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Ball Launching Robot and Object Retriever with V- Belt Method and Robotic Arm Method

Sarifudin[1], Syaiful Rachman[2], Khairunnisa[3], Muhammad Wahyu[4], Ivan Maududy[5], Zuraidah[6], Nurkamilia[7], Rif'at[8]
[1,2,3,4,5,6,7,8] Electronic Engineering Study Program, Banjarmasin State Polytechnic

ABSTRACT: This research develops a ball launcher and object picker robot controlled remotely /wirelessly using a microcontroller. The robot is designed to enhance mechanical work efficiency and control in the Indonesian robot contest, with the ability to automatically throw balls and collect objects in a designated area. The robot's drive system utilizes DC motors for mobility, with ball launching and pneumatic systems used for the object collection mechanism. This study emphasizes designing a more efficient system that offers good responsiveness, aiming to provide optimal robot control. The test results showed that the robot could perform ball launching with adequate accuracy and collect objects with suitable speed and precision. With the application of this technology, the robot is expected to be useful in various fields, including industry, sports games, education, agriculture, and other entertainment activities. This robot research opens opportunities for further development in more advanced and practical remote control robotic systems.

KEYWORDS: Robot, ball, DC motors, ball launcher, robotic arm

I. INTRODUCTION

The rapid innovation in technology, especially in the field of mechatronics, is advancing significantly. Mechanical work and control are integrated into a controlled machine operation. Robotics technology is part of this innovation, with its development encompassing various fields, not only in industry but also extending to education, sports, and entertainment. A ball-launching robot can be used for research on human-robot interaction, sports training, and as an entertainment medium.

This ball-launching robot has the potential to be further developed into a robot with different functions and applications. For example, it could be designed as an agricultural robot, such as a coconut harvesting robot.

The control system based on a microcontroller forms the foundation for automation system development. With flexible programming, the microcontroller controls various robot components, such as sensors, actuators, and the drive system. In the construction of this ball-launching robot, the microcontroller functions as the brain of the robot's mechanical operation, enabling precise and repeatable control in the ball-launching process.

The creation of this ball-launching and object-picking robot is expected to contribute to the development of mechatronic and robotic systems in Indonesia. The aim is to build a prototype that is both effective and efficient in terms of performance and operational time.

II. LITERATURE REVIEW

Robotics is a branch of technological innovation that involves the design of systems, control systems, algorithm design, manufacturing, assembly, and operation of robots. Robots are built using appropriate programming languages to execute tasks as expected. The role of robots in the industrial sector is crucial, as they can significantly enhance mechanical work performance in terms of efficiency and effectiveness. Robots can operate for extended periods with high success rates. The operational mechanism of robots is fundamentally based on the capabilities of the electronic brain embedded in each robot. The electronic brain serves as the controller for the mechanical systems and sensors, functioning simultaneously.

The design of the ball-launching and object-picking robot is divided into several operational concepts, including:

A. Manual System

This means that the robot operates with the assistance of an operator. The robot does not incorporate intelligence through inputs from multiple sensors. It cannot think or command mechanical actions. Without an operator, the robot becomes a machine that is rendered useless.

B. Wireless System

Wireless communication is a method of communication without cables [7]. This communication uses a signal transmitter and a signal receiver. By employing a wireless system, the control of the robot is conducted through remote communication.T he use of wireless technology greatly enhances the robot's mobility, allowing it to maneuver in any direction without significant obstacles. This flexibility enables the robot to move more freely. The term "wireless" refers to the absence of cables [8]. Typically, a signal receiver module is installed on the robot, enabling it to receive operational commands from an operator who sends the control signals.

C. Microcontroller Module

The microcontroller module serves as the brain that provides operational commands to all components related to mechanical functions. The command system can operate simultaneously between the drive motors and other systems, [4]. The microcontroller is programmed using a specific programming language, enabling it to coordinate tasks across various robot components while monitoring analog and digital terminals on the microcontroller module.

D. Motor Driver Module

The motor driver module is a crucial component in the design of the ball-launching and object-picking robot. The selection and use of the appropriate motor driver significantly impact the robot's overall performance, functionality, and mobility. Using the correct programming language, along with integration with other actuators, is essential for achieving optimal work results [5]. Understanding the functions and applications of the motor driver allows system designers to create robots that are more efficient and effective in performing their tasks.

Controlling Speed and Direction of the Motor:

The motor driver is expected to control both the speed and direction of the motor's rotation [10]. In the ball-launching robot, the rotational speed of the motor can be adjusted to regulate the strength of the ball throw as desired. This control module is also connected to the four drive motors of the wheels, allowing the robot to maneuver in any direction on the floor surface.

