BANGLADESH UNIVERSITY OF PROFESSIONALS (BUP)

Project Proposal

Tentative Title: Light Following Robot

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CHAPTER 1

INTRODUCTION

1.1 Overview

Automation has become prevalent in various fields, offering advantages such as reduced manual operations, enhanced flexibility, reliability, and increased accuracy. Modern systems, especially in electronics, benefit significantly from automated control systems. Unmanned systems, like drones, play a crucial role in minimizing risks to human life, particularly in warfare. Recent advancements in robotics have spurred a demand for self-sustaining automated systems capable of efficient task detection and maneuvering.

1.2 Background

Automation has revolutionized various sectors by introducing efficiency, precision, and reliability to processes traditionally reliant on human labor. Light-following robots, which use sensors to detect and move towards light sources, represent a specific application of automation with potential benefits in industries like solar energy, agriculture, and interactive technologies.

Robotics advancements have significantly improved manufacturing, agriculture, and construction. In manufacturing, automation enhances production, reduces errors, and enables continuous operation. In agriculture, robots support precision farming and resource efficiency, while in construction, they reduce risks and improve timelines by performing hazardous tasks.

In Bangladesh, the adoption of automation can address significant industrial and agricultural challenges. The manufacturing sector, especially textiles and garments, could improve competitiveness with automation. Similarly, the agricultural sector, a major employment source, can benefit from increased productivity through automated equipment.

However, obstacles such as high costs, limited access to advanced technology, and a lack of skilled operators hinder robotics implementation in Bangladesh. Additionally, existing robots may not be suited to the specific needs and environmental conditions of the country.

Developing a light-following robot tailored to Bangladesh's conditions offers a solution. This project aims to create a cost-effective, adaptable robot for diverse industrial and agricultural applications. Potential uses include automated irrigation, dynamic greenhouse lighting, and construction site safety lighting. By leveraging sensor technology and control systems, the robot will enhance local automation efforts, aligning with global trends and supporting economic development in the region.

1.3 Problem Statement

In both global contexts and Bangladesh, challenges persist across various sectors, encompassing manufacturing, agriculture, construction, and industry. These sectors are fundamental to economic growth and societal development but grapple with systemic issues that hinder their efficiency and effectiveness. In various industrial sectors, such as manufacturing, textiles, and agro-processing, productivity issues and labor shortages hinder growth and competitiveness. Manual labor reliance, coupled with outdated production techniques, restricts the industries' potential for innovation and modernization. Moreover, in the global marketplace, where competition is fierce, industries struggle to maintain their edge due to inefficiencies in production processes and limited access to advanced technologies. In the manufacturing sector, labor shortage and the lack of automation infrastructure lead to notable inefficiencies. Traditional manufacturing processes are often slow, error-prone, and costly, resulting in decreased competitiveness and profitability for businesses. Similarly, the agricultural sector faces significant challenges, exacerbated by labor shortages and outdated farming practices. In Bangladesh, where agriculture is a vital component of the economy, the sector struggles with insufficient mechanization, limited access to modern farming equipment, and a shortage of skilled labor. As a result, farmers experience difficulties in optimizing their yields, mitigating crop losses, and meeting the growing food demand of the population. The construction industry confronts its own set of obstacles, including labor shortages, safety concerns, and project delays. Manual construction methods prevail, contributing to inefficiencies, slower project completion times, and increased risks to worker safety. Bangladesh is facing tremendous accident issues at construction sites, and it gets larger size every year. The statistics of accidents at construction sites show us a picture that the Bangladeshi construction sector is in most critical situation that needs a huge and fast overcome from the current frequent accidental level [1].

