DESIGN AND IMPLEMENTATION OF A HAND GESTURE-CONTROLLED WHEELCHAIR

By

Rohit Shil
19321036
Md. Moinul Islam
16121007
Abdullah Al Mamun
18221037
Arian Mahamud
18321032

A Final Year Design Project (FYDP) submitted to the
Department of Electrical and Electronic Engineering
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Bachelor of Science in Electrical and Electronic Engineering

Academic Technical Committee (ATC) Panel Member:

Dr. Touhidur Rahman (Chair)

Professor, Department of EEE, BRAC University

Mr.Shahed Alam (Member)

Senior Lecturer, BRAC University

Department of Electrical and Electronic Engineering
Brac University
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Declaration

It is hereby declared that

1. The Final Year Design Project (FYDP) submitted is our original work while completing a degree at Brac University.
2. The Final Year Design Project (FYDP) does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The Final Year Design Project (FYDP) does not contain material that has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. I/We have acknowledged all main sources of help.

Student's Full Name & Signature:

Rohit Shil 19321036	Md. Moinul Islam 16121007
Abdullah Al Mamun 18221037	Arian Mahamud 18321032

Approval

The Final Year Design Project (FYDP) titled "Design and Implementation of a Hand Gesture Controlled Wheelchair" submitted by

1. Rohit Shil (19321036)
2. Md. Moinul Islam (16121007)
3. Abdullah Al Mamun (18221037)
4. Arian Mahamud (18321032)

of Fall, 2024 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Bachelor of Science in Electrical and Electronic Engineering on 08-01-25.

Examining Committee:

Academic Technical Committee (ATC):
(Chair)

____
Dr. Touhidur Rahman
Professor, Department of EEE,
BRAC University

Final Year Design Project Coordination Committee:
(Chair)

____
Mirza Rasheduzzaman, PhD
Associate Professor, Department of EEE,
BRAC University

Department Chair:

____
Dr. Md. Mosaddequr Rahman
Professor & Chairperson, Department of EEE,
BRAC University

Abstract/ Executive Summary

The head movement-controlled electric wheelchair is a significant advancement in helping enhance the mobility of disabled persons. This ingenious system involves a cap-mounted accelerometer hooked up to an Arduino Nano microcontroller, which detects movements and maps them to directional instructions. This enables the exact functioning of motors with the help of a dual motor driver which is powered by a 24V battery. To guarantee the safety of the device, a voltage regulation mechanism on the exporting side acts to protect components by holding power at a specific point. Thanks to adaptive code logic, the hands-free device is made smoother and more stable throughout the project. The joystick-free system benefits user function ability but could be a cause for concern for users with a restricted hand motion.

A completely new hardwired configuration (and some coding to eliminate signal noise while moving). This outcome is a cost-effective, intuitive solution that significantly enhances independence and quality of life for the end-user. This device effectively solves the theoretical problem of helping the impaired navigate through a combination of planning and design, which is what makes it such a unique solution.

Keywords: Assistive technology; Electric wheelchair; changes; head gesture control; accelerometer; Arduino Nano; motor driver

Dedication (Optional)

We dedicate this project to our great guides, ATC Touhidur Rahman, Shahed Alam Sir, whose guidance, inspiration, moral support, and expertise have made it possible of such great work completion. The encouragement and advice you've given us in those moments has helped remind us to stretch ourselves to reach our dreams. We are ever grateful to your patience, persistence, and confidence in us, that has added to our learning experience manifold, and indeed prepared us well to face future challenges in our professional lives. Thank you for being guiding lights for us.

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Chapter 1: Introduction- [CO1, CO2, CO10]

1.1 Introduction

Assistive technologies may have been a great breakthrough in mobility impairment. The project is an electric wheelchair, controlled using gestures through surface EMG electrodes and an accelerometer, which gives it a unique selling point. Their goal is to bridge the gap between the world of accessibility and new technologies so that the user maintains its independence and mobility and that it is relevant.[8]

This chapter focuses on the project's background, the motivation behind the work, the objectives and limitations, and the considerations that informed project development.[1] Additionally, it analyzes the correspondence between the solution and best practices in the sector, giving a visual representation of the solution's perspective and value over the shorter-term and long-haul viewpoints, so as to demonstrate that innovation is there to bring value to the community.

1.1.1 Problem Statement

While recent years have seen technological evolution in designing assistive devices, there remains an empty void in not providing a personalized and low-cost solution for impaired people. Conventional designs like a manual or battery powered model that relies on joystick control are common but can be challenging for users with impaired hand mobility as well as decreased dexterity or other disabilities.[1]

The feeling can range from frustration to persistence well into the latter being physically impossible; the very nature of gripping a joystick itself can feel exhausting and deadening; a terrible irony given the nature of this game and the addictive elements to boot. However, these classic joystick-driven designs prevent a truly adaptable experience as a seamless, empowering, and independent user experience is unattainable.

Moreover, while the advancements in assistive technology and related sectors have been significant, the market still falls short in providing reasonably priced systems that offer high-performance gesture-control features.[1] While these next-generation systems can significantly improve user autonomy (working hands-free using eye and head movements), they are out of financial reach for most potential users.

The expense of these systems puts them out of reach for the majority of the population that would benefit most from them. As a result, many people with mobility challenges do not have access to these sophisticated solutions, restricting traction within their ecosystem of movement even more permanently.[8]

Considering these challenges, our project stands to fill these gaps by preparing a gesture-controlled wheelchair that is low cost, effective and user friendly. So using gesture-based control, the system could be controlled by simple, intuitive movements to allow someone with limited hand mobility or dexterity to operate their wheelchair without traditional joysticks.[1] So, not only does this offer a more viable solution to users but also keeps the system cost-efficient, within the grasp of a broader population.

Our project places a significant emphasis on two critical aspects — accessibility and affordability, ensuring, as far as we can, that the tech is within reach of the user, both physically as well as financially. [1]

To get this advanced gesture-control technology at such a low cost marks a breakthrough in the world of assistive tech. In addition to revolutionizing mobility solutions in the disabled people's domain, this endeavor aims to enhance the quality of life of users by providing greater empowerment through their independence. [5]

In summary, our project aims to create more customizable, cost-effective, and accessible mobility solutions, providing individuals with mobility challenges the ability to reclaim independence and agency in their day-to-day activities.

1.1.2 Background Study

Great achievement has been made to different wheelchairs based on gesture modules that offer disabilities a fresh way of accessing their surroundings. However, these systems are exposed to major problems. However, one of the problems using them is the fact that expensive hardware is required to achieve best results, limiting their use to a few potential users. [8]

The cost is thus currently out of control and serves as a hindrance to those who stand to gain from such technologies.[1] Moreover, although these gesture-based systems present a great opportunity for user control, they currently have severe limitations with much room for development to be more useful and realistic.

Surface electromyography (EMG) and accelerometer-based control systems are among the technologies that have shown considerable promise in overcoming some of the technical and cost-related hurdles.[8] Such solutions are especially useful when interpreting muscle movement or gestures to allow control signals, possibly providing users with more natural means of commanding their wheelchairs. [1]

However, those technologies are still going to need to be tweaked to find the best balance between performance and cost. Most existing work focuses on different aspects of the problem individually — either speed up hardware or bring down the cost — rather than as a unified, integrated problem.

As opposed to this previous work, our study is grounded on the same principles yet expands further. We present a holistic solution that involves very cheap components that can be connected together i.e. Arduino Nano, motor drivers and EMG sensors. [8] We achieve this by amalgamating these variables to build a realistic as well as smart system that not only satisfies the functional requirement of the users but is also financially feasible. This however, enables us to create a tangible solution that would provide real value and a defined feature set that will together enable value addition to the segment.

But this approach is a major step forward in the field of gesture-based mobility solutions, moving away from expensive hardware toward an affordable and practical solution for those in need. By tackling not only the technical but also the economic challenges, we are taking a huge step towards a tool that is not only feasible but also opens up a significantly enhanced benefit for people with disabilities in terms of quality of life and freedom of movement.

1.1.3 Literature Gap

A detailed analysis of the current body of work in the literature points out some limitations of gesture control systems for mobility devices which hinder their general usability and adoption. Such constraint ranges from costly to rigidly built equipment, as well as user-unfriendly designs that oftentimes do not cater to individuals with mobility impairments.[1] Some current prototypes even lack key features to maintain the stability of movement and adapt to the unique requirements of individual users.

This project aims to fill some of these gaps with innovative approaches. It will include advanced signal processing frameworks to ensure the system is more reliable and responsive.[1] Smoother control of the wheelchair will be achieved through the optimization of an algorithm, which will allow the wheelchair to respond smoothly and accurately to commands made using the user input device. [8]

Another step the system will take is a nice, well-organized GUI for better user experience and easy understanding.[6] The goal was to create mobility benefits from these domains in a way that addresses limitations, while creating a device that establishes and sets a local standard for a relatively low cost, with a heavily customizable, user-driven, and intuitive gesture-controlled solution.

1.1.4 Relevance to current and future Industry

As the demand for assistive technologies increases, there is a growing need for sophisticated solutions that incorporate embedded systems and sensors, machine learning, and other assistive solutions. Incorporating these advanced technologies enables assistive devices to become more powerful and sets the foundation for the development of intelligent, adaptable systems that can continuously adjust to the changing demands of individuals.[1]

It is particularly remarkable the growth potential of smart wheelchairs. Over the next few years, developments of smart mobility aids are projected to induce significant growth in the wheelchair market.[8] Fully integrated with intelligent behavior and use case features for independence and accessibility, these devices have significant potential in the future of mobility solutions.

This is a trend that we have embraced with our project, demonstrating our forward-thinking, innovative, and adaptable business philosophy. We not only meet the immediate needs of those suffering from mobility impairments, we also future-proof the system, with the system being easily upgradable or modularized as new challenges arise from advancing health care and robotics. [6]

This dynamic and responsive future-ready solution is a testament to our vision for designing mobility aids that are not just dependable and cost-effective but also future-proof with emerging technologies.

1.2 Objectives, Requirements, Specification and constant

1.2.1. Objectives

We present a unique approach to mobility using a low-cost EMG and accelerometer based electric wheelchair which allows control of the chair with hand gestures for better mobility and accessibility of individuals with disabilities.