Receiving Signals from the Microcontroller:

The motor driver receives digital signals from the microcontroller as command signals and converts them into signals that can be processed by the drive motors [5]. This communication between the signals and the motor driver ensures that the robot can respond accurately according to the instructions given, utilizing the programming language

Supporting Various Types of Drive Motors / Actuators:

The motor driver module is often used for various drive motors, including DC motors, stepper motors, and servo motors [3]. Each type of drive motor has unique properties and characteristics that can be utilized according to the specific needs in the design of robotic systems.

Ball-Launching Robot:

In the design of this ball-launching robot, the motor driver is used to operate the mechanism that throws the ball, consisting of two rotating wheels. By adjusting the motor's rotational speed, the robot can be configured to ensure that the ball is thrown at the desired distance and speed.

Robot Arm for Object Picking:

The motor driver is essential for operating the robotic arm, which functions to lift and lower objects that have been collected from the floor. Proper configuration of the motor driver allows the robot to operate efficiently and accurately during the process of lifting and lowering the collected objects

E. Pneumatic System

The pneumatic system installed on the robotic arm for object picking is a technology that uses air pressure to control and operate various components within the robotic arm. Pneumatic systems are widely used in industrial automation processes due to their ability to provide rapid, precise movements while handling relatively light loads.

Pneumatic Cylinder:

The pneumatic cylinder is a key component that converts compressed air energy into linear [2]. This pneumatic cylinder moves back and forth in response to the air pressure applied. When the pneumatic system is activated, the air compressor generates pressure that is routed into the pneumatic cylinder through a valve. When the pneumatic valve opens, air enters the pneumatic cylinder and pushes the pneumatic piston to move. This piston movement enables the robotic arm to move back and forth. The robotic arm is equipped with a picking tool, such as a gripper. When the arm reaches the correct position, the gripper can open and close to pick up objects. The operation of the pneumatic system is controlled using a microcontroller module that executes a program based on the desired logic.

F. Conveyor Belt

A conveyor is a mechanical system used to move objects from one place to another within a system. In the ball-launching robot, the conveyor functions as a medium to transport balls from the floor to the launching mechanism, ensuring a consistent and orderly ball flow.

Belt: The most important part of a conveyor system, typically made from flexible materials like rubber or PVC. The conveyor belt is mounted on a frame and moves around two aluminum cylinders or pulleys [1].

Aluminum Cylinder / Pulley: These are rotating aluminum wheels where the belt loops and moves. The main pulley is connected to a drive motor that transmits power [1].

Conveyor Frame: The frame supports the conveyor to ensure the belt stays on the designated track. This frame must be sturdy to prevent misalignment or shifting of the pulleys.

G. Operator Control Console

The operator control console is a patented, mass-produced device that communicates with the microcontroller via a Bluetooth system. This console has multiple buttons that can be used for various commands in the programming of the ball-launching and object-picking robot. The communication capability of this console is well-regarded, especially within the effective range of a Bluetooth system. The ball-launching and object-picking robot utilizes 14 command buttons on the control console, with each button connected to a specific robot operation command.

III. RESEARCH METHODOLOGY

In this research, which focuses on the design and development of a ball-launching and object-picking robot with wireless control, the robot is capable of moving in all directions with highly flexible maneuvers. The robot is equipped with four Mecanum wheels powered by PG 45 drive motors. Mecanum wheels allow the robot to move and shift easily in any direction. The movement of the wheels is controlled by settings on the motor driver module.

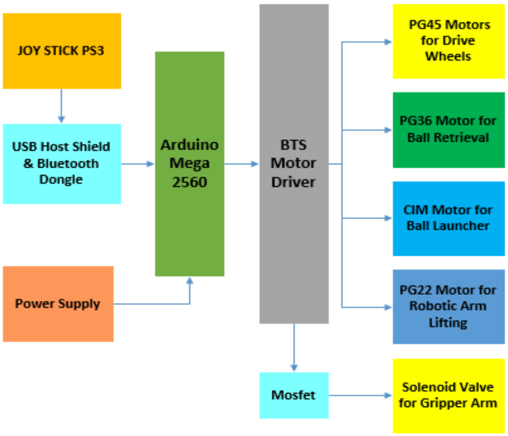


Figure 3.1. Block diagram of a working system

The robot features a conveyor frame, which serves the function of transporting balls from the floor to the launching area. The method used involves installing two rubber belts mounted on aluminum pulleys. This approach is highly suitable for the ball-launching robot, as it allows the balls to be easily moved to the launching area.

