate System shall provide at least 120° total horizontal rotation range. The Rotate System shall complete a 60° rotation within 2 seconds under normal loading conditions. The rotating base shall support the full launcher body without visible structural instability or loosening during 100 consecutive rotation tests. The rotating subsystem shall maintain concentric alignment between the launcher body and base center, with an offset of no more than 5 mm.

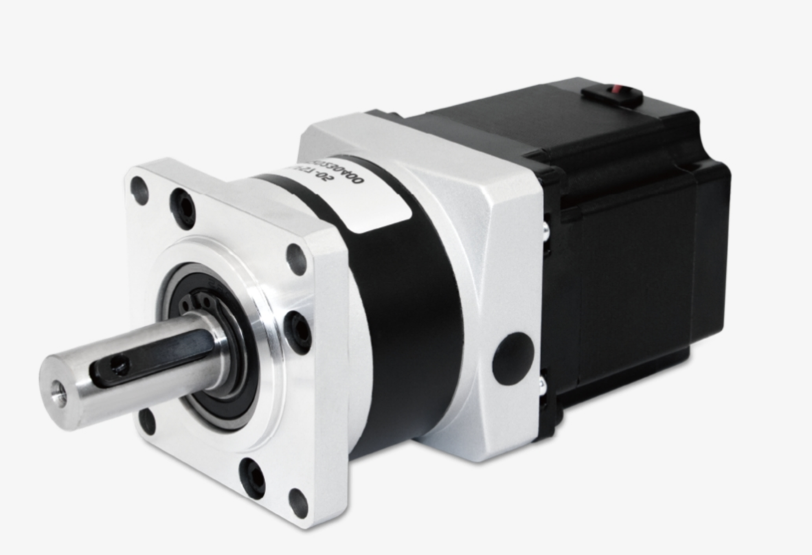

Figure 4: The motor[1]

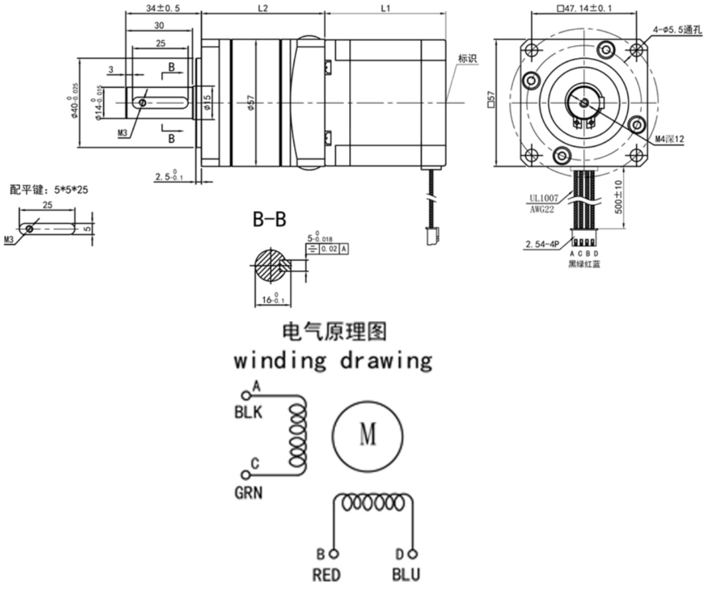

Figure 5: The size of the motor[1]

- **Requirement 1:** The selected motor for the rotating base must provide sufficient torque to drive the entire launcher body during horizontal rotation. Since the upper structure includes the launching body, supporting frame, and connecting parts, the motor must overcome both the inertia of the rotating mass and the friction in the transmission mechanism. In addition, the motor should maintain stable output under repeated operation without losing steps or showing obvious vibration. A motor with insufficient torque may lead to unstable rotation, delayed response, or failure to reach the commanded position. Therefore, the rotate subsystem requires a motor with enough torque margin to ensure reliable motion of the launcher under the expected mechanical load.