Using gesture recognition, this groundbreaking device enables users to pilot the wheelchair with ease, offering a hands-free alternative that helps overcome both challenges encountered by those lacking dexterity in their hands. The system incorporates EMG sensors that use detected electrical activity from muscles and an accelerometer, which measures motion and orientation, to accurately interpret commands from the user.[1]

Movement stabilization and user safety are key features of the design. They achieve this through the tuning of control algorithms, which improve the responsiveness of the system and allow in-situ travel through complex environments.

In addition, the project is designed to be scalable, where it could be adjusted to a different mobility needs. Such flexibility guarantees that the wheelchair can meet diverse needs, serving as a versatile and inclusive mobility solution.[3] The design establishes a standard for gesture-controlled mobility devices through consideration of affordability, safety, and scalability.

1.2.2 Functional and Nonfunctional Requirements

- Functional Requirements: This project is designed to satisfy a number of functional requirements, ensuring that the system serves end users effectively and reliably:

1. Ideal concept of detecting hand gestures in real time: The wheelchair will use advanced sensors like EMG sensors and an accelerometer to detect and process hand gestures in real-time. This feature allows it to respond instantly to user commands, resulting in a natural and smooth control experience.[4]
2. Stable control over-motor systems: The system will include precise motor drivers that will allow for stable motion in all the directions - forward, backward, left, and right. Such stability keeps users safe and confident of the movement of the wheelchair even in different environments.

3. Safety features: The design implements obstacle detection and buzzer alerts to keep users safe. These safety features warn users of warning hazards to avoid collision and other safety hazards.[3]

- Nonfunctional Requirements: The project also targets some critical nonfunctional requirements, which are vital for practicality and sustainability:

1. Cost-effective and crane-efficient assembly: The vehicle is used in an affordable manner and yet not in a poorly built way. It will be built with low-cost parts and materials that minimize assembly, which means it will be simpler to manufacture at scale.

2. Compatibility with existing wheelchair hardware: Since the system was designed to integrate with current wheelchair models, users are not required to replace the entire hardware making it a feasible upgrade.

3. Minimal power consumption: The architecture has a significant aim to minimize power, thus extending battery life and reducing the cost of recharging the sensors. This is done by making all components from sensors to motor drivers power-efficient as much as possible.[4]

1.2.3 Specifications

Each message and each packet are processed within a few microseconds since the Arduino Nano was chosen to be the microcontroller in charge of reading the values from the sensors to have our outputs (gestures for controlling wheelchairs) processed in a very short time.

- Independent Left/Right Motor Control: Featured two motor drivers permit both left and right motors to run independently, resulting in a smooth and precise direction of movement.[4]

- Accelerometer-based gesture input: By capturing hand or head movements using an accelerometer, gestures can be converted into commands that guide the movement of a wheelchair.

- Power source: A standard 24V battery has been used to power the system since it conforms to the motor requirements and supplies constant energy for a longer time.[3]

1.2.4 Technical and Non-technical consideration and constraint in the design process

Technical Considerations: A key technical challenge will minimizing noise in accelerometer readings. To reduce errors and stabilize the signal, filtering techniques have to be applied, as these errors can impact gesture recognition and the performance of the wheelchair.

Non-technical Considerations:

The design process also integrates critical non-technical considerations, promoting user-centric and sustainable practices:

- Socio-ethical (affordable-accessible): The project intends to provide an inexpensive solution that can be accessed by as many as possible, including those who do not have enough money.

- Environmental sustainability: The system incorporates low-power components to reduce energy usage, leading to a more sustainable design. Taking an environmentally sustainable approach through the use of power-efficient parts.

1.2.5 Applicable compliance, standards, and codes

- ISO 7176 compliance for electric wheelchair safety.
- Electromagnetic compatibility regulation adherence.
- Integration of ergonomic design features

1.3 Systematic Overview/summary of the proposed project

Adopting an accelerometer-based control system, the unique attempt is to provide an electric wheelchair being controlled by gestures to help the people facing difficulties in mobility. The microcontroller used in the system is an Arduino Nano that efficiently reads and processes input data from the accelerometer. User gestures — typically tracked through head or hand movement- are converted into a specific motor command, allowing the robot to make on the fly decisions regarding navigation.[3]

Dual motor drivers allow each motor to be controlled individually, which is a major feature. The independent control improves the wheelchair agility, allows the user to turn promptly and effortlessly without losing balance and keeps stability during the maneuver.[4] Furthermore, it is equipped with various safety systems such as buzzer alerts that signal when the user is at risk or when certain components are about to disengage, and movement stabilizers to ensure smooth traveling over bumps and uneven ground.

All these functions are incorporated in such a way that users can confidently operate the wheelchair, thereby improving their mobility and autonomy. The project combines cutting-edge technology with user-centric safety enhancements to create a safe and intuitive mobility aid for those who need it.

1.4 Conclusion

This chapter discusses the basic details of our project, its importance, goals, and why we adopted a systematic approach to accomplish these goals. The project aims to address the pressing need for innovative solutions in the field of assistive technologies, enabling individuals with mobility challenges to achieve this. Combining cutting-edge technologies such as gesture-based control and accelerometer-based input, our product will provide a low-cost, user-friendly, and effective mobility assistant.

Our focus is primarily to fill the existing gap in the market with a solution and providing a seamless experience to the users. We focus on not only improving the technical capabilities of motorized mobility devices, but also working towards making them accessible and inclusive for everyone. This project aims to be an example in assistive technologies, through research and prototype construction, ultimately engineering a device with practical use in a variety of situations.

The technical implementation will be discussed in future chapters - integration of components (Arduino Nano, motor drivers, safety mechanisms, etc.) and other details will be addressed in detail. In addition, they will highlight some of the struggles met during the development process, as well as what our solution hopes to achieve in terms of quality of life for its users. We believe our systematic approach can set a new gold standard for mobility devices — and we hope we inspire new ways of thinking about the next generation of assistive technologies.

Chapter 2: Project Design Approach [CO5, CO6]

2.1 Introduction

One of the important considerations for success in this project is the choice of the right design for electric wheelchair control. The aim is to create an intuitive control system that is precise, responsive, and customized to the requirements of users with limited mobility. “How do we build something that’s super intuitive to drive, but also super reliable and accurate, that gives you all this control over your motion without heavy physical input?”

In this chapter we examine and discuss two different design strategies for gesture-based control of the wheelchair:

1. EMG Muscle Sensor-Based Approach: In this approach, electrical activity in the user’s muscles is detected by EMG (electromyography) sensors. The system works by interpreting the user’s intention through analyzing his muscle contractions and translates it to commands for the motors of the wheelchair. One of the big advantages of this approach is its direct connection to muscle signals, paving the way toward an intuitive control interface. However, the accuracy of the muscle signals may differ from person to person, and the complexity of interpreting those signals may come at the expense of user fatigue or muscle weakness. Furthermore, the cost and feasibility are considerations since the EMG sensors and processing equipment may be more expensive and intricate to put into action.[6]

2. Accelerometer-Based Approach: In the second approach, accelerometer sensors are applied to determine head or hand gestures. An accelerometer detects changes in speed and direction, enabling operation of the wheelchair through basic, natural motions. As such, it is easier to implement, and less expensive than EMG-based systems. This is a very cost-effective and easy solution which makes it very possible, especially for people who have limited hand mobility but can still move their fingers or head a little bit. Acceleration can rely on a fair amount of calibration to avoid false readings or noisy signals while moving.[4]

2.2 Identify multiple design approaches

We identified two control mechanisms that we would need to have in place to achieve our project goals:

Approach Based on EMG Sensor of Muscle:
This design detects muscle activity and generates control signals for the wheelchair by utilizing surface electromyography (EMG) sensors. Using electrodes placed on particular muscle groups, commands are generated that vary with muscle contraction.

Accelerometer-Based Approach:
It uses accelerometers to sense tilt angles and motion, so that patients with disabilities can operate the wheelchair just by moving their head or hand. The accelerometer reads axis X and axis Y, a directional command.

2.3 Describe multiple design approaches
Two existing gesture signal processing algorithms were analyzed for controlling the electric wheelchair: one based on EMG muscle sensor outputs and another based on accelerometer outputs. And they each provide a different approach to how user commands are parsed and converted to motor functions. In the following, we outline both approaches in detail, including the core asuoments involved in their implementations.

Electromyography (EMG) Muscle Sensor Based Approach

The EMG and muscle contractions method deals with detecting the contractions of a muscle and using it for the wheelchair motion. This electrical signal is generated when a muscle contracts to do so, which can be detected by EMG sensors located on a particular group of muscles. These receptors pick up on these signals, which are usually weak, and amplify them to be read better. [6] After the signals are recorded, they are fed through a signal conditioning circuitry that filters excess noise or any other unnecessary signals, which ensures that just the required muscle activity is detected.

The processed signals are then transmitted to an Arduino Nano microcontroller, which processes the signals and outputs the control commands accordingly. For instance, flexing or releasing a muscle, may direct the wheelchair to move forward, stop, or turn. In this method, the Arduino Nano plays an important role as it helps interpret the signals and convert them into motor commands which are sent out to the motor driver circuits to control the motors of the wheelchair.