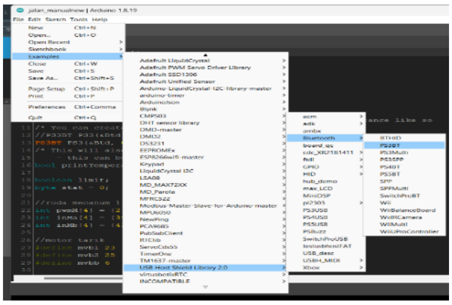
At the end of the conveyor, two rubber wheels are installed that can rotate according to the desired speed settings. Their purpose is to ensure that the balls can be launched at the distance expected by the operator. There are several speed settings for the rubber wheels, which are useful for positioning the ball launch to the intended area.

The frame of the robotic arm, designed for picking up objects, is constructed with a pneumatic drive system. At the end of the robotic arm, a gripper is installed to allow the robot to easily grasp the objects it needs to pick up. This gripper is made from 3D-printed plastic and has a rubber coating on its surface. The grip of the robotic arm is very strong, enabling it to perform well during the processes of picking up objects, lifting, lowering, and moving items from the starting position to the intended destination.

3.1 The truth table for the BTS 7960 driver

Digital		PWM	Direction Motor
PWM	LPWM	R_EN/L_EN	
0	0	0	*Stop*
0	0	1	*Stop*
	1	0	*Stop*
0	1	1	CCW
1	0	0	*Stop*
1	0	1	CW
1	1	0	*Stop*
1	1	1	*Stop*

To connect the PS3 joystick (PlayStation 3) to the microcontroller/Arduino using the USB Host Shield, the program uploaded to the Arduino utilizes the library from USB Host Shield Library 2.0 [5], which is provided on arduino.cc. The header for the program is #include <PS3BT.h>.



```
/* You can creat
//PS3BT PS3(&Btd
PS3BT PS3(&Btd,
/* This will als
    - this can b
bool printTemper

boolean limit;
byte stat = 0;

//roda mecanum 1
int pwmM[4] = {2
int inMa[4] = {3
int inMb[4] = {4

//motor tarik
#define mvb1 23
#define mvb2 25
#define mvbb 6
```

Figure 3.2 *PS3BT*. Library

IV. RESULTS AND DISCUSSION

H. Design and Construction of the Robot

The construction of the ball-launching and object-retrieving robot has reached its final stage. The results obtained show that the robot can operate optimally as expected. Wireless communication functions well within a control distance of 20 meters. The robot can maneuver in all directions for position changes. It can easily retrieve balls from the floor to the launching area using the conveyor system. The rubber wheels, serving as the ball launcher, operate effectively, allowing the balls to be launched to the designated area. The robotic arm functions perfectly using the pneumatic system, enabling the robot to lift and lower objects from one position to another.

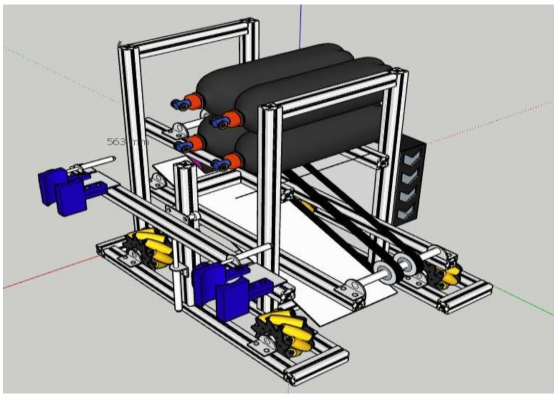


Figure 4.1. Design of the Ball-Launching and Object-Picking Robot

I. System Operation Testing

Walking Mechanism Testing

The testing of the ball-launching and object-retrieving robot focuses on the walking mechanism capabilities. The robot's walking movements can be illustrated as shown in Figure 4.2, which depicts the control of the walking mechanism: (a) moving forward, (b) moving backward, (c) sliding left, (d) sliding right, (e) turning right, (f) turning left, (g) diagonal left, and (h) diagonal right.

The robot's movements correspond to the wheel rotations that have been predetermined. In the trials, the robot was able to move according to the illustrated patterns, following the designated wheel rotations. The PWM speed testing data for the robot's walking motion can be seen in Table 4.1 below, which outlines the various speeds of the driving motors after several test trials have been conducted.