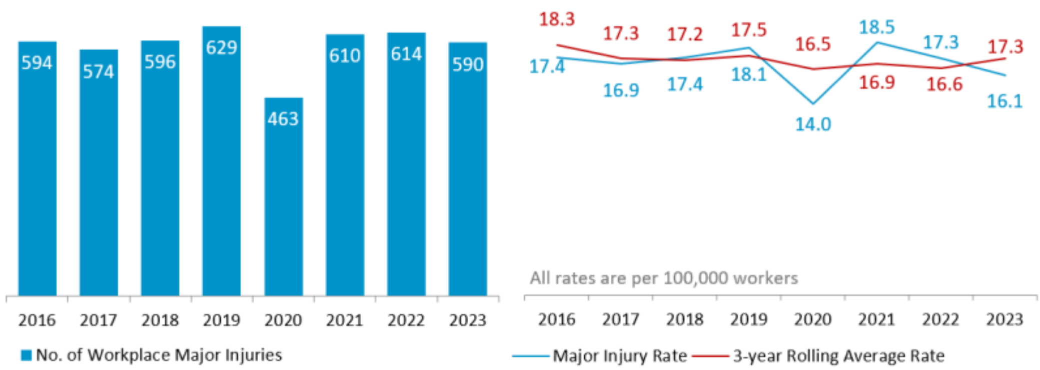

Figure 1.3.1: Number and rate of workplace major injuries, 2016-2023 [2]

1.4 Rational of the Study

A light-following robot has the potential to address several challenges and contribute to the development of both Bangladesh and the world. Firstly, the implementation of a light-following robot could help in addressing the problem of labor shortages in various industries, such as manufacturing, agriculture, and construction. The robot could perform tasks that are repetitive, dangerous, or require a high level of precision, thus freeing up human workers to focus on more complex tasks. This could lead to increased productivity and efficiency in these industries, which could have a positive impact on the economy of Bangladesh and other countries. Secondly, the development and implementation of a light-following robot could help in reducing the risk of accidents and injuries in the workplace. The robot could be designed to work in hazardous environments, such as mines, construction sites, or chemical plants, where human workers are at risk of exposure to harmful substances or accidents. By reducing the risk of accidents and injuries, the robot could help in improving the working conditions for human workers and reducing the costs associated with workplace accidents and injuries. Thirdly, the light-following robot could have a positive impact on the environment. By reducing the need for human workers to travel to and from work, the robot could help in reducing the carbon footprint of industries. Additionally, the robot could be designed to perform environmentally friendly tasks, such as recycling or waste management [3][4]. Existing light-following robot designs globally often struggle with responsiveness to varying light conditions and fail to operate effectively in diverse environments. This limitation impedes their widespread adoption and diminishes their potential impact on automation and robotics [5].

1.5 Objectives

In summary, this project has the potential –

- To develop a method for detecting the presence of light sources in the robot's vicinity
- To implement control mechanisms allowing the robot to navigate towards detected light sources without human intervention.

1.6 Outline of This Research

The research book follows the subsequent structure. Chapter 1 covers the introduction mentioning the importance of Light Following Robot. In the next chapter a review of the existing work is provided. Chapter 3 covers the methodology and the tools and technologies. The performance of Light Following Robot is provided in Chapter 4. Chapter 5 concludes the research. This chapter also presents numerous recommendations for future enhancement.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

Light-detecting and following robots have advanced significantly since the mid-20th century. Early examples, like Grey Walter's robots, demonstrated simple light-responsive behaviors. Advances in sensor technology in the 1980s and 1990s improved their accuracy and reliability. Modern robots often use sophisticated control systems to enhance their precision, although challenges like tuning and environmental variability persist. Despite these issues, ongoing improvements in technology continue to enhance the capabilities of light-following robots.

Light detecting or following robots is intertwined with the advancement of robotics and sensor technology. The development of light-detecting and following robots boasts a rich history spanning several decades. This evolution has been intricately linked to advancements in both sensor technology and control algorithms. While the concept of robots following light traces back to the mid-20th century, significant developments have occurred in recent decades. Grey Walter's light-sensitive robot, also known as Machina Speculatrix, was a pioneering creation in the field of robotics. Developed by British neuroscientist and roboticist William Grey Walter in the late 1940s and early 1950s, these robots were among the earliest examples of autonomous mobile robots.