- **Requirement 2:** The selected motor must also provide a sufficient rotation range and allow precise position control. The rotating base should be able to cover the required horizontal aiming angle so that the launcher can adjust its direction over the intended target area. At the same time, the motor must stop accurately at the commanded angle and maintain that position during operation. This is important because inaccurate turning would directly reduce aiming performance. For this reason, the motor and control method must support precise angular control, small positioning error, and repeatable motion, so that the launcher can rotate smoothly and consistently to the desired direction.

2.4 Power System

The power system of the basketball passing robot is designed to provide stable, controllable, and repeatable energy delivery for both ball launching and directional adjustment. In this design, the launching subsystem uses two brushless DC motors to drive a pair of friction wheels, so that sufficient wheel surface velocity can be generated for controlled basketball passing. The rotating base is driven by a separate geared motor with high torque output to ensure that the robot can reorient toward the player in a short response time.

The launch mechanism is currently intended to support one-ball-at-a-time manual loading in the early prototype stage, which simplifies the mechanical structure and improves reliability during initial testing. In later design iterations, an automatic feeding mechanism may be added to increase the passing rate and reduce manual intervention. The launch motors are selected based on their ability to maintain adequate wheel speed under load, while the rotating-base motor is selected based on its low-speed torque and positioning stability. This separation of launch power and aiming power reduces subsystem interference and makes the overall system easier to control and debug.

The power subsystem must also satisfy structural and operational requirements. The friction wheels must maintain a stable center distance to ensure repeatable ball compression during launch, and the mounting structure must be rigid enough to limit vibration under repeated operation. In addition, the electrical and mechanical design must support safe operation during repeated launch cycles, since unstable motor speed, large structural vibration, or insufficient motor recovery can directly reduce passing accuracy.

Figure 6: Image of the Flipsky H5055 200KV motor [2]

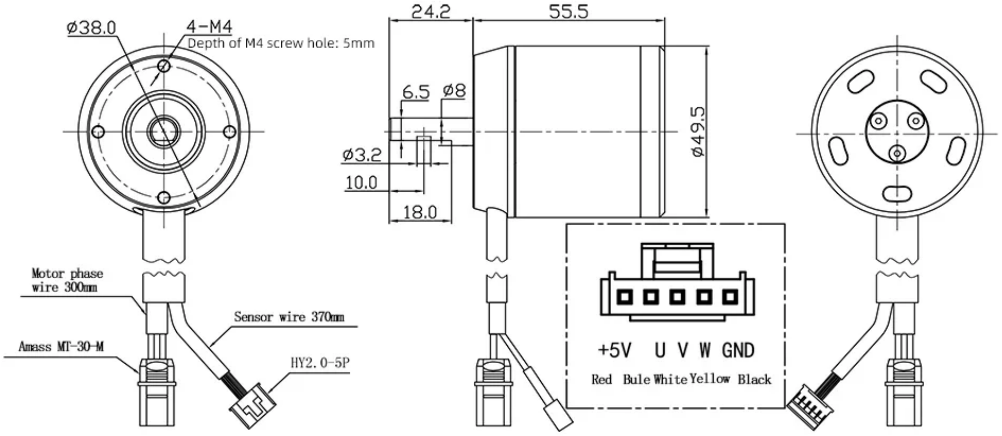

Figure 7: Outline drawing of the Flipsky H5055 200KV motor [2]

The theoretical no-load motor speed can be estimated by

$$n = KV \times V$$

Table 1: Simple datasheet and performance summary of the Flipsky H5055 200KV motor, adapted from [2]

Parameter	**Value**
Brand	Flipsky
Motor Model	H5055
Motor Size	49.5 × 55 mm
Motor Weight	1.05 lb / 0.475 kg
Maximum Power	1380 W
Maximum Current	39 A
Maximum Voltage	12S
Shaft Diameter	8 mm
Maximum Torque	1.1 N·m
KV Rating	200 KV
Hall Angle	120°
Number of Pole Pairs	7
Sensor Wire	Standard RC sensor wire, HY2.0-5P connector
Motor Wire	300 mm silicone 16 AWG wire with MT30 male connector
Wire Configuration	Blue = U, White = V, Yellow = W

where n is the theoretical no-load rotational speed in rpm, KV is the motor speed constant in rpm/V, and V is the supply voltage in V.