The calculation of PID (Proportional-Integral-Derivative) for a motor is generally done to control the speed or position of the motor to match the desired setpoint [3][10]. Here is a general overview of how to calculate and implement PID control on a motor:

Define Variables and Parameters

Setpoint (SP) : The target value to be achieved
Process Variable (PV) : The actual value of the system
Error (e) : The difference between the setpoint and the process variable.

$$e(t) = SP(t) - PV(t)$$

$$\boldsymbol{u}(t) = K_p e(t) + K_i \int e(t)dt + K_d \frac{de(t)}{dt}$$

$$u(t) = output\ kontrol$$

$$K\_p = Proportional\ Koefficient$$

$$K\_i = Integral\ Koefficient$$

K_d = Derivative Koefficient

$$e(t) = Error\ (difference\ between\ set\ point\ and\ measured\ value)$$

$$\int e(t)dt = integral\ of\ error$$

$$\frac{de(t)}{dt} = Derivatif\ of\ error$$

PWM (Pulse Width Modulation) control in a DC motor is a method used to regulate the motor’s speed by adjusting the duty cycle of the PWM signal. The duty cycle is the percentage of time the PWM signal remains in a "high" state within a single cycle. Here is the calculation and implementation of PWM control in a DC motor:

Duty Cycle (D): The percentage of time the signal remains in the "ON" state during one PWM cycle.

$$D = \frac{Time\ On}{Full\ Time} x\ 100\%$$

PWM Frequency (f): The switching frequency of the PWM signal, typically ranging from 1 kHz to 20 kHz depending on the application. The period of the PWM signal is the inverse of its frequency:

$$T = \frac{1}{f}$$

Relationship Between Duty Cycle and Motor Speed

The speed of a DC motor is correlated with the average voltage supplied to the motor. This average voltage is determined by the PWM duty cycle:

$$V_{avg} = V_{input}\ x\ \frac{D}{100}$$

Vavg is the average voltage received by the motor.
Vinput is the full supply voltage.
D is the duty cycle as a percentage.

By changing the duty cycle, the average voltage received by the motor also changes, which in turn affects the motor’s speed.

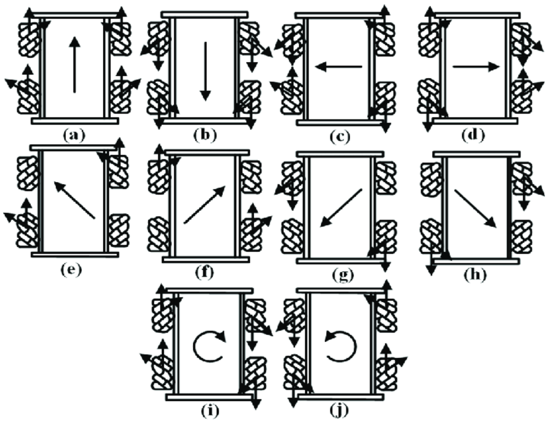
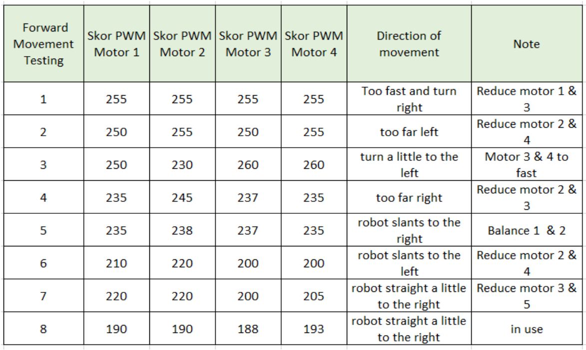


Figure 4.2 Control Mechanism for Walking.

4.1. Table forward Movenment Testting



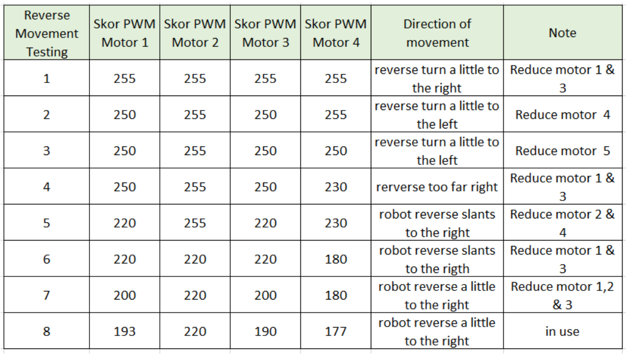
Forward Movement Testing	Skor PWM Motor 1	Skor PWM Motor 2	Skor PWM Motor 3	Skor PWM Motor 4	Direction of movement	Note
1	255	255	255	255	Too fast and turn right	Reduce motor 1 & 3
2	250	255	250	255	too far left	Reduce motor 2 & 4
3	250	230	260	260	turn a little to the left	Motor 3 & 4 to fast
4	235	245	237	235	too far right	Reduce motor 2 & 3
5	235	238	237	235	robot slants to the right	Balance 1 & 2
6	210	220	200	200	robot slants to the left	Reduce motor 2 & 4
7	220	220	200	205	robot straight a little to the right	Reduce motor 3 & 5
8	190	190	188	193	robot straight a little to the right	in use