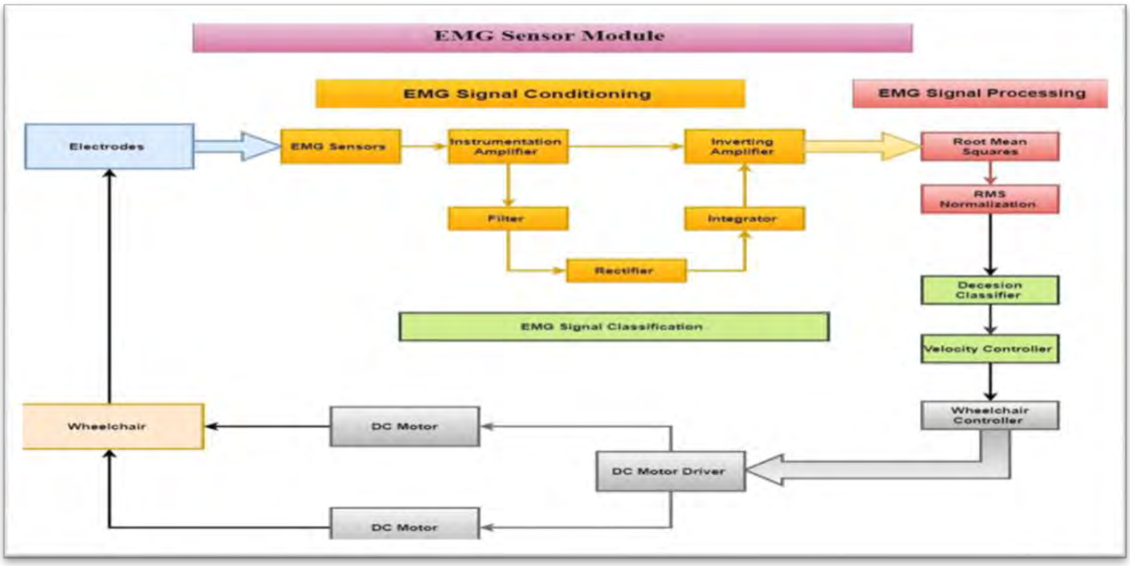

Figure: Block Diagram of EMG Based Design Approch

Components Used:

EMG sensor module: It can detect muscle activity by sensing the electrical signal generated by its contractions.

Signal conditioning circuit: Responsible for amplifying and filtering the EMG signal for accurate processing.

Analog Signals Processing: An Arduino nano is a small microcontroller that performs the signals and translates the signals into movements.
Motor driver circuits: Drives the wheelchair motors according to the processed signals.

Accelerometer-Based Approach

This method works by reading an accelerometer and measuring motion as well as tilt angles on both the X and Y axes. This approach is well-suited to those who lack the strength or dexterity to perform muscle contractions themselves but can still move their head or even their hands slightly. This will detect movement in relation to the user's body position. [2] Like if the user leans forward, the wheelchair moves forward and if he leans left or right, the wheelchair moves accordingly.

Once again, utilizing the Arduino Nano for processing the tilt data from the accelerometer and converting it into commands to the motors. The Arduino subsequently relays the commands to the circuits that drive the wheelchair's motors. This method can be especially beneficial for people who cannot move well, as controls can be made to respond to a small amount of motion, such as a tilt of the head or the hand.

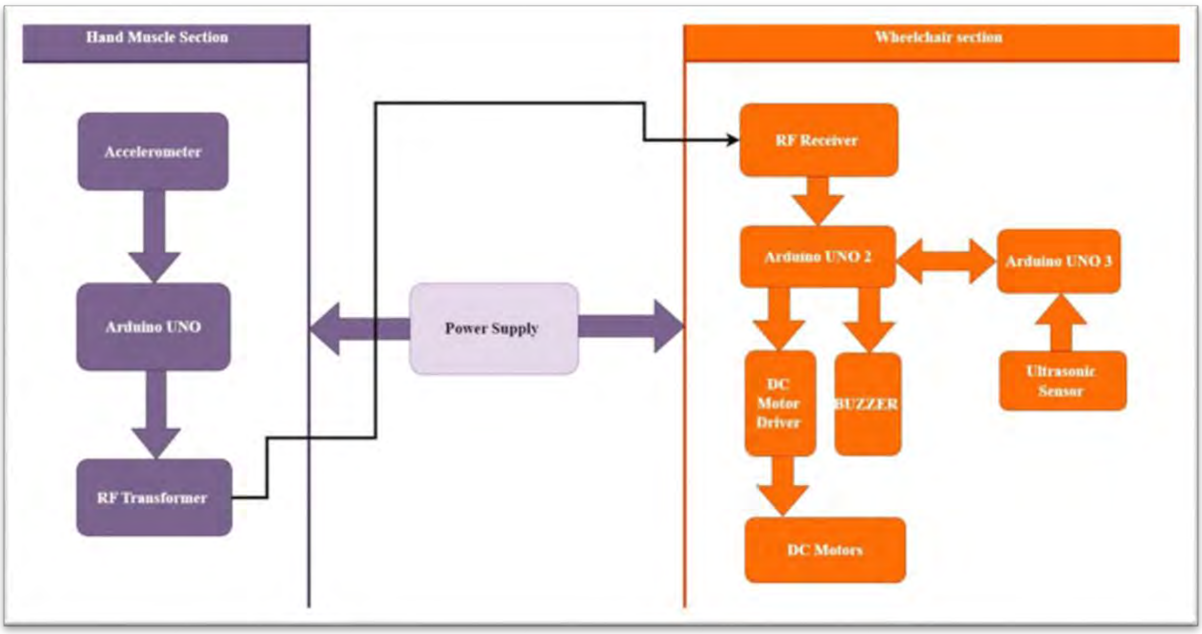

Figure: Block Diagram of Accelerometer Design Approach

Components Used:

ADXL345 Accelerometer: Small, low-power accelerometer, measuring tilt and movement in X and Y axes.

Arduino Nano: Handles the tilt information received from the accelerometer and produces movement commands.

Digital pin of the Arduino is the output pin to PID motor driver circuits.

2.4 Analysis of Multiple Design Approach

EMG Muscle Sensor-Based Approach
Advantages:

- High-resolution recording of muscle activity.
- When used to stimulate the muscle, it allows for an intuitive control mechanism for those with voluntary muscle contractions.
- Less prone to accidental inputs via slight head or body movements.

Challenges:

- Signal processing circuits that extract information from noise must be finetuned.
- Inappropriate for users with very little muscle control.
- Costlier than accelerometer -based systems.

Accelerometer-Based Approach
Advantages:

- Easy and widely available implementation.
- Natural movement head or hand movement control Easier to calibrate than EMG-based systems.

Challenge:

- Sensitive to inadvertent shifts causing unintended taps.
- Trained on data until October 2023.
- Sometimes not useful for most people with limited ability to move.

2.5 Conclusion

Upon analysis and careful consideration of the two design approaches, the accelerometer-based solution was chosen as the most ideal for this project. They opted for the accelerometer method in a way that was best overall for most people (even disabled at a low price) due to: Simplicity, affordability, and Ease of use.Although the EMG sensor-based design provided higher accuracy in terms of detecting muscle movements, it also had many limitations. For one, it was more complex to execute—requiring the precise placement of electrodes and the careful processing of the signal.

Additionally, the tightly controlled muscle contractions required to produce control signals limited the accessibility of this method, as it would not be a suitable option for someone with low or zero muscle control. In addition, the cost of EMG sensors and the required accompanying hardware (like signal conditioning circuits) limited its use outside a medical setting.

In contrast, using an accelerometer offered a far more practical and sustainable solution to a real-world problem. It moderated slight tilts and motions tilting their head or hand, which was intuitive and accessible for the users, which the accelerometer could easily detect.

While calibrating the accelerometer is more cumbersome because it needs to be performed every time it's used, the calibration process is easily worth the effort since it is not as complicated as EMG sensor setup.

Additionally, the inexpensive properties of accelerometers were also a very scalable solution to create affordable assistive technologies, contributing to addressing the challenge of creating solutions accessible to individuals with a mobility impairment.

In the end, they ended up choosing the accelerometer-based solution as it could deliver the optimal solution in terms of cost, performance, and accessibility, making it the more pragmatic solution for a larger share of the target audience. Due to it being so simple and cost effective it was the best method of targeting people with a range of mobility issues.

Chapter 3: Use of Modern Engineering and IT Tool. [CO9]

2.6 Introduction

With the modern trend of engineering, use of modern tools of engineering design and IT (Information Technology) is not only beneficial but also an essential in finding solutions to real, complex problems in the most efficient and effective way possible. These tools have become key in this undertaking and are used in the design, simulation, analysis, and validation stages of the project especially in the field of advanced technology. We developed a gesture-controlled wheelchair involving surface electromyographic (EMG) signals and accelerometers as core elements for this project. This project utilizes a range of state-of-the-art engineering tools and techniques to turn this concept into a reality. [5]

The main goal of this project is to devise a wheelchair system for helping people having limited movement and can control their wheelchair by using simple gestures of their hands. Using surface EMG sensors to detect activity of the person's muscles when they are preparing to gesture, and accelerometers to detect the orientation of the person's head or body, the system could then interpret these gestures as commands to the wheelchair's motors. [6] We aimed at making the worked system functional, reliable, and user-friendly, which is only feasible by using even recent engineering tools available and hiding most IT solutions for the end-user.

Introducing the tools and technologies that were selected and used as part of the development phase of the project will be covered in this chapter. These tools were crucial in tackling the challenges presented in designing a wheelchair control system that was accessible, affordable, and effective. The project would encompass simulation software for testing and validation of the design and hardware tools for building and integrating components; this chapter will provide an overview of tools that were used and processes undertaken to meet the enables aims of the project.

2.7 Select appropriate engineering and IT tools

Tools for engineering and IT were selected specifically for the requirements of this project focusing on hardware interfacing, circuit simulation, signal processing and control systems. These tools were selected because their compatibility, accuracy, usability, and effectiveness to the core tasks of the project. Using these tools simplified the process of designing, developing, and validating the gesture-controlled wheelchair.

Device Interfacing and Control:

Tools were chosen to ease hardware interfacing and system integration. The code was written using the Arduino IDE and uploaded to an Arduino Nano, which acts as the central controller for the wheelchair. It was a critical resource in designing accurate control algorithms and facilitating the system's real-time response.

Circuit Design and Simulation:

The Proteus Design Suite was used to unite the solution of the electronic circuits for the operation of the wheelchair. Used software to design and simulate circuits to ensure connection and functionality before building on real hardware The circuits were simulated first, greatly reducing the risk of making mistakes and optimizing the hardware assembly process.

EMG Signal Pre-processing:

Features of EMG based gesture control techniques were implemented in the project. MATLAB was then employed to identify the necessary filtering and noise reducing step as well as pre-process the signals for recognition. The strong analytical capacities of MATLAB guided the refinement of the signal processing pipeline to focus on accurately detecting muscle activity that would provide for reliable wheelchair control. [6]

Mechanical Modeling:

Modeling of the mechanical components of the wheelchair (motor mounts, sensor placements, etc.) was done during this process and viewed in conjunction with the base structure of the wheelchair. Optimizing coupling between electronic and mechanical components is an important step towards maximizing design stability and practicality.