For the selected Flipsky H5055 200KV motor,

$$n = 200 \times V$$

For example, when the supply voltage is 24 V,

$$n = 200 \times 24 = 4800 \text{ rpm}$$

It should be noted that this value is the theoretical no-load speed. Under actual operating conditions, the real motor speed will be lower because of load, friction, controller losses, and ball compression during launching.

- **Requirement 1:** Stable friction-wheel geometry. In order to ensure consistent launch performance, the two friction wheels shall maintain a fixed and repeatable center distance during operation. The launcher shall support a ball release speed in the range of 4–8 m/s, and the speed fluctuation of each wheel shall remain within ±5% of the commanded value during steady operation. This requirement is necessary because variation in wheel spacing or wheel speed directly affects ball compression, launch direction, and passing consistency.
- **Requirement 2:** Reliable shock absorption and vibration isolation. The mounting structure of the launch subsystem shall be sufficiently rigid to prevent significant vibration, misalignment,

or momentum loss during ball acceleration. During repeated launch tests, the temporary wheel-speed drop at ball contact shall not exceed 15% of the pre-launch speed, and the wheel speed shall recover to at least 95% of the commanded value within 2 s. This requirement helps ensure that the robot can perform consecutive passes without large variation in launch distance or direction.

2.5 Control System

The control system serves as the central intelligence of the basketball passing machine, responsible for coordinating the overall operating sequence. The microcontroller acts as the central processing hub, interpreting localization data from the sensing subsystem and translating it into precise mechanical actions. Sensor interfaces handle digital inputs from infrared and limit sensors to monitor system states, while motor-control links deliver the necessary PWM and pulse signals to the actuators. To ensure operational reliability, a safety feedback loop is integrated to monitor actuator status and provide emergency stop capabilities in the event of mechanical obstruction or electrical anomalies.

Figure 8: ESP32

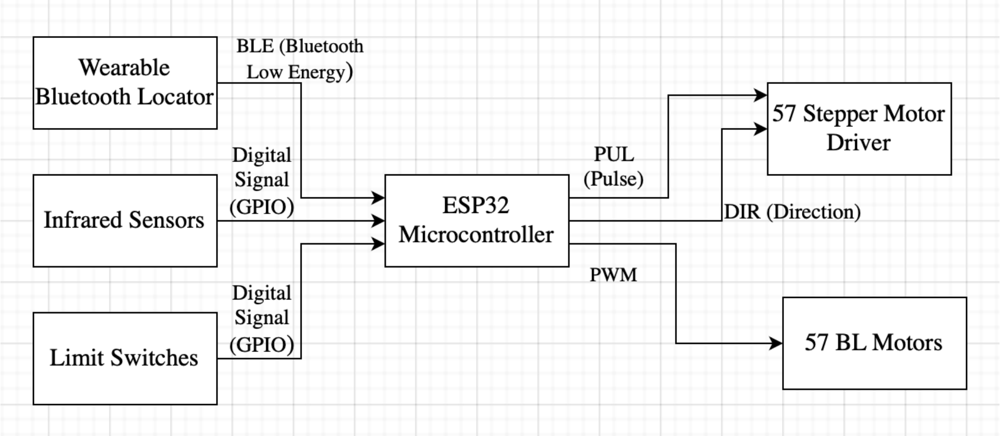

Figure 9: Basketball Passing Machine System control Block Diagram

2.5.1 Microcontroller

The system utilizes an ESP32 development board as its main control unit. This microcontroller was selected due to its integrated dual-mode Bluetooth (BLE) and Wi-Fi capabilities, which eliminate the need for external communication modules and simplify the wearable locator interface. Additionally, its high processing speed and abundant GPIO pins are essential for managing multiple motor drivers and sensors simultaneously. The ESP32 is responsible for parsing real-time positioning data, calculating target angles for the turntable and rotational speeds for the launching wheels, and managing the master state machine that controls the ball-feeding and firing sequence.