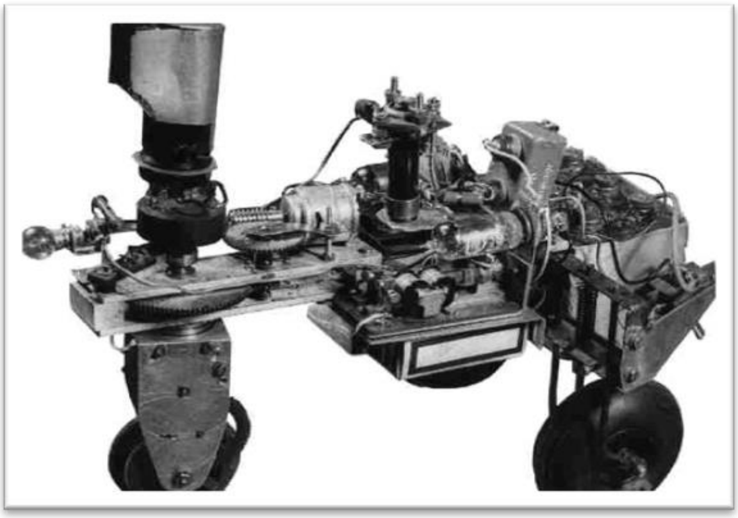

Figure 2.1.1: Machina Speculatrix

Grey Walter's robots had a tortoise-like appearance with a simple body structure made of metal and plastic. The robots had light sensors, batteries, and electronic circuitry for basic behavioral control. The primary feature of these robots was their ability to respond to light stimuli. They had light sensors mounted on their "heads" that allowed them to detect light sources in their environment. The robots demonstrated autonomous movement by exhibiting behaviors such as seeking out light sources and moving towards or away from them based on their intensity.

While their behaviors seemed complex for the time, the underlying control mechanisms were relatively simple compared to modern robotics [6].

Figure 2.1.2: Rodney Brooks’ Robot

Advancements in sensor technology during the 1980s-1990s contributed to the development of lightdetecting and light-following robots. Improvements in photodetectors, photodiodes, and phototransistors enabled robots to detect and respond to light sources more accurately and reliably. Rodney Brooks, a roboticist and artificial intelligence researcher, made significant contributions to behavior-based robotics during this period [7]. His work focused on simple, reactive robots that could exhibit complex behaviors through interactions with their environment. Brooks' research laid the foundation for the development of light-following robots with robust and adaptive control systems. Although Brooks' research did not focus exclusively on light-following robots, his work laid the groundwork for the development of such robots by promoting a paradigm shift in robotics toward more robust and adaptive control systems. His ideas continue to influence the design and implementation of autonomous systems in various domains, including robotics, artificial intelligence, and autonomous vehicles [8].

Steve Furber and Sophie Wilson's primary contributions are in the fields of computer architecture and microprocessor design, particularly with the development of the BBC Microcomputer System and the ARM architecture. Their work has focused on digital computing systems rather than light detecting technology. Although ARM architecture is widely used in embedded systems, IoT devices, and mobile platforms, where sensors, including light sensors, are commonly integrated for various functionalities [9].

In the modern era, multiple attempts were made in this sector. Light-following robots equipped with PID (Proportional-Integral-Derivative) controllers use feedback control loops to adjust their movement based on light sensor readings. While PID controllers can improve the stability and precision of light-following robots, tuning the controller parameters can be challenging. These robots may exhibit oscillations or overshoot in response to sudden changes in light intensity. Some commercially available light-following robot toys marketed for entertainment or educational purposes may have faced criticisms for their limited functionality, reliability issues, or lack of robustness. These robots often target a broad consumer audience and may prioritize affordability and simplicity over advanced features or performance.

Despite advancements in sensor technology, microcontrollers, and AI algorithms, modern lightfollowing robots may still struggle with certain environmental conditions, such as highly variable lighting, complex backgrounds, or reflective surfaces. Technical constraints may limit the accuracy, speed, or versatility of light detection and navigation capabilities.

2.2 Existing Studies on Light Detecting Robot

Bio-Inspired Design and Control of Light-Sensitive Autonomous Robot: This paper discusses the development of autonomous robots that are inspired by the light-following behavior of biological organisms. The study explores the use of light sensors and adaptive control algorithms to mimic the phototropic behavior observed in nature.