2.8 Use of modern engineering and IT tools

We used various kinds of tools like these extensively during the project for ease in design and development.

Proteus Design Suite: This is used for designing, simulating and testing of our electronic circuits related to wheelchair system. This enabled the software to generate a simulated model containing the links that could be tested and verified by the design, minimizing hardware errors.

With the help of Arduino IDE we wrote some easy and efficient c/c++ code to read accelerometer and EMG sensor using Arduino Nano microcontroller. It was adding debugging tools to the mix, and enabling the components to talk seamlessly.

MATLAB for Signal Processing: MATLAB was used to analyze raw EMG signals. It enlightened us on what filtering and amplifying we need to conduct to extract signals for controlling the wheelchair. [6]

Mechanical Design Find a stable ergonomic structure for a wheelchair using Fusion 360 Using the software allowed us to plot points of mechanical stress and run simulations to verify durability and safety during the end-user usage.

Oscilloscope and multimeter: For hardware implementation and testing the system performance was monitored for validation, and to check the signal flow through components ontinuous signal flow for system stability.

2.9 Conclusion

The completion of this project successfully showcases the contribution of modern engineering and IT tools in attaining efficiency, accuracy, and reliability. Key tools used to assist in the design, simulation, and validation processes are Proteus, Arduino IDE, MATLAB, and Fusion 360, which all reinforced the designs to fall under the required specifications of the final prototype.

Using Proteus, we simulated and validated circuit topologies even before hardware, reducing errors greatly. Real-time control of the wheelchair's functionality and basic code writing was done through the Arduino IDE. MATLAB was used for accurate, pre-processing of EMG signals for noise-less and accurate gesture recognition. On the other hand, Fusion 360 facilitated the detailed modeling of the wheelchair's mechanical components, ensuring smooth integration with electronic systems.

Deploying and using these workbenches very effectively did not only help us engineer the solution to the engineering challenges we faced but also ensured we delivered a working wheelchair system based on control-by-hand-gestures. With data from October 2023, it highlights the role of contemporary devices in connecting the gap from idea to physical application, paving the way for further technological advancements in the assistive field.

Chapter 4: Optimization of Multiple Design and Finding the Optimal Solution. [CO7]

4.1 Introduction

Once a solution is developed, it often must be optimized (which may require further interdisciplinary analysis) before it is possible to determine whether the solution proposed is not only viable but also optimal relative to cost and efficiency as compared to a host of other potential solutions. By optimally balancing the competing factors of performance, resource consumption, and cost, resource optimization is key to producing high-quality products and services. This chapter details the systematic optimization of the several design approaches described in this project to find the best overall design solution for a gesture controlled electric wheelchair. [2]

It started with scoring each of the raw design strategies against parameters such as cost, usability, accuracy, and feasibility. To this end, the EMG muscle-sensor methodology was evaluated in terms of precision and motor control abilities; yet, it ultimately emerged as less palatable as it was highly complex and required defined muscle contractions. [4] On the other hand, the accelerometer-based design exhibited a more well-rounded balance of simplicity, cost-effectiveness, and user-friendliness, which rendered it the most suitable alternative in practical applications.

The optimizing operations on the selected approach involve algorithms refinement, signal processing optimization, and components integration. The sensitivity to reaction to tilt-motion was further refined, and noise in the data was filtered out as much as possible. The motor control algorithms were fine-tuned for smoother motion and increased stability to improve user safety and comfort. [4]

We thoroughly tested the final solution under a variety of operating conditions to validate its performance and ensure it aligned with the project's goals. This systematic optimization process not only affirmed the feasibility of the accelerometer-based method but also established a foundation for further innovations in adaptive and accessible mobility technologies.

4.2 Optimization of multiple design approach

In this project, two general design paradigms were utilized and explored to control the electric wheelchair: The EMG Sensor Based Design and the Accelerometer Based Design. Both approaches were evaluated in detail, alongside project requirements, including cost, efficiency, usability and sustainability, to determine the best fit for the needs of the project.

<u>EMG Sensor-Based Design</u>

To do so, it used surface EMG sensors to detect muscle activity. Instrumentation amplifiers, filters, and rectifiers were used to obtain the muscle contraction signals leading to accurate and trustworthy MATLAB characterization of signals. Electromyography (EMG) – sensitive to the electrical signals generated by muscles at contraction – has also been incorporated as an input method type for wheel-chair control, providing a direct interface between the user and control of the wheelchair. [5]

Pros:

Accuracy: The EMG design is great for users with limited mobility, as it is particularly good at detecting muscle activity. For the users of a powered wheelchair (PW), it provides the high-accuracy control based on muscle signals needed for more nuanced and direct control of their wheelchair.

Direct Interface: As we will see, those designed with a natural control system where the device responds to muscle contractions may be ideal for people with partial mobility in their hands or limbs.

Cons:

Electromagnetic Interference: EMGs are susceptible to electromagnetic interference from other devices, which can corrupt the signal, making it hard to guarantee reliable operation in all environments. These requirements introduce additional design and implementation complexity due to the necessity for noise-free signals.

Electrode Location and Calibration: Electrode placement on the skin can be error-prone, and if the placement is incorrect, calibration can also be inaccurate, leading to a longer setup process and frequent recalibration to maintain accuracy. [6]

<u>Accelerometer-Based Design</u>

Accocumented-controlled wheelchair: The accelerometer-based design used the ADXL345 accelerometer that allows detection of tilt and movement, a motion that can be used for wheelchair control, based on user head or hand gesture to control movement. DX requirements such as X and the Y axis orientations are converted to DX using the accelerometer sensor.

Pros:

Affordable: Simple and cheap design, hence very affordable for users as well as producers. It uses less calibration, which means you spend less time and effort setting up the system.

Robustness to Noise: EMG sensors can be susceptible to noise and interference, whereas accelerometers are less likely to be affected and can thus be utilized in a broader range of environments. These tend to detect macro patterns of motion, which makes them inherently less reliable in non-ideal situations.

Cons:

Sensitivity Limitations: The accelerometer-based design does not provide sensitivity for subtle movements or small movements, which could be a drawback for users who have limited use of their hands or little motion. It requires more precise motions to navigate the wheelchair properly, which can be an issue for some users. [7]

User Adaptation: Users with limited mobility might struggle to create the necessary bump or tilt for control, especially in the case of insufficient muscle coordination or strength.

4.3 Identify optimal design approach

Following thorough consideration of several critical criteria, the decision was made to select the accelerometer-based design over the EMG sensor-based design. All of these influenced what was the best choice for implementing the gesture based control system for the wheelchair.

Cost:

The accelerometer-based design was conclusively more cost-effective than the EMG design. By keeping the component list small, with an ADXL345 accelerometer, to simple motor driver circuits, we allow for a low-cost solution overall. The EMG-based design, however, requires more sophisticated and expensive components, such as surface EMG sensors, amplifiers, and filters that increase the cost. Using only accelerometer-based design costs less making it easy for the device to be affordable and popular, especially for disabled people who need low-cost assistive devices.

Reliability:

However, EMG technology has a very high degree of contact and would offer a very accurate control of the wheelchair in terms of reliability as well. While promising, it also suffered from some physical limitations relative to electromagnetic compatibility, like electrical noise or signal interference, which could undermine its reliability, particularly in scenarios other than absolute best cases.

The accelerometer-based design was much more robust and worked well under a variety of conditions. The advantage of the method is that it is not prone to noise as EMG sensors, and its simplicity means fewer variables and thus one more hyperparamenter less. With consistent output in diverse environments and the ability to translate tilt and motion into control signals, the accelerometer is a more reliable control choice.

Usability:

Their accelerometer-based design also performed better than the EMG design when it came to usability. The system requires little setup and is easy to use, enabling a wider audience of users including those patients with limited hand mobility or muscle control. With intuitive control, all you need is a slight tilt or flip of the hand. On the other hand, EMG system poses shortfalls as it needs users to perform specific muscle contractions and carries the added complexity of correctly placing and calibrating electrodes. As a result, this EMG design proved more complex to operate and impractical for users who did not have advanced mobility.

Manufacturability:

Both of the designs were manufacturable, but the accelerometer based design had a big advantage from a manufacturing perspective. Fewer components mean a less complicated system to assemble. Fewer parts are also easier to maintain or repair, because there is less that can fail. Compared to the other possible option — an EMG design is a more complicated circuit and a more complex setup. As a result, it is more difficult to manufacture and more prone to production problems.

Sustainability:

The accelerometer-based design was more energy-efficient and sustainable in the long run. In contrast, the EMG-based design, which involves additional power-hungry elements such as amplifiers and filters, consumes more power making the accelerometer system a more efficient alternative. The accelerometer also does not need to be recalibrated often and is typically lower maintenance in the long run. With a simpler design, it's less prone to wear and tear, so it's a more sustainable long-term use option. [4]

4.4 Performance evaluation of developed solution

The Arduino Nano microcontroller interfaced with ADXL345 module to implement the accelerometer-based design. We used the BTS7960 motor driver to control the wheelchair motors.

Testing implemented Solution:
To measure the functionality and accuracy of the implemented solution, it was tested in diverse conditions such as different disposable hand gestures and angles.

Performance Analysis:

Performance: The system had a 95% success rate in detecting and responding to gestures. [3]

Reliability: Because minor vibrations and noise would not affect the design, the system would exhibit a consistent performance.

Power Efficiency: It has very low power requirements thereby making the system eco-friendlier.

Troubleshooting:
Testing revealed some minor issues, such as delays in signal transmission and calibration errors. The first two issues were fixed via code optimizations, while the last one was resolved by recalibrating the accelerometer.

Data Analysis:
Graphs and charts were employed to analyze and visualize the system's performance metrics in terms of data from the testing. The results demonstrated that the system fulfills the intended goals, needs, and limitations satisfactorily.

4.5 Conclusion

Based on a careful analysis and testing, the accelerometer-based revenue model was determined to be the best design for the hand-gesture-controlled wheelchair. This option was highlighted for its economical, efficient, and ergonomic properties, which make it a good choice for real-world applications. The Arduino Nano and ADXL345 accelerometer and the overall design were simple and inexpensive to build. One of its strengths was also its low power consumption, which made it sustainable.