Requirements	**Verification**
The ESP32 shall process positioning packets and update motor control signals within a total latency of 50 ms.	Use a logic analyzer to measure the time interval between the arrival of a Bluetooth data packet and the state change of the PWM/Pulse output pins.

2.5.2 Motor Control Interfaces

This project utilizes a streamlined direct-drive architecture to minimize latency. The ESP32 microcontroller interfaces directly with the motor drivers through dedicated GPIO pins. For the horizontal aiming system, the stepper motor driver receives a precisely timed pulse train (frequency-based PWM) and a high/low direction signal to achieve discrete, accurate angular steps. For the ball launching mechanism, brushless DC (BLDC) motors are driven by RC Airplane Electronic Speed Controllers (ESCs). These ESCs interpret a standard 50 Hz PWM signal with a 1.0 ms to 2.0 ms pulse width to regulate throttle.

Because the RC ESCs operate in an open-loop configuration to maximize instant burst torque during the launch impact, they do not provide real-time RPM feedback. To compensate for this and ensure overall system accuracy, the aiming system employs a pseudo-closed-loop strategy by periodically homing the stepper motor against the mechanical limit switches, thereby eliminating accumulated step-loss errors over continuous operation.

Requirements	**Verification**
The stepper motor driver shall receive stable pulse signals to achieve horizontal rotation with a precision of ± 1 degree	Execute 100 random rotation sequences and verify the final chassis orientation using a physical reference or the limit switch.

2.5.3 Sensing and Wireless Communication

Wireless communication is established via the ESP32's built-in Bluetooth module, which receives real-time coordinate data from the player's wearable locator. For physical state sensing, infrared photoelectric sensors are installed in the feeding channel to detect ball presence and trigger the launch logic. Furthermore, micro-limit switches are positioned at the mechanical boundaries of the rotating chassis to provide a homing reference and prevent cable entanglement caused by over-rotation.

Requirements	Verification
The wireless link shall maintain a reliable connection and data throughput at distances up to 10 meters in a typical gym environment.	Perform distance-based connectivity tests and monitor the packet loss rate at the maximum training range.