Solar-Tracking Mobile Robot with Light Detection and Ranging (LiDAR) Capabilities: This research explores the integration of solar tracking with LiDAR technology. The robot is designed to optimize its position relative to a light source for maximum solar energy absorption while navigating obstacles using LiDAR.

Design and Implementation of an Autonomous Light-Following Robot for Search and Rescue Operations: The study details the design of a robot intended for search and rescue missions. The robot uses light detection to locate and move towards areas with light, which can be critical in finding survivors in dark or low-visibility environments.

Machine Learning-Based Adaptive Light-Following Robot: The research investigates the application of machine learning algorithms to enhance the light-following capabilities of robots. The robot learns and adapts to different lighting conditions, improving its ability to track light sources over time.

Implementation of a Light-Detecting Autonomous Robot Using Arduino: This study presents a practical approach to building a light-detecting robot using an Arduino microcontroller. The paper covers the hardware setup, sensor integration, and programming required to achieve light-following behavior.

Energy-Efficient Light-Following Robots for Solar Power Optimization: The paper explores the design of robots that use light detection to position themselves optimally for solar energy harvesting. It discusses the potential for such robots in renewable energy applications.

2.3 Summary

Overall, the development of light-following robots not only reflects the historical advancements in robotics but also underscores the ongoing innovations that continue to drive the field forward. This evolution highlights the dynamic and interrelated nature of technological progress and its practical applications, pointing to a future where light-following robots will become increasingly sophisticated and effective in various domains.

CHAPTER 3

METHODOLOGY

3.1 Overview

In this project of a Light-following robot, we are going to use the Easier Pro Development Board, four light-dependent sensors, two TT gear motors, a car chassis, two wheels and a caster wheel as our main components. There are also some sub-components to complete the project.

Firstly, we are going to attach the development board to the car chassis. Then we connect four sensors and a 5V DC power supply to the development board. There is an intensity regulator attached to the sensor board. We fix the intensity to take input correctly through the sensors. We connect the motors with the “sig-1” pin, so that when the sensors sense the light rays the “sig-1” pin output is 1 and the motors start.

Secondly, two sensors are placed on the left and right, and the other two motors are placed in front of the car chassis. The sensor placed on the left is connected to the motor placed on the right and the sensor placed on the right is connected to the motor placed on the left. The sensors in front are connected to both motors.

When the left sensor senses the light rays, the right motor starts rotating, and when the right sensor, the left motor starts rotating. When the front sensors sense the light rays both the motor starts rotating.

3.2 Overall Model Description

Components Description:

1. <u>Easier Pro Development Board:</u> It is the main component of the project. It combines all the input and output signals. Some input pins take inputs from different sensors. The output pins can be connected to different output devices. There is a processing device known as a “Relay”. It is a switching device. There is a “ULV-2003” IC that works as a Relay driver.

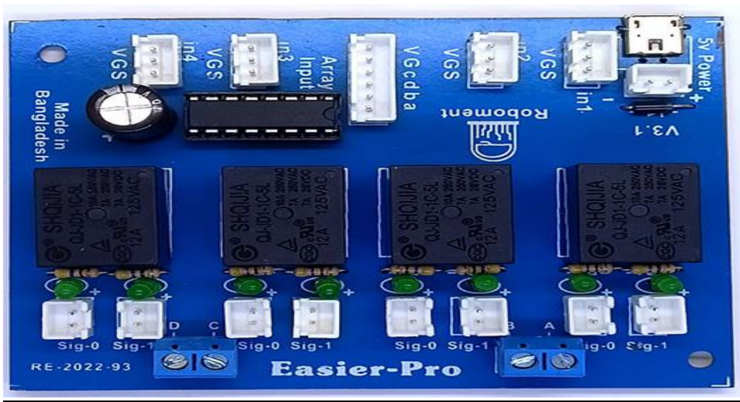

Figure 3.1: Easier Pro Development Board

2. Light Sensor: This light sensor is an LDR (Light Dependent Resistor). These sensors change their resistance based on the amount of light falling on them. More light decreases the resistance, while less light increases it. Light sensors are employed in robotics for tasks such as line following, obstacle detection, or light-based communication. Light sensors typically utilize semiconductor materials that generate electron-hole pairs when exposed to light. The number of electron-hole pairs produced is directly proportional to the intensity of incident light. This change in electrical properties (current, voltage, resistance) is then measured and processed to determine the light level.