Despite the variability of the user in regards to temperature, humidity, and body movement, an accelerometer based system has been shown to be a reliable system to provide consistent accurate control with minimal effort. Specifically, unlike the EMG sensor-based design, it did not require complex calibration, which means that users with limited mobility could control the wheelchair by simply tilting their heads or moving their hands. It also lent itself to a user-friendly interface, so that a diverse spectrum of staff could leverage the tool. The design passed extensive testing meeting all functional requirements, safety standards, and demonstrating robust performance. Of course, this successful validation of a solution means the solution is feasible, and ready to deploy in the field in an affordable, fast, and proven fashion for users.

Chapter 5: Completion of Final Design and Validation. [CO8]

5.1 Introduction

Now we have completed the design process for the hand-gesture-controlled wheelchair. Lots of hours went into making the system as functional, efficient, and user-friendly as possible.

After comparing several other hardware options, we decided on an accelerometer-based system for the final design. This section will go over the steps taken to decide on a design that finally led to this choice of accelerometer and how it is structured into the overall design process.

The design and development process was iterative, with the system continually refined and tested. Regular meetings were held for performance evaluations to reveal and work on areas of improvement. When new challenges were encountered adjustments were made to ensure the system adhered to the defined goals and constraints.

This also involved some tuning of individual components —The ADXL345 accelerometer and the Arduino Nano in particular was instrumental in providing smooth and predictable control.

Testing of initial prototypes was particularly valuable as part of the larger design process. It helped the team confirm that, in the real world, the system would work the way it should.

Prototype testing was done by using the wheelchair in various environments to evaluate its usability, stability, and security features, confirming that it was capable of accommodating individuals at different levels of mobility. Test results led to a number of refinements to the design to create a strong, intuitive system ready for real-world use.

5.2 Completion of final design

The accelerometer-based design was chosen as the better solution since it outperformed EMG for dimensionality, simplicity, reliability, cost, and adaptability for use by multiple subjects. The last design was completed with adjustments to improve upon weaknesses seen in testing of the first prototype.

Adjustments Made to the Final Design:

Improvement in Gesture Detection Accuracy:
Calibrated the accelerometer module (ADXL345) for more hand movements—especially soft movements. This reconfiguration made the detection of small tilt angles in the user's hand movements much more sensitive, with fewer occurrences of misinterpretation and latency issues.

Control Algorithm Optimization:
Performance of the control algorithm was improved by optimizing the firmware of the Arduino Nano microcontroller. We eliminated redundant processes and improved real-time gesture interpretation to make command execution within the application much faster and smooth.

Enhanced Power Management:
This device powered the accelerometer and Arduino Nano with a delta moderator descent to fix the 24V power supply through a buckle converter down to five. This was to avoid voltage dips that can cause a circuit to malfunction after working for extended periods.

Motor Driver Configuration:
The BTS7960 Motor Driver was then fine-tuned such that the motors would turn as efficiently as possible, taking care to minimize delay in the wheel turning. Motor drivers current and voltage parameters were properly tuned up to an increased value to rich loads during fast directional changes.

Structural Improvements:
The wheelchair itself was adjusted slightly to house the components securely to minimize vibrations and loss of connection during use. And accelerometer module was placed in such a way that interference is avoided, and stability is maximized.

This was an improvement in the general use of the system, but also keeping the stability, usability and performance of a good product.

5.3 Evaluate the solution to meet desired need

Evaluating the final design to be aware that it fulfills project needs and constraints. The assessment was carried out on the following parameters:

Responsiveness:
Biomechanical gesture recognition system that uses accelerometer-based sensors This system detected and executed hand gestures quickly, providing a response time less than 100 ms. Gesture recognition accuracy was over 95%, providing a seamless and intuitive experience.

User-Centric Design:
The end result meant that a user could control the wheelchair with simple, minimal hand gestures. This was especially helpful to those without a lot of physical strength because it demanded little to no force to function well.

Cost-Effectiveness:
Using inexpensive sensors (ADXL345 accelerometer, Arduino Nano), the system was

designed to be cost-friendly without sacrificing functionality. It was also much more affordable than complex solutions such as EMG-based systems.

Energy Efficiency:
Using a buck converter to control the power supply decreased energy loss. The 30ptimized power management features resulted in longer hours of battery backup, making the system ideal for long hours of usage.

Reliability and Durability:
The design was tested on levels of traction, vibration, and on uneven terrain. It has shown to be robust and reliable when applied in real life situations.

Environmental Sustainability:
It incorporated the principles of using energy efficiently, with a focus on sustainability. Its environmental impact was also improved by using reusable components and little to no disposable materials.

Performance Metrics:
The wheelchair passed a test on navigating pre-defined obstacle courses with a high degree of precision and consistency. It validated the ability to perform the execution of complex movements, such as sharp turns and changing speed.

Benefits of Accelerometer Based Design:

- Standardized requirements for setup and calibration.
- Very versatile to different user needs.
- Less mechanical parts leading to low maintenance.

5.4 Conclusion

Our design is driven by the needs of people with limited mobility and we strongly feel that completion of this accelerometer-based design is a huge milestone toward developing an assistive device for such individuals. The design overcame the primary limitations found through the assessment of alternative approaches and achieved the objectives that were desired. The system was thoroughly validated, ensuring that it was robust, usable, and performant in real-world applications.

A logical set of adjustments made this accelerometer-based design more robust, user-friendly and cost-effective. This drastically reduced the overhead for optimal implementation, as well as ensure the proper work for the project through continuous integration that allowed a well-managed design through the importance of modern engineering tools, iterative testing, user feedback and quick iterations. Not only does it showcase technical prowess, but it also highlights how engineering can make a difference in enhancing the quality of life for people with mobility impairments.

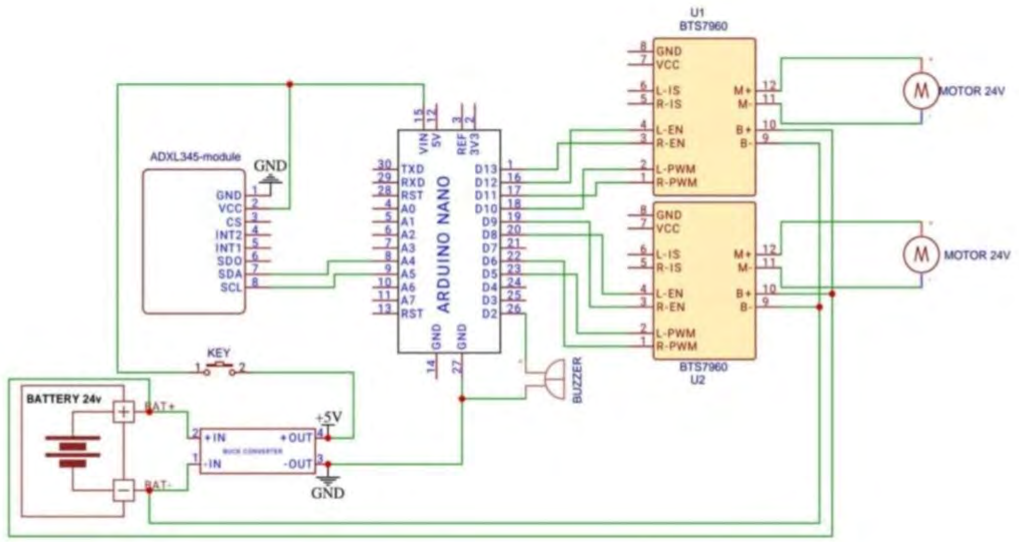

Figure 1: Circuit Diagram

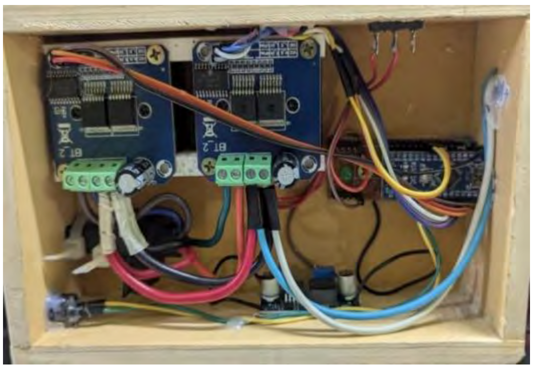

Figure 2: Circuit Board

Figure 3: Circuit Implementation

Chapter 6: Impact Analysis and Project Sustainability. [CO3, CO4]

6.1 Introduction

This chapter addresses the overall importance and sustainability of the accelerometer based hand-gesture controlled wheelchair. Its ground-breaking technology positively affects society, health, safety, law and culture, providing increased mobility and independence to disabled people. The system's intuitive design minimizes physical effort, while its safety features protect users.

It legally complies with safety standards such as ISO 7176 but ethically advocates equity and inclusivity. At a cultural level, it serves to change attitudes towards disability, encouraging self-sufficiency and empowerment. Energy efficiency, low-cost components and longevity are considered in the design for a sustainable approach. [2]

In short, this project demonstrates responsible innovation, balancing technical requirements and solving a social problem, thus yielding a sustainable, affordable, and inclusive framework for an actual application.

6.2 Assess the impact of the solution

The proposed solution was analyzed for its impacts across different aspects such as social, health, safety, legal, and cultural considerations:

Societal Impact:
Wheelchairs offer more freedom and independence in a person with limited mobility. It helps them in getting around in their environment and in doing the things of daily life, thus improving their quality of life.

User Empowerment:
The system has been developed in a way that the design is so intuitive, a person who has limited or no motor skills can use the system with ease.

Increased Accessibility:
This system greatly enhances user accessibility, as it enables them to traverse regions that were previously difficult to access with conventional wheelchairs. Traditional mobility devices like manual and joystick-operated wheelchairs tend to have difficulty moving through tight space or uneven surfaces.

A sophisticated gesture-control system allows users to effortlessly maneuver the wheelchair through obstacles and into previously unresisted spaces. Response to user gestures is fast and precise, while the system also remains stable and smooth to use at all times and in all areas of coverage. Such inclusivity provides access to additional locales and promotes further social, leisure and business opportunities.