The analysis results in Table 4.2 conclude that the robot is capable of moving backward effectively in most trials. The robot's speed can be controlled by adjusting the PWM values of motor 1, motor 2, motor 3, and motor 4. The robot is able to move backward in a straight and stable manner during most trials. However, in some trials, the robot slightly veered off course while moving backward.

The analysis results in Table 4.3 conclude that the robot is capable of moving forward diagonally to the left effectively in the third trial. The diagonal left movement can be achieved by activating motor 2 and motor 3 or the front right motor and the rear left motor.

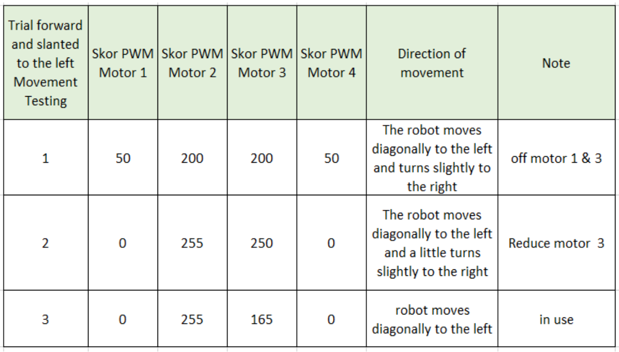
The analysis results in Table 4.4 conclude that the robot is capable of moving backward diagonally to the left effectively in the third trial. The diagonal left backward movement can be achieved by activating motor 1 and motor 4 or the front left motor and the rear right motor.

4.2. Table reverse Movenment Testting



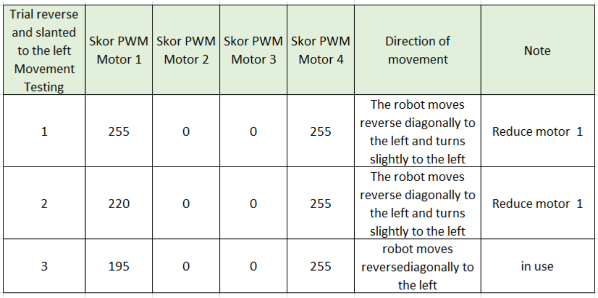
Reverse Movement Testing	Skor PWM Motor 1	Skor PWM Motor 2	Skor PWM Motor 3	Skor PWM Motor 4	Direction of movement	Note
1	255	255	255	255	reverse turn a little to the right	Reduce motor 1 & 3
2	250	255	250	255	reverse turn a little to the left	Reduce motor 4
3	250	255	250	250	reverse turn a little to the left	Reduce motor 5
4	250	255	250	230	rerverse too far right	Reduce motor 1 & 3
5	220	255	220	230	robot reverse slants to the right	Reduce motor 2 & 4
6	220	220	220	180	robot reverse slants to the rigth	Reduce motor 1 & 3
7	200	220	200	180	robot reverse a little to the right	Reduce motor 1,2 & 3
8	193	220	190	177	robot reverse a little to the right	in use

4.3. Table forward slanted to the left Movenment Testting



Trial forward and slanted to the left Movement Testing	Skor PWM Motor 1	Skor PWM Motor 2	Skor PWM Motor 3	Skor PWM Motor 4	Direction of movement	Note
1	50	200	200	50	The robot moves diagonally to the left and turns slightly to the right	off motor 1 & 3
2	0	255	250	0	The robot moves diagonally to the left and a little turns slightly to the right	Reduce motor 3
3	0	255	165	0	robot moves diagonally to the left	in use

4.4. Table reverse and slanted to the left Movenment Testting



Trial reverse and slanted to the left Movement Testing	Skor PWM Motor 1	Skor PWM Motor 2	Skor PWM Motor 3	Skor PWM Motor 4	Direction of movement	Note
1	255	0	0	255	The robot moves reverse diagonally to the left and turns slightly to the left	Reduce motor 1
2	220	0	0	255	The robot moves reverse diagonally to the left and turns slightly to the left	Reduce motor 1
3	195	0	0	255	robot moves reversediagonally to the left	in use

The testing of the ball pickup mechanism

The testing of the ball pickup mechanism was conducted using the PG-36 motor and a v-belt that has been integrated with the robot's mechanics. The testing can be seen in Figure 4.3, where the ball pickup mechanism was tested using a battery with a voltage of 24 V. The Li-Po battery used is the extreme type, 12 V 2200 mAh, and it was connected in a series circuit, resulting in a total battery voltage of 24 V.