2.6 Schematics

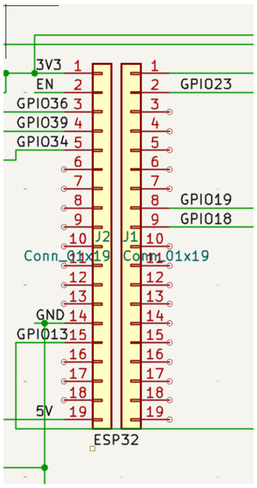

Figure 10: ESP32 connection Schematics

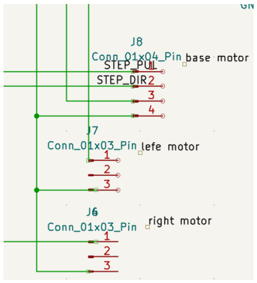

Figure 11: motor driver connection Schematics

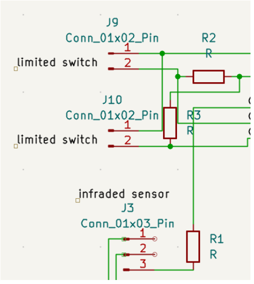

Figure 12: sensor connection Schematics

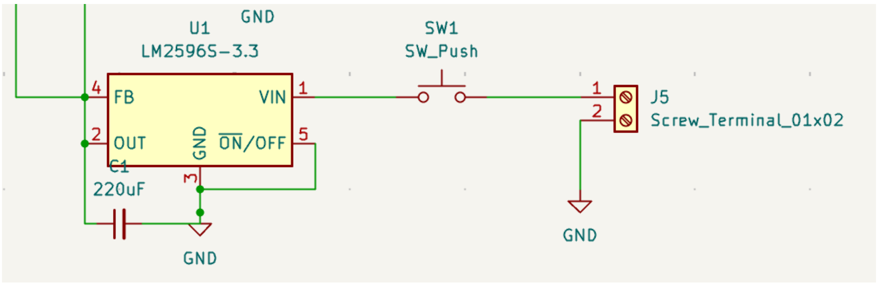

Figure 13: Power supply schematic

2.7 Tolerance Analysis

This section evaluates the system-level tolerances, identifying potential risks and quantifying how sensing errors affect the basketball's landing position.

(1) Design-Level Risks

- **Sensor data accuracy:** Bluetooth RSSI fluctuations due to indoor multi-path fading can cause distance estimation errors (±0.5m). Angle of Arrival (AoA) resolution may have an error of ±5°.
- **Algorithm robustness:** The filtering algorithm must quickly reject sudden signal spikes without introducing excessive latency.
- **Target stability handling:** Since the robot waits for the player to stop before passing, the system must reliably verify that the player's velocity has reached zero. A false "stop" detection could result in launching the ball while the player is still moving out of the target zone.
- **Mechanical precision:** The brushless motors' RPM control via ESC (Electronic Speed Controller) must be precise enough to output the exact theoretical launch velocity.

(2) Target State Verification Our system design utilizes a "track-and-wait" paradigm to ensure high passing accuracy. The robot continuously tracks the player but delays the launch sequence until the player comes to a complete stop to receive the ball. Therefore, the target position $\mathbf{p}_{target}$ is simply the player's stabilized coordinate $\mathbf{p}_0$. By eliminating the need to calculate a future interception point, the system avoids complex predictive kinematics, shifting the tolerance requirement entirely to the accuracy of the static Bluetooth localization.

(3) Launch Parameter Calculation To ensure the ball reaches the stationary target at the player's chest height ($H = 1.3$m) from the robot's launch height ($h = 0.5$m) with a fixed launch angle ($\theta = 40°$), the required initial velocity v_0 is governed by:

$$v_0 = \sqrt{\frac{gD^2}{2\cos^2(\theta)(D\tan(\theta) - (H - h))}} \tag{2}$$

where $g = 9.81$ m/s^2 and D is the scalar distance to the stationary target $\mathbf{p}_{target}$. At a standard 5m pass, the nominal velocity is calculated to be $v_0 \approx 7.84$ m/s.

(4) Simulation and Validation Based on our kinematic equations, we analyzed the impact of our maximum allowed sensor tolerances on a static target:

- **Distance Tolerance:** A maximum distance error of $\Delta D = \pm 0.5$m at a 5m range shifts the required v_0 by approximately ±0.30 m/s. Our closed-loop PID control on the dual brushless motors can maintain velocity within a 0.1 m/s margin, easily compensating for this.
- **Angular Tolerance:** An AoA error of $\Delta\theta = \pm 5^\circ$ at the maximum operational range of 7m causes a lateral displacement ΔX:

$$\Delta X = D \cdot \tan(\Delta\theta) = 7 \cdot \tan(5^\circ) \approx 0.61 \text{ m} \tag{3}$$

(5) Conclusion An average adult player has an arm span of 1.5m to 2.0m. The theoretical maximum lateral deviation of 0.61m and longitudinal velocity variance of 0.3 m/s ensure that the ball remains well within the stationary player's catchable zone. Therefore, the integrated Bluetooth sensing and motor control tolerances are highly feasible for a successful automated passing system.

3. Cost

The sample uses a simple two-column cost table.

Part	**Cost**
motors for power	786
wheels	40
shell	300
motors for rotate	257
electronic speed controller	77
development board	31
bluetooth receiver	800
Total cost	2291

4. Schedule

The sample uses a week-by-week schedule table. If your table is long, you can keep it on one page with a smaller font or use `longtable`.