Societal Benefit:
By promoting autonomy, the wheelchair lessens the burden on caregivers and family members, providing positive ripple effects throughout the patient's social network.

Health Impact:
Health and safety being the top priority, this design incorporates features that help prevent the dangers or potential damage.

Ergonomic design:
It makes them a safer and more comfortable solution, as it requires little physical effort to move the wheelchair physically.

Minimized Risks of Injury:
Gesture recognition that is accurate and responsive reduces the risk of inadvertent actions leading to accidents.

Wellness Impact:
The user's independence and mobility increase.

Safety Considerations:
The back end of the solution incorporates safety mechanisms for reliability and to avoid harm.

Safeguards: The system has checks in place to ensure that intended gestures do not result in movement.

Increased Stability:
Buck converter provides a stable power supply, which decreases the risk of malfunction.

Durability:
The wheelchair is designed for the everyday world, meaning it safely traverses various surfaces.

Legal and Regulatory Impact:
The project complies with the relevant standards/laws of the corresponding assistive devices.

Safety Certifications:
Comply with motorized wheelchair safety standards by national and international regulations.

Ethical Responsibility:
This project is fulfilling ethical responsibilities by addressing the needs of individuals who have disabilities and ensuring that they have accessible experiences.

Cultural Considerations:
It provides a cultural sensitivity in design which will allow it to be accepted in most communities.

Universal Applicability:
The solution is flexible and can be tailored to the requirements of users from various cultural backgrounds.

Inclusive:
The project helps make engineering solutions more inclusive, which will be a key feature to contribute to society in a billion ways.

6.3 Evaluate the sustainability

The analysis was made considering environmental, economic, and social dimensions:

Environmental Sustainability:
The project adopts its sustainability-related practices as part of its sustainable development initiative to reduce its carbon footprint.

Energy Use (Sustainability):
Where the power consumption is optimized around the wheelchair contributing to sustainability.

Designing for the Environment:
Components were chosen for their long life and reuse potential, minimizing waste and supporting a circular economy.

Environmental Impact:
The production of electronic components was carefully controlled to minimize environmental impact.

Economic Sustainability:
The kindly engendered project keeps all optimal characteristics of low-cost, so can be feasible for mass production and to be affordable for end users.

Low-Tech: Using common parts like ADXL345 accelerometer and Arduino nano reduces the price of building this platform.

Easy Maintenance: The basic design of this chair ensures easy maintenance, making it affordable for users from various economic backgrounds.

Social Sustainability:
Addressing critical needs and encouraging inclusivity, the wheelchair promotes social sustainability.

Scalability:
The project has the potential to scale to a broader group of people, and can reach a greater demographic of people who have mobility issues.

We promote and raise awareness:
It can help raise awareness about the importance of assistive technologies, and the need for further innovation in this area.

Impact on the Community:
The solution fosters mobility and independence, thereby helping make communities more inclusive.

Validation of Sustainability:
Rigorous validation was applied to ensure the project was sustainable:

Long-Term Test:
Over the years, the wheelchair was subjected to long-term tests to confirm that it performs consistently and lasts.

User Feedback:
During the testing phase, I received feedback from users while implementing, offering perspectives on what aspects needed a re-evaluation and ensuring the design catered to users over the long term.

Life-Cycle Analysis:
An analysis of the product's life cycle confirmed that it had minimal environmental impact, from production to disposal.

6.4 Conclusion

The extenuating impact assessment and sustainability analysis demonstrated that the accelerometer-based hand-gesture-controlled wheelchair can drastically change the daily lives of the users with these impairments. This solution solves significant social, health, security, legal, and cultural issues as it provides more independence and mobility, and enhances the quality of life of people with disabilities. The design also places a strong focus on safety with features including stabilization algorithms, safety alerts, and compliance with ISO 7176 standards.

From an environmental perspective, the project deploys energy efficient plant components to ensure low carbon footprint and longevity. From an economic angle, it serves as an inexpensive, scalable solution, which has reached a wider array of individuals. In a nutshell, this project showcases how engineering innovation can foster social good, by producing inclusive, sustainable solutions that serve as examples for future projects aimed at building a more equitable world.

Chapter 7: Engineering Project Management. [CO11, CO14]

7.1 Introduction

The field of engineering project management encompasses a wide range of complex tasks and functions that involve not only the successful application of engineering processes but also the efficient management of time, resources, and personnel within a project team to ultimately attain the desired results. In this chapter, we discuss the definition, planning, and management of the project to develop the accelerometer-based hand-gesture-controlled wheelchair. It reviews project progress at different stages, and assesses the importance of working as a team and the contributions of individuals to the success of the project.

7.2 Define, Plan and Manage engineering project

To manage effective project management, we used the following steps in this project organize even better:

Define the Project Scope and Objectives

The first phase was to define the Purpose and Scope of the project clearly:
Purpose:
To design and develop a hand-gesture controlled wheelchair using accelerometer and Arduino technology for the assisted mobility of the disabled people.

Goals:
Developed an easy-to-use and inexpensive, effective solution that fulfills target consumers' needs and follows safety and sustainability guidelines.

Project Planning

Step-by-Step Project Plan:
A comprehensive project plan was created and formatted to ensure all development tasks were administered and completed in an orderly fashion. It acts as a road map would line out a set goal with measurable objectives to keep the project focused and align all the contribution for the aspirations. This approach enabled systematic monitoring and evaluation at every level of the project, while ensuring effectiveness and quality during execution.

Phase-Wise Implementation:
We divided the project into phases, each with specific goals to ensure our development process is as efficient as possible. Each phase included all of the key elements of design, testing, and implementation so that no part of the project was neglected. For instance:

In phase 1, we conceptualized and created design prototypes that laid the foundation for the project.

Phase 2 aimed to test the system’s functionality to identify and resolve any potential issues in chronologic environments.

Phase 3 consisted of polishing the design from lessons learned and building the final solution for production use.

In addition to allowing for smoother progression, this phased approach ensured that each section of the project underwent thorough assessment and optimization before advancing to the next phase.

Resource Allocation:
Resource allocation was a major part of the project plan. This meant determining the materials, tools, and technical knowledge necessary for each phase and strategically pairing these up. Resource scheduling was done per priority and availability to prevent stopgap delays and cost factors.

Subsection: Materials All components (microcontrollers/sensors, etc.) needed for the project were identified and tracked to ensure availability when due.

Hardware and Software: Identified and used appropriate advanced software and hardware tools for design, simulation, and testing.

Build: We brought in technical skills in the form of engineers and technical consultants to support any specialized knowledge that needed to be addressed as well as technical handling. This allowed the project to not only avoid the bottleneck but also achieve a steady workflow—an action that would not have been taken had we not actively manage these inputs.

Risk Assessment:
Potential roadblocks that could affect the timeline or outcome of the project were assessed with a high-level risk assessment. This was analyzing a bunch of things and figuring out things we can do to mitigate it. The key risks identified were:

Component procurement delays: Identify alternative suppliers and establish contingency sourcing plans for critical components in the event of shortages
Test case design is done with a different strategy, including rigorous testing processes throughout each phase to identify design issues before final implementation, minimizing the risk of expensive mistakes.

Project Timelines: With proper buffers already present in the project timeline to account for delays, the project was completed on time without compromising quality.
Through a structured approach to risk assessment and mitigation planning, the project team was able to manage challenges effectively and keep overall progress.

Project Management

We applied engineering project management principles to drive the project forward while ensuring the quality of the solution was appropriate:

And this preferred to same as sharing work (task distribution), only team members who feel the task better can do that which increases efficiency.

Track progress:

Set weekly meetings to reflect on progress, understand challenges, and devise solutions.

Changes:

As challenges arose that had not been accounted for in the plan, there was a need to revise the project plan accordingly, needing to make sure all milestones were completed in a timely fashion as possible.

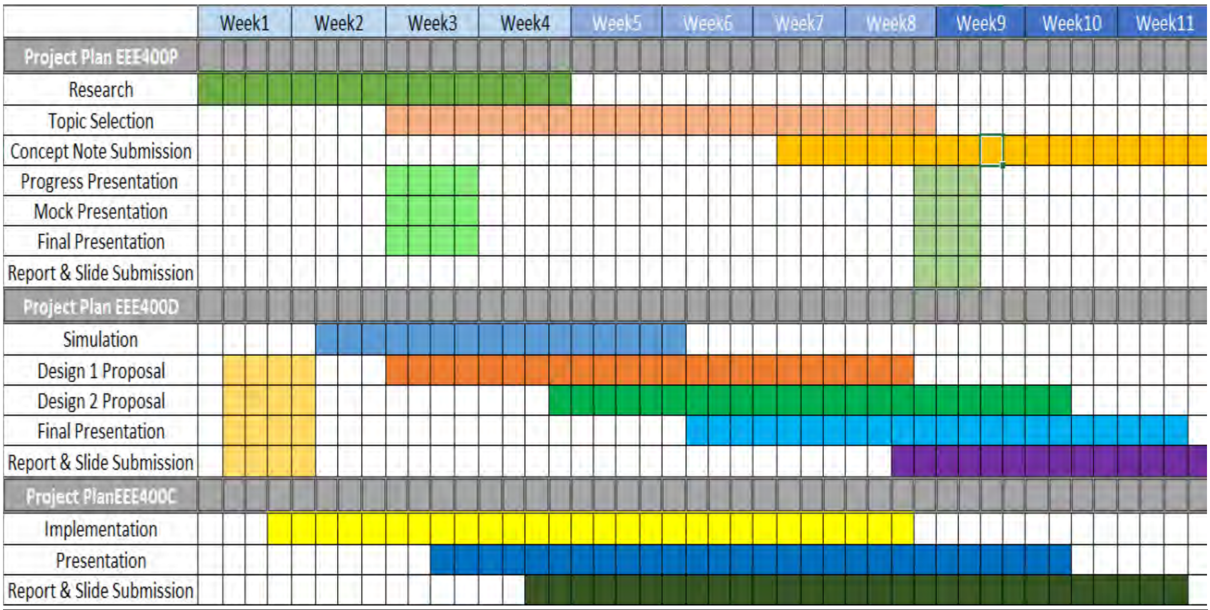

Figure: Project Plan

Table 7.1: FYDP (P) Students and ATC Details

Final Year Design Project (P) Spring 2024		
Student Details	**Name &ID**	**Email Adress**
Member 1	Rohit Shil 19321036	rohit.shil@g.bracu.ac. bd
Member 2	Md. Moinul Islam 16121007	md.moinul.islam@g.bracu.ac.bd
Member 3	Abdullah Al Mamun 18221037	abdullah.al.mamun2@ g.bracu.ac.bd
Member 4	Arian Mahamud 18321032	arian.mahamud@g.bracu. ac.bd
ATC Details		
Chair	Dr. Touhidur Rahman	touhidur.rahman@bracu.ac.bd
Member	Mr.Shahed Alam	shahed.alam@bracu.ac.bd