The testing of the ball pickup mechanism used PWM motor 235 with a duration of 3 minutes for each trial. A total of 12 balls were picked up, with 0 being missed, indicating a successful trial. If the number of balls picked was less than 12 within the 3-minute timeframe, the trial was deemed unsuccessful, as shown in Table 4.5 for the ball pickup tests.

In this study, V-belt calculations involve several fundamental parameters, such as belt length, rotational speed, transmission ratio, and force [1]. The commonly used calculations are as follows:

Calculating V-Belt Length

For measuring the length of a V-belt with two pulleys, the formula used is:

$$L = 2C + \frac{\pi(D_1 + D_2)}{2} + \frac{(D1 - D2)^2}{4C}$$

L = Length of the V-belt (in mm or inches)

C = Center distance between the pulleys

$D1$ = Diameter of the larger pulley

$D2$ = Diameter of the smaller pulley

Pulley Rotational Speed

The formula for calculating the rotational speed of the pulley is:

$$N_2 = \frac{(D_1 \,.\, D_2)}{D_2}$$

$N1$ = Rotational speed of the driving pulley (in rpm)

$N2$ = Rotational speed of the driven pulley (in rpm)

$D1$ = Diameter of the driving pulley (in mm or inches)

$D2$ = Diameter of the driven pulley (in mm or inches)

Power Transmitted by the V-Belt

The power transmitted by the V-belt can be calculated using the formula:

$$P = (T_1 - T_2).v$$

P = Power transmitted (in watts, W)

$T1$ = Tension on the tight side of the belt (in newtons, N)

$T2$ = Tension on the slack side of the belt (in newtons, N)

v = Linear speed of the belt (in meters per second, m/s)

If you know the rotational speed of the driving pulley, the linear speed ***v*** of the belt can be calculated using the formula:

$$v = \frac{\pi(D_1 \,.\, N_1)}{60}$$

v = Linear speed of the belt (in meters per second, m/s)

$D1$ = Diameter of the driving pulley (in meters)

$N1$ = Rotational speed of the driving pulley (in revolutions per minute, rpm)

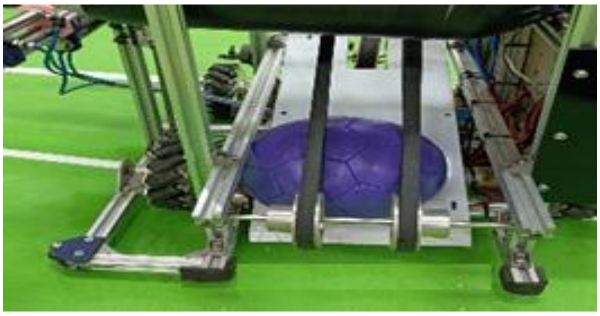


Figure 4.4 The testing of the ball pickup mechanism

4.5. Table the testing of the ball pickup mechanism

Time	PWM Motor	Number of balls	the ball is taken by the van belt	Ball failed	Results
3 minute	150	12	7	5	Fail
3 minute	165	12	7	5	Fail
3 minute	190	12	8	4	Fail
3 minute	200	12	10	2	Fail
3 minute	220	12	10	2	Fail
3 minute	235	12	12	0	Succeed
3 minute	250	12	11	1	Fail
3 minute	260	12	10	2	Fail

The testing of the ball launching mechanism

The testing of the ball launching mechanism utilized a CIM motor placed in the center of the robot's mechanics, integrated with wheels to serve as the ball launcher. The mechanism has undergone multiple trials to determine whether the motor, combined with the wheels, produces a good ball launch, with the motor rotation matching that of the wheels [6]. The testing can be seen in Figure 4.4, which illustrates the ball launching mechanism. The purpose of the ball throwing test is to analyze the robot's performance in terms of throwing distance, accuracy, and stability when launching the ball.