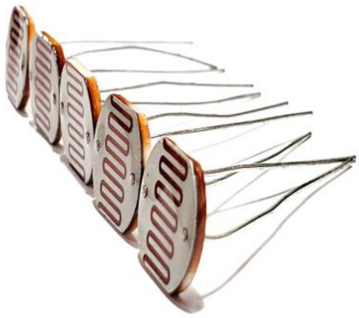

Figure 3.2: Light Sensor

3. TT Gear Motor: The TT gear motor contains a small electric motor that converts electrical energy (from a battery or power supply) into mechanical energy. When electricity flows through the motor, it causes the motor's shaft to rotate. The gearbox consists of gears (typically metal) that control the speed and torque (rotational force) of the motor's output. Gears in the gearbox mesh together to transmit power from the motor to the output shaft.

Figure 3.3: TT Gear Motor

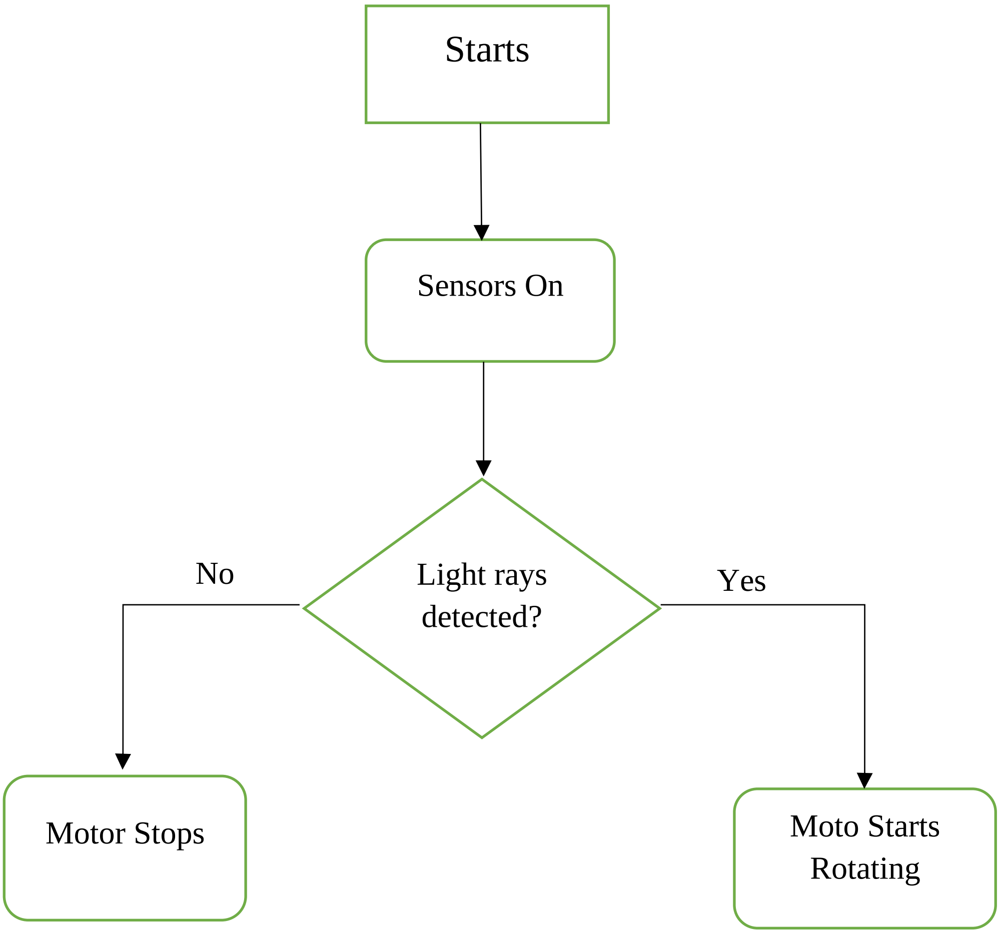

Figure 3.4: Process Flowchart

When the light sensor (LDR) senses the light rays, it sends a signal to the output pin through the processor. The processor driver transforms the signal into an electric high voltage. And the processor works like a switch so the motor starts rotating.