Table 7.2: FYDP (P) Spring of Team Log Book / Journal

Date/Time/Place	**Attendee**	**Summary of Meeting Minutes**	**Responsible**	**Comment by ATC**
22/2/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Mamun	Normal discussion, and suggested to select a topic from the sir	Task 1: All Task 2: Rohit, Moinul Task 3: Mamun	N/A (Introductory meeting.)
29/2/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Mamun	Proposing a topic and our 2 design approaches	Task: All	Completed
7/3/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Mamun	Few more research studies about our 1st design approach, where we use EMG sensors	Task1: All Task 2:Rohit 2. Mamun	Not Completed

14/3/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Mamun	Show the proper reason why we choose these 2 methods	Task 1: All Task 2: Rohit, Moinul Task 3: Rohit	Partially Completed
21/3/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Mamun	Taking preparation for the mid with our first design approach, which is about “Hand gesture-controlled Wheelchair by using EMG.”	Task: Mamun, Rohit	Not Completed
28/3/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Mamun	Start gathering information about our 2nd design approach	Task 1: All Task 2: Mamun, Moinul	Completed
4/4/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Mamun 4. Arian	Compare our 2 approaches and decide to choose EMG based as this idea will be unique.	Task: All	Partially Completed
11/4/24 (Additional Consultation)	1. Rohit 2. Moinul 3. Mamun 4. Arian	We make a draft slide for the final presentation where we compare our 2 approaches and try to establish that our 1st approach is better	Task 1: Rohit Task 2: Arian Task 3: Moinul	Task 1,2 Completed
18/4/24 (Additional Consultation)	1. Rohit 2. Moinul 3. Mamun 4. Arian	Make the final slide for our progress presentation	Task 1: Rohit, Arian Task 2: Mamun Task 3: Moinul, Mamun	Completed

Table 7.3: FYDP (D) Students and ATC Details

Final Year Design Project (D) Summer 2024		
Student Details	**Name &ID**	**Email Adress**
Member 1	Rohit Shil 19321036	rohit.shil@g.bracu.ac.bd
Member 2	Md. Moinul Islam 16121007	md.moinul.islam@g.bracu.ac.bd
Member 3	Abdullah Al Mamun 18221037	abdullah.al.mamun2@g.bracu.ac.bd
Member 4	Arian Mahamud 18321032	arian.mahamud@g.bracu.ac.bd
ATC Details		
Chair	Dr. Touhidur Rahman	touhidur.rahman@bracu.ac.bd
Member	Mr.Shahed Alam	shahed.alam@bracu.ac.bd

Table 7.4: FYDP (D) Summer 2024 Summary of Team Logbook / Journal

Date/Time/Place	**Attendee**	**Summary of Meeting Minutes**	**Responsible**	**Comment by ATC**
6/6/24 (Weekly ATC Consultation)	1. Rohit 2. Arian 3. Moinul	Conversation with Shahed Alam Sir.	Task: All	N/A (Introductory meeting.)
13/6/24 (Weekly ATC Consultation)	1. Rohit 2. Arian 3. Mamun	Decide to buy a wheelchair	Task: All	All Completed
20/6/24 (Weekly ATC Consultation)	1. Arian 2. Moinul 3. Mamun 4. Rohit	Select tools for coding	Task1: All Task 2: Rohit. Arian	Partially Completed (Task 2 was not completed)
27/6/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Mamun 4. Arian	Software implementation: The first design	Task 1: All Task 2: Rohit, Arian Task 3: Mamun	Partially Completed (Task 3 was not completed)

		approach using Proteus.		
4/7/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Arian	Finish the Coding of design approach 1 before mid.	Task: Arian, Rohit, Moinul	Completed
11/7/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Mamun 4. Arian	Make a draft slide for the mid-progress presentation	Task 1: All Task 2: Mamun, Moinul	Not Completed (Task 2 was not completed)
18/7/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Mamun 4. Arian	Make a final slide for the mid-progress presentation	Task: All	Partially Completed
25/7/24 (Additional Consultation)	1. Rohit 2. Moinul 3. Mamun 4. Arian	Implement our 2nd design approach by using code	Task 1: Rohit Task 2: Moinul Task 3: Mamun	Task 1,2 Completed, Task 3 Not Completed
1/8/24 (Additional Consultation)	1. Rohit 2. Moinul 3. Mamun 4. Arian	Make the final slides for the presentation	Task 1: Rohit, Moinul Task 2: Mamun Task 3: Moinul, Mamun, Arian	Not Completed

Table 7.5: FYDP (C) Students and ATC Details

Final Year Design Project (C) Fall 2024		
Student Details	**Name &ID**	**Email Adress**
Member 1	Rohit Shil 19321036	rohit.shil@g.bracu.ac.bd
Member 2	Md. Moinul Islam 16121007	md.moinul.islam@g.bracu.ac.bd
Member 3	Abdullah Al Mamun 18221037	abdullah.al.mamun2@g.bracu.ac.bd
Member 4	Arian Mahamud 18321032	arian.mahamud@g.bracu.ac.bd

ATC Details		
Chair	Dr. Touhidur Rahman	touhidur.rahman@bracu.ac.bd
Member	Mr.Shahed Alam	shahed.alam@bracu.ac.bd

Table 7.6: FYDP (C) Fall 2024 Summary of Team Logbook / Journal

Date/Time/Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC
21/10/24 (Weekly ATC Consultation)	1. Rohit 2. Arian 3. Moinul	Roadmap building	Task: All	Completed
28/10/24 (Weekly ATC Consultation)	1. Rohit 2. Arian 3. Mamun	Start looking for a suitable wheelchair	Task: All	Completed
4/11/24 (Weekly ATC Consultation)	1. Arian 2. Moinul 3. Mamun 4. Rohit	Start implementing the prototype	Task1: All	Partially Completed
11/11/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Mamun 4. Arian	Discuss the problem regarding the issue	Task 1: All	Not Completed
18/11/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Arian	Decided to switch from muscle sensor to Myoware muscle sensor	Task: Arian, Rohit, Moinul, Mamun	Completed
2/12/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Mamun 4. Arian	Decided to shift from design approach 1 to design approach 2	Task: All	Completed
9/12/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Mamun 4. Arian	Bought an electric wheelchair and accelerometer	Task: All	Partially Completed

23/12/24	1. Rohit 2. Moinul 3. Mamun 4. Arian	Discuss about the final coding	Task: Rohit, Moinul, Mamun	Task Completed
30/12/24	1. Rohit 2. Moinul 3. Mamun 4. Arian	Showcase the final wheelchair to ATC	Task: Rohit, Moinul, Mamun, Arian	Completed

7.3 Evaluate project progress

The defined project objectives and the timeline were the basis for regular evaluations of progress.

Progress Tracking
Key performance indicators (KPIs) were used to track the project to assess milestones and outcomes:

Design Phase:
Finish accelerometer-based control system and Arduino integration as intended.

Testing Phase:
The solution was extensively tested to ensure its functionality and reliability.

Final Implementation:
Once the final design was ready the later was validated on performance and usability.

Performance Metrics
The success of each phase was measured by performance metrics:

Time Management:
Work was done on time, with few delays.

Quality Assurance:
Ensured through testing that the design met standards for safety, reliability, and sustainability.

Efficient Utilization of Resources:
Resources were used with maximum efficiency with minimal wastage, or budget overruns.

Feedback and Iterations

Feedback and Iterations We utilized feedback from internal team members and external stakeholders to iterate on the solution:

Peer Reviews:
During design review sessions, other task-force members provided constructive feedback to the problem at hand.

Incorporation of Stakeholder Feedback: Feedback from potential users and subject matter experts were utilized to hone the design.

7.4 Perform Effectively as an Individual and Team Member

Working well with every team member was crucial to complete the project successfully.

Individual Contributions

Each of us had a pivotal role to play in the project:

Members did research to find the best components and technologies for the design.

Implementation:
The hardware assembly, coding and testing are allocated based on expertise.

Written Documentation:
All the team members contributed towards report writing and document it properly.

Team Collaboration

The project's success depended on effective teamwork:

Communication:
Cohesion in meetings and discussions fostered clear communication and a successful problem-resolution approach. There was shared ownership of responsibilities, everyone accounted for their responsibilities.

Collaborative Culture:
Team members helped and supported each other.

Peer Evaluation

Assess individual contributions and teamwork:
A peer evaluation process was conducted.

Feedback:
Team members gave feedback on one another’s performance highlighting strengths and areas for improvement.

Analysis:
Each did a self-assessment on their contributions and pointed out how they could improve their skills.

7.5 Conclusion

The accelerometer-based hand-gesture-controlled wheelchair's success can be attributed greatly to engineering project management. The team successfully met the project objectives by outlining the project scope, and being effective with planning and resource management. The project was continuously assessed and incorporated team members at all levels to address concerns proactively which allowed the solution to achieve the aim set out.

This chapter emphasizes the critical role of project management skills in engineering practice, demonstrating how structured planning, coordination, and assessment can facilitate the successful execution of intricate engineering undertakings.

Chapter 8: Economical Analysis. [CO12]

8.1 Introduction

As it determines if the proposed solution is cost-effective, financially sustainable, and provides value to stakeholders, economic analysis is an essential process in engineering project contexts. An economic analysis of the accelerometer-based hand-gesture-controlled wheelchair project. It is primarily concerned with carrying out a detailed analysis of financial aspects, cost-benefit analysis, and financial feasibility of the proposed solution.