A ball-launching motor involves several key aspects, including speed, torque, energy, and other parameters necessary for effective launching. Here's an overview of these factors:

Speed (Rotational Speed)

The motor's rotational speed determines how quickly the launching mechanism operates. High speed can increase the launch velocity, especially if using a flywheel mechanism.

The motor's speed and torque are also related to power P :

$$P = T \cdot \omega$$

P = Power (in watts, W)
ω = Angular velocity of the motor (in radians per second, rad/s), which can be calculated from the rotational speed (in rpm) using:

Torque

Torque is crucial for overcoming the resistance and inertia of the ball during launch. A motor with adequate torque can apply the necessary force to the ball, ensuring it achieves the intended speed.

$$T = F \cdot r$$

T = Torque (in Newton-meters, Nm)
F = Force exerted on the ball (in Newtons, N)
r = Radius from the center of rotation to the point where force is applied (in meters, m)

Energy (Kinetic Energy of the Ball)

The kinetic energy required for the ball can be calculated using:

$$E_k = \frac{1}{2} \mathrm{m} v^2$$

Ek = Kinetic energy needed for the ball (in joules, J)
m = Mass of the ball (in kilograms, kg)
v = Linear velocity of the ball after launch (in meters per second, m/s)

Calculate the Force (F) Required

The force needed to accelerate the ball to a certain speed can be calculated with Newton's second law:

$$F = m \cdot a$$

m = Mass of the ball (in kilograms, kg)
a = Acceleration needed to reach the desired launch speed (in meters per second squared, m/s^2)
To calculate a, you can use the equation:

$$a = \frac{v}{t}$$

v = Target launch speed of the ball (in meters per second, m/s)
t = Time over which the ball is accelerated (in seconds, s)

4.6. Table the testing of the ball launching mechanism

Time	PWM Motor	Radius	Number of balls	Success Ball	failed Ball	Results
3 minute	255	30	12	7	5	Fail
3 minute	245	30	12	7	5	Fail
3 minute	230	30	12	8	4	Fail
3 minute	225	30	12	10	2	Fail
3 minute	210	30	12	12	0	Succeed
3 minute	200	30	12	10	2	Fail
3 minute	180	30	12	11	1	Fail
3 minute	150	30	12	5	7	Fail

Testing of Pneumatic Devices

In this section, the author will test the wind supply bottle, hoses, pneumatic valves, solenoid valves, and pneumatic cylinders. All devices are tested by applying air pressure; if there are no leaks, the equipment is deemed usable. The illustration of the pneumatic device testing and the results can be found in Table 4.7, which presents the results of the pneumatic device testing.

Calculating the pneumatic system for a robotic gripper involves understanding the force required to operate the gripper, the size of the pneumatic actuator, and the pressure in the system. Here's a breakdown of how to perform these calculations:

Determine the Required Force (F)

First, determine the force needed to grip the object securely. The required gripping force can be calculated based on the weight of the object and any additional factors such as friction or safety factors [6].

$$F = m \cdot g$$

F = Force required (in Newtons, N)
m = Mass of the object being gripped (in kilograms, kg)
g = Acceleration due to gravity (approximately 9.81 m/ s^2)

Calculate the Pneumatic Cylinder Area (A)

The area of the pneumatic cylinder that generates the force can be calculated using the formula [2]:

$$A = \frac{F}{P}$$

A = Area of the cylinder (in square meters, m^2)
P = Pressure of the pneumatic system (in Pascals, Pa)

Calculate the Diameter of the Cylinder (D)

Once you have the area, you can calculate the diameter of the cylinder using the formula for the area of a circle [2]:

$$A = \pi \left(\frac{D}{2}\right)^2$$

Rearranging to find D:

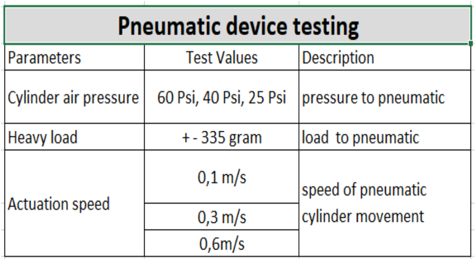
$$D = 2\sqrt{\frac{D}{\pi}}$$

The testing results in Table 4.7 show that the pneumatic system can operate effectively under various air pressures, heavy loads, and actuation speeds. The pneumatic system is capable of generating sufficient force to lift heavy loads at varying speeds. Based on the analysis above, it can be concluded that the tested pneumatic system performs well and can be utilized for various applications that require fast and precise movements [6].