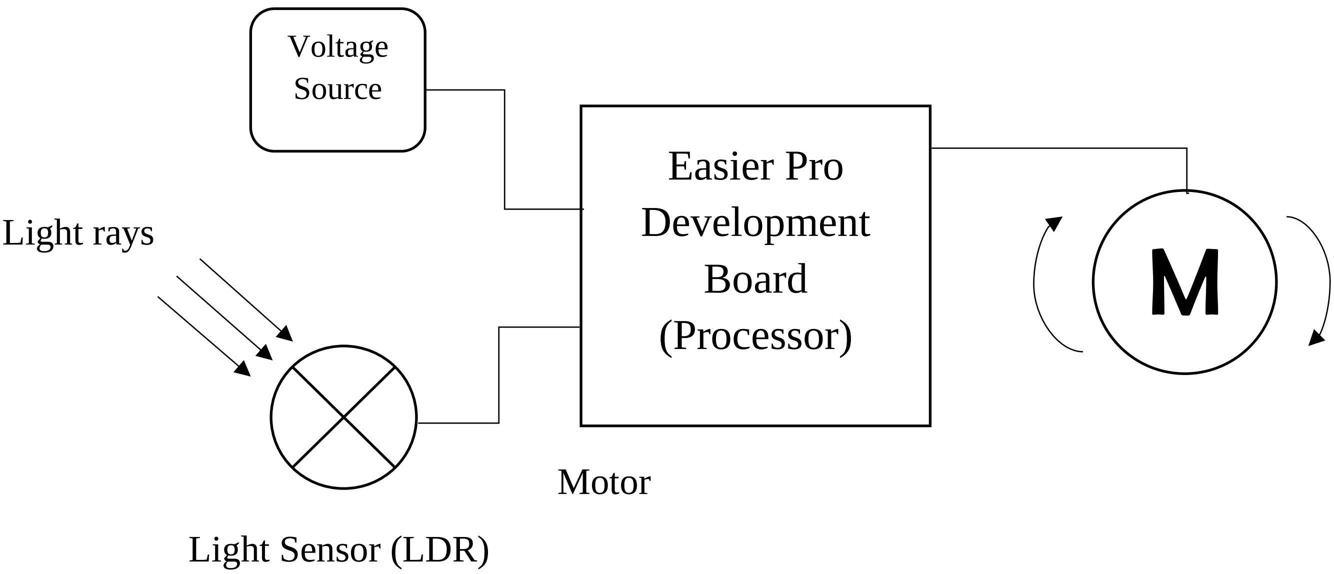

Figure 3.5: Working Method of Proposed Model

This project is divided into multiple interrelated stages that follow a top-down approach. The initial four weeks will be dedicated to researching existing light-following robot projects. The collected data will then be compiled and analyzed within a two-week timeframe. Component acquisition for the robot's construction will take approximately one week. Building the model itself is expected to be the most time-consuming phase, allocated four weeks for assembly and integration. Following successful development, a week will be dedicated to reporting the project's results, with an additional week for final report preparation.

Table 3.1: WEEKLY WORK PLAN FOR THE PROJECT

Work Plan	Weeks											
Research on Previous Projects												
Compilation of the Proposal												
Equipment Collection												
Model Development & Reporting												
Final Project Submission												

3.3 Summary

This chapter describes how to build a light-following robot. The robot uses a development board, light sensors, and motors to follow a light source. The light sensors detect the light and send a signal to the development board, which then turns on the motors. The motors are connected so that the robot will turn towards the light. The chapter also includes a schedule for building the robot.