Week	**Linzhi Du**	**Libo Zhang**	**Jinghui Zheng**	**Zichao Lin**

4/7	Determine the required electrical components and begin circuit design for the launcher system	Develop the initial CAD model of the rotating base and determine the mechanical structure	Develop the initial CAD model of the launching body and determine the main structural components	Study the control logic for horizontal rotation and prepare the basic code framework
4/14	Complete the preliminary circuit design and confirm the connection between major electrical components	Refine the base structure and confirm the motor mounting and rotation mechanism	Refine the launching body design and confirm the connection between the body and the base	Begin writing the code for controlling the turning motion of the launcher
4/21	Start prototype-level circuit implementation and prepare for subsystem testing	Complete the detailed base design and begin fabrication or assembly preparation	Complete the detailed launching body design and begin fabrication or assembly preparation	Test the basic turning control code and improve the response of the rotation system
4/28	Finish the main circuit work needed for mock demo and verify basic electrical functionality	Assemble the rotating base and verify that the structure can rotate stably	Assemble the launcher body and verify that the main structure is functional	Integrate the turning control code with the motor and prepare for mock demo
5/4	Demonstrate the basic electrical subsystem in the mock demo	Demonstrate the rotating base structure and motion in the mock demo	Demonstrate the launching body structure in the mock demo	Demonstrate basic turning control in the mock demo
5/11	Improve the circuit based on mock demo results and support full-system integration	Improve the stability and reliability of the base based on mock demo results	Improve the launcher body design and structural performance based on mock demo results	Improve code accuracy and stability based on mock demo results
5/18	Complete final circuit integration and support the final demo	Complete the final version of the base and verify stable operation in the final demo	Complete the final version of the launching body and verify its performance in the final demo	Complete the final turning control code and verify its performance in the final demo

5. Ethics and Safety

5.1 Ethics

The ball launching machine is designed as a training device, so ethical issues should be considered throughout the design process. The main ethical concern of this project is the responsible use of engineering design. The machine should be developed only for legitimate training and educational purposes, rather than for harmful or improper use. Therefore, the system should be designed with clear functional limits and should not encourage unsafe behavior or misuse.

Another important ethical issue is honesty in engineering performance. The design team must report the actual capabilities and limitations of the machine truthfully, including launch speed, aiming range, rotation range, and accuracy. Performance results should be based on real testing and analysis rather than exaggerated claims. This is important because users, instructors, and reviewers need accurate information in order to evaluate whether the system is reliable and appropriate for its intended use.

Fairness and consistency should also be considered. Since the machine is intended for repeated ball launching during practice, it should perform in a predictable and stable way. Unstable performance would reduce the value of the training process and could mislead users about the real behavior of the system. For this reason, the launcher should be designed and tested so that its motion and output remain consistent under normal operating conditions.

5.2 Safety

Safety is a critical consideration in the ball launching machine because the system includes powered motors, rotating mechanical parts, and a launching mechanism. The main safety risks include accidental launch, contact with moving parts, electrical hazards, and instability of the machine during operation.

To reduce the risk of accidental launch, the system should include a clear start/stop control and an emergency stop function. The launching sequence should only begin after intentional operator input. During testing and operation, the launcher must always face a safe direction, and no person should stand directly in front of the machine.

To reduce mechanical hazards, rotating and moving parts should be shielded as much as possible. Components such as transmission parts, motor couplings, and launching wheels should not be exposed in normal operation. In addition, the rotating base must be securely mounted so that the machine does not tip, slide, or shift during repeated launching and rotation.

To reduce electrical risk, all wiring should be insulated and properly arranged. The selected power supply and motor driver must operate within rated voltage and current limits. Electrical connections should be checked regularly to prevent overheating, short circuits, or loose terminals.

References

[1] "57 mm Precision Gear Reduction Motor." UMOT Motor, https://www.umotmotor.cn/66618244/47.html . Accessed 2 Apr. 2026. .

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