Testing of Motor & BTS Driver

In this testing, each BTS Driver will be directly connected to the PG-45 motor and CIM motor. The driver will be controlled by an Arduino that has been programmed. If the motor can rotate clockwise and counterclockwise, then the driver and motor can be utilized.

4.7. Table testing of pneumatic devices



Pneumatic device testing		
Parameters	Test Values	Description
Cylinder air pressure	60 Psi, 40 Psi, 25 Psi	pressure to pneumatic
Heavy load	+ - 335 gram	load to pneumatic
Actuation speed	0,1 m/s	speed of pneumatic cylinder movement
	0,3 m/s	
	0,6m/s	

Testing a motor and its BTS (Bipolar Transistor Switch) driver involves calculating various parameters like current, voltage, power, torque, and efficiency. Breakdown of the calculations and formulas used in motor and BTS driver testing:

Motor Testing Parameters

The motor’s input voltage and current can be measured directly with a multimeter [9].

The power consumed by the motor can be calculated as:

$$P = V \,.\, I$$

P = Power (in watts, W)
V = Voltage
I= Current (in amperes, A)

Motor Efficiency (η)

Efficiency of the motor can be calculated by comparing the output power to the input power:

$$n = \frac{P_{Out}}{P_{in}} x\ 100\%$$

Pout = Output power (in watts, W), usually calculated from torque and angular velocity
Pin = Input electrical power (in watts, W)

BTS Driver Testing Parameters

The BTS driver (BTS7960 motor driver) controls the motor by switching on/off power to the motor. Important parameters include the switching efficiency and thermal performance.

Voltage Drop Across the BTS Driver

The BTS driver’s output voltage may slightly differ from the input due to internal resistance. The voltage drop (Vdrop) across the driver can be measured:

$$V_{drop} = V_{in} \,.\, V_{out}$$

Vin = Input voltage to the BTS driver (in volts, V)
Vout = Output voltage from the BTS driver to the motor (in volts, V)

Current Flow

The current flowing through the driver can be measured using an ammeter. This helps in checking if the driver is handling the motor load within its rated current limit.

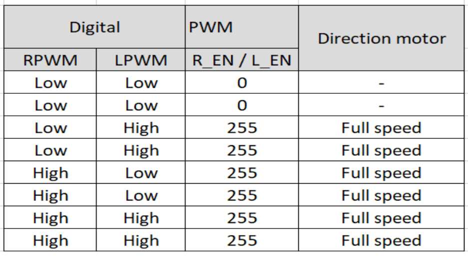
Power Dissipation

The power dissipation in the BTS driver, which can cause heat, is given by:

$$P_{diss} = I^2 . R_{on}$$

I = Current through the driver (in amperes, A)
Ron = On - resistance of the BTS driver (in ohms, Ω)

4.8. Table testing of pneumatic devices



Digital		PWM	Direction motor
RPWM	LPWM	R_EN / L_EN	
Low	Low	0	-
Low	Low	0	-
Low	High	255	Full speed
Low	High	255	Full speed
High	Low	255	Full speed
High	Low	255	Full speed
High	High	255	Full speed
High	High	255	Full speed

Table 4.8 shows that the BTS 7960 driver can effectively control the direction and speed of the motor. The RPWM and LPWM signals are used to control the direction and speed of the motor, while the R EN and L EN signals are used to activate/deactivate the motor and can also adjust the motor speed.

V. CONCLUSION

The control of the ball-throwing robot and object-grabbing mechanism is performed remotely via wireless communication, allowing the operator to operate and control the robot's functions. The microcontroller serves as the main brain of the robot's mechanical system, processing signals from the control interface and simultaneously managing the driving components and mechanics. This research emphasizes the design of a more efficient system capable of providing a good response, aiming to deliver optimal robot control.

The test results show that the robot is capable of performing ball-launching tasks with adequate accuracy and can pick up objects with both speed and precision. With the application of this technology, it is expected that the robot can be utilized in various fields, including industry, sports, education, agriculture, and entertainment activities. This research opens up opportunities for further development in robotic systems with more advanced and practical remote control applications.

SUGGESTIONS

During testing, several challenges were encountered, including:

- The air pressure in the ball significantly affects the robot's ability to pick up the ball from the floor and during the ball-launching process. Frequent failures occurred due to the ball's air pressure not being at the appropriate level.
- The conveyor belt system often jammed and shifted position. This was caused by either the ball being too hard or the belt not being tightly installed.
- The air pressure in the storage tank must be controlled. Minor leaks in the system were frequently observed, which caused the pneumatic cylinder to not function optimally.

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