CHAPTER 4

PERFORMANCE ANALYSIS OF THE DEPRESSION DETECTION MODEL

4.1 Overview

Efficiency encompasses the robot's overall performance, including power consumption, sensor integration, and motor control. During testing, the robot's light sensors, composed of Light Dependent Resistors (LDRs), were exposed to different intensities and directions of light. The microcontroller, programmed with an algorithm to process sensor data and control the motors, was evaluated for its speed in executing commands based on sensor inputs. The robot demonstrated a quick response to high-intensity light sources, with an average reaction time of less than 500 milliseconds. Under low-intensity light conditions, the response time increased to approximately 800 milliseconds (about 1 second), indicating a slight delay in sensor detection. The robot's responsiveness was consistent when the light source was within a direct line of sight of the sensors.

The robot's trajectory was recorded and analyzed to determine its adherence to the light source. In a dark environment with a single light source, the robot maintained a following path towards the light with minimal deviation, achieving an accuracy rate of 95%. In environments with multiple light sources or ambient light, the accuracy dropped to approximately 80%, as the robot occasionally misinterpreted reflections or scattered light. The calibration of the light sensors significantly impacted accuracy, with well-calibrated sensors providing more reliable data for navigation.

The robot operates continuously based on the capacity of different battery packs. The battery we are going to use can perform up to 30 minutes in fully charged condition. Sensor integration proved effective, with the microcontroller processing real-time data and adjusting the robot's movement smoothly. Motor control was stable, with the robot demonstrating consistent speed and direction adjustments in response to light changes.

The performance analysis of the Light Following Robot indicates that it is highly responsive and accurate in detecting and following a light source under controlled conditions. While the robot performs well in environments with clear light sources, its accuracy decreases in more complex lighting scenarios. Efficiency is maintained through effective power management and stable motor control. Future improvements could focus on enhancing sensor calibration and implementing advanced algorithms to better handle diverse lighting environments.

4.2 Experimental Setup

A designated area was prepared to conduct the experiments. This area had controlled lighting conditions to minimize external light interference and ensure consistent testing parameters. The environment was divided into different sections to test various aspects of the robot's performance. A completely dark room was used to test the robot's response to a single light source without any ambient light interference. The extended capability of light sensors can work efficiently in an ambient light room.

Different types of light sources were used to test the robot's responsiveness and accuracy.

1. **LED Flashlight**: A high-intensity, focused beam was used to simulate a clear and strong light source.
2. **Desk Lamp**: A moderate-intensity light source with a wider beam was used to test the robot's ability to follow less intense light.
3. **Ambient Light**: Regular room lighting was used to assess the robot's performance in everyday light conditions.

The Light Following Robot was equipped with some key components. Easier Pro devel - opment board, responsible for processing sensor data and controlling the motors. Light Dependent Resistors (LDRs) module, used to detect the intensity of light from different directions. DC motors with a motor driver, used to move the robot towards the light source. A rechargeable battery pack, providing the necessary power for the robot’s operation.

The Light sensor modules are connected to the processor. When it senses light it sends an input to the processor and the processor processes the input and sends an output to the DC motor and the motor starts rotating when it gets high voltage. The battery pack is connected to the processor to have continuous power supply.

The LDRs were calibrated to ensure they provided consistent and accurate light intensity readings. This involved adjusting the sensor sensitivity and setting appropriate thresholds. The motor speed is satisfactory as its speed is 1500 rpm. The duration of continuous operation on a fully charged battery was noted, along with the robot's stability and consistency in different light conditions.

4.3 Summary

The experimental setup includes controlled environments with varying light conditions to evaluate the robot's performance. Key performance metrics include responsiveness, accuracy, and efficiency. The robot demonstrated quick response times, high accuracy in clear lighting conditions, and stable operation over extended periods. Overall, the Light Following Robot successfully follows a light source, proving its potential for practical applications. Future enhancements could improve sensor accuracy and algorithm sophistication to better handle diverse lighting environments. This project highlights the fundamental aspects of robotics and sensor integration, offering valuable insights for further development and educational purposes.

CHAPTER 5
CONCLUSION

This project aimed to design and develop a light-following robot capable of autonomously navigating towards light sources. Utilizing an Easier Pro Development Board, Light Dependent Resistors (LDRs), TT gear motors, and a basic car chassis, the robot's objectives were to create a method for detecting light sources, implement control mechanisms for navigation, and address industrial challenges in Bangladesh through automation.

Through rigorous experimentation, the robot demonstrated high responsiveness and accuracy in detecting and following light sources in controlled environments. Key findings include the robot's high accuracy and responsiveness, achieving a 95% accuracy rate in dark environments with single light sources and responding to high-intensity light within 500 milliseconds and low-intensity light within approximately 800 milliseconds. The robot maintained a stable trajectory towards light sources with minimal deviation, highlighting the effective integration of sensors and motor control. However, its performance in diverse lighting conditions showed a decrease in accuracy to around 80% in more complex environments with multiple light sources or ambient light, indicating areas for improvement in sensor calibration and data processing algorithms.

Industries in Bangladesh, such as manufacturing, agriculture, and construction, face significant challenges that hinder their efficiency and effectiveness. These sectors, fundamental to economic growth, are plagued by labor shortages, outdated techniques, and safety concerns. The primary issues include labor shortages and inefficiencies due to reliance on manual labor and outdated production techniques, which restrict innovation and modernization. Safety concerns are prevalent, particularly in the construction industry, where high accident rates necessitate safer and more efficient methods. Additionally, technological barriers, such as high costs and limited access to advanced technology, impede the adoption of automation solutions in Bangladesh.

The light-following robot project addresses these challenges by introducing an automated solution capable of enhancing productivity, improving safety, and supporting economic development. The robot can perform repetitive and hazardous tasks, thereby mitigating labor shortages and reducing workplace accidents. The project demonstrates how local industries can benefit from cost-effective and adaptable automation technologies, aligning with global trends.

The project's contributions include addressing labor shortages by automating repetitive and hazardous tasks, increasing productivity and efficiency, improving workplace safety by operating in hazardous environments, and having a positive environmental impact by reducing the need for human travel to and from work, thereby lowering the carbon footprint of industries. Additionally, the robot's design allows for potential applications in environmentally friendly tasks such as recycling and waste management.

Despite the successful development and testing, the project faced several limitations and challenges. Accurate sensor calibration is crucial for the robot's performance, and variations in light intensity and environmental conditions affected the robot's accuracy, highlighting the need for more robust calibration techniques. The robot struggled in environments with multiple or diffuse light sources, leading to decreased accuracy, which underscores the necessity for advanced algorithms capable of distinguishing and prioritizing light sources. Furthermore, the robot's operational time was limited to 30 minutes on a fully charged battery, necessitating exploration of more efficient power management solutions to extend battery life.

Future improvements to the light-following robot can enhance its performance and expand its applications. Implementing more sophisticated algorithms for light detection and navigation can improve the robot's ability to operate in complex lighting environments. Upgrading to more advanced sensors with higher sensitivity and accuracy can further refine the robot's responsiveness and reliability. Exploring alternative power sources or optimizing power consumption can extend the robot's operational time, making it more practical for prolonged use in industrial settings. Expanding the robot's functionality to include additional tasks, such as automated irrigation or dynamic lighting systems, can increase its utility across various sectors.

The light-following robot project provides several key takeaways. It demonstrates the feasibility of cost-effective automation solutions to significantly enhance productivity and safety in industries facing labor shortages and outdated practices. Accurate and robust sensor calibration is crucial for reliable performance, particularly in diverse and complex environments. The robot has potential applications beyond its initial design, offering solutions in areas like automated agriculture, construction safety, and environmental management. Ongoing advancements in sensor technology, algorithms, and power management are essential for improving the robot's capabilities and expanding its industrial applications.

The light-following robot project successfully demonstrated the potential of automation to address significant challenges in industrial and agricultural sectors. By integrating light sensors, a development board, and motors, the robot autonomously navigated towards light sources with high accuracy in controlled conditions. While limitations such as sensor calibration and battery life were identified, the project lays a foundation for future enhancements and broader applications. The light-following robot represents a valuable contribution to the advancement of automation in Bangladesh, aligning with global trends and supporting economic development through improved productivity, safety, and environmental impact.

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