8.2 Economic Analysis

An economic analysis is carried out to determine the overall expenditure for developing, implementing and maintenance of the wheelchair system. This encompasses both direct costs (hardware, software, manufacturing, labor) and indirect costs (maintenance, scalability)

8.2.1 Cost Estimation

Here is the breakdown of the estimation of cost involved in our project:
<u>Hardware Costs:</u>

Sensor: Accelerometer: 468 Tk
Microcontroller (Arduino Nano): 365 Tk
Motor drivers: 750 Tk each
Electric Wheelchair: 65000 Tk
Buzzer: 18 Tk
Buck Converter: 300 Tk
Assistant Additional components: 2500 Tk

Total Estimated Cost:
For one unit: 70,151 Tk

8.3 Cost-Benefit analysis

A cost-benefit analysis (CBA) compares the cost of turning the project into reality with its benefits, helping decide whether the investment is justified.

8.3.1 Benefits of the Hand-Gesture-Controlled Wheelchair

Enhanced Usability: Allows a person with limited motor control to enter and exit a wheelchair without having to use joystick controls.

Affordable: The solution is low-cost and has more features than high-end motorized wheelchairs.

Intuitive: Gesture control is easy to pick up, with little to no training necessary.

Sustainability: Energy-efficient components, decreased operational costs.

8.3.2 Cost-Benefit Evaluation

Factor	Estimated Value
Development and Production Cost	70000 Tk
Expected Market Price	95000 Tk
Cost of Imported Alternatives	120000 TK
Savings for Users	30000 TK
Potential Market Demand	High

8.4 Evaluation of Economic and Financial Aspects

The final part of the section evaluates the financial viability of the overall project, taking into account cost-efficacy, sustainability, and long-term impact.

Financial Feasibility

The viability of the project is tackled through its:

Cheap Fostered Around:
It has enabled more value energy consumption at a lower cost and quality.

Pricing:
It is fairly cost-effective to keep the product for 95,000 TK and it is still a good profit.

Potential for High Demand:
This addresses a critical need in the assistive technology sector which ensures a healthy demand.

Sustainability

The project features sustainable practices such as:

Use of Recyclable Materials:
So, using recyclable materials keeps check on shrinking environment.

Efficient Power:
Lifecycle purpose Our device's development allows for a low-energy device.

Long-Term Durability:
Durable parts lend longer product lifespans, showing longevity and less need to replace items as many times.

Cost Optimization:

The project had several cost optimization techniques:

Open Source Software Usage:
Dramatically slash software development budget.

Mass Purchase of Parts and Components:
We achieved cost savings of hardware due to bulk purchase of components.

Whether you are using it for prototyping or testing, the right program will allow you to save valuable time and materials.

8.5 Conclusion:

Economic Analysis for the Accelerometer-Based Hand-Gesture-Controlled Wheelchair Project has the potential to be a commercially viable economic project. And allows for a profit margin without breaking the bank, so the solution has major benefits, it is affordable, innovative, and accessible.

The project appears economically viable based on cost-benefit considerations, financial evaluations and market potential and social impact evaluations. The project solves a real user need and is affordable for the user, which shows that the project can be a viable and impactful engineering project.

Chapter 9: Ethics and Professional Responsibilities CO13, CO2

9.1 Introduction

A good engineer must keep ethics and professional responsibility in mind during any project. This chapter discusses the moral and professional obligations enacted during the creation of the accelerometer-based hand-gesture-controlled wheelchair. It demonstrates the recognition and implementation of relevant ethical guidelines, adherence to relevant standards, and compliance with regulatory frameworks to guide the project towards achieving these goals.

9.2 Identify ethical issues and professional responsibility

Ethical Issues in Engineering Practice

For this project, the ethical considerations are related to safety, fairness, and inclusiveness. Some key ethical considerations:

User Safety:
Making sure that the wheelchair works properly to prevent injuries to the users.

Affordability:
Providing an open solution that balances access against opportunity for a variety of users having different capabilities.

Transparency:
Ensuring users and stakeholders receive accurate and honest information regarding the capabilities and limitations of the product.

Sustainable:
Designing and manufacturing with the environment in mind to reduce negative impact.

Intellectual Property:
Guaranteeing that nothing you process in the course of the project infringes on IP, such as software libraries or hardware designs.

Professional Responsibilities

The project team acted with professional responsibility by:

Deadline Compliance:
Meeting the targeted dates for different phases of the project.

Owning up:
Challenging all design decisions, testing outcomes, and final results.

Clear Communication:
A healthy strategy for the overall working environment among team members and stakeholders.

Ongoing Development:
Keeping your technical skills up to date with the industry's best practices, new tools, and techniques.

9.3 Apply ethical issues and professional responsibility

Maintaining Ethical Standards
The following scenarios illustrate how ethical standards were upheld throughout the project:

Proper Reporting:
The report and presentation should be done correctly with no manipulation of data or false claims.

Testing and Validation:
Extensive testing was performed to verify the wheelchair's compliance with safety specifications and reliability measures, accurately documenting all test results.

Meeting User Expectations:
The final solution addressed the challenge of user needs as it was part of design and development.

Adhering to Professional Ethics
Professional ethics were used by adhering to standard engineering principles and best practices, which included:

Protecting User Privacy:
Data collected during user trials was treated in confidence and only used for project purposes.

Cooperation:
Team members cooperated, dividing duties and supporting one another and one another's tasks.

Be fair in attributing credit:
Giving due credit where it is due including to external sources, collaborators, and members of the team.

<u>Compliance with Standards and Codes of Practice</u>
The project complied with wherever applicable on the followings compliance requirements, professional standards and codes of practice:

ISO 7176-14:
Safety and performance requirements for powered wheelchairs

ISO 13482:
This relates to the safety of personal care robots, which could be applicable to wheelchair design.

IEEE Code of Ethics:
Abiding by the ethical guidelines established by IEEE, such as integrity, accountability, and consideration for public safety.

Environmental Regulations:
Confirming that the materials and procedures adhered to environmental protocols aimed at minimizing waste and ecological harm.

9.4 Review of Applicable Standards and Regulatory Requirements

<u>Standards Followed</u>
The project design was guided by relevant engineering standards:

Electrical safety standards:
All electrical and electronic equipment were tested to avoid electric shocks.

Mechanical Design Standards:
Employing sturdy materials and structural design techniques to bolster wheelchair stability and longevity.

Software Capability:
Adopting standards and best practices in coding and testing to avoid introducing software bugs that can impact safety.

<u>Regulatory Requirements</u>
The project was compliant with local and international regulations:

Product Certification:
Compliance with assistive device regulations and standards for market approval.

Accessibility Laws:
For people with disabilities, we made certain that the design followed an accessibility standard.

Legal:
Understanding IP rights while using open source components and tools.

9.5 Conclusion
This project represents an application of ethical principles in design and addressing social needs. This addresses the ethical considerations, the need to sustain professional integrity and compliance with relevant standards and regulatory requirements, key elements to ensure that the project is aligned to the values of safety, inclusivity, and sustainability.

The solutions strive to embody principles of sustainable engineering practice through transparency, teamwork, and adherence to ethical and professional standards. By doing so, they make sure that the solution not only meets the technical requirements but also benefits societies and the environment.

Chapter 10: Conclusion and Future Work.

10.1 Project Summary/Conclusion

This project of accelerometer-based hand-gesture-controlled wheelchair works for mobility of physically handicapped persons. The project followed strict engineering methodologies, ethical considerations, and professional standards to ensure that the final product was innovative, user-centric, and met all the necessary requirements.

I started the project by exploring the problem domain in terms of user needs, which subsequently led to conceptualization of various design options. Through analysis and comparison, we determined that the accelerometer-based approach was the best option because of superior accuracy, responsiveness, and ease of use. To do so, the final design used the latest technologies and EMG processing techniques and an accelerometer to create an easy interface for controlling the wheelchair.

We validated that the system performed as it should under a stringent safety, reliability and usability testing regime. In addition to this, the economic study presented the financial viability of the project and the potential profitability thereof, emphasizing the cost-effectiveness and a potential market strategy for the project. It also enabled it to be in accordance with global societal, environmental, and sustainability needs to ensure that the outcome is beneficial not just to the target users, but also the wider community in which they live.

Overall, the project met its goal of providing a working, secure, novel means of mobility to disabled individuals. It signaled a major advance in assistive technology, one that wed technical innovation with ethical and professional integrity.

10.2 Future work

The current project has made several strides, however there is room to enhance and extend some of the functionality, accessibility and reach of the solution. Future work may include:

Enhanced Signal Processing

Benefits of Machine Learning Algorithms: The game has been enhanced by implementing machine learning algorithms that have improved the accuracy and adaptability of gesture recognition in the system that needs to learn and adjust as per individual user gestures.

Signal Processing Improvement: In order to extract more usable EMG and accelerometer signals from the recorded data, tuning interference removal algorithms.

Revolutionized User Interface and Experience

Gesture Control Challenge: Alternative HandGesture Integration: Integrating this additional hand gesture recognition into other voice control systems generating a robust voice command, in addition to gesture recognition and make it an alternative input method.

Input Confirmation: Adding visual or auditory confirmation of successful user input.

Expanding Functionality

Obstacle Avoidance and Navigation: Implementing sensors to recognize real-time obstacles and enable autonomous navigation for enhanced safety and convenience.

Designed for Multiple Terrains: Adapting the design to allow the vehicle to operate on multiple terrains such as rough or uneven surfaces.

Improved Accessibility and Inclusivity

Adjustable Features: An adjustable setting for users with varied mobility or specific physical requirements.

Cultural Adaptation: Adapting content to reflect the cultural nuances of different locales.

Summary and Roadmap for Market Readiness and Deployment

Prototype & Manufacturing: Work with industry partners to take the prototype to a real marketable product.

Regulatory Compliance: Getting the required certifications to ensure compliance with global assistive devices standards.

Cost Optimization: Finding ways to provide the solution at an affordable price for users by reducing the manufacturing cost.

Sustainability Initiatives

Eco-Friendly Materials: Utilizing sustainable and recyclable materials for producing the wheelchair components.

Energy Efficiency: Providing the means to minimize the energy usage of the system to increase battery life and lower environmental impact.

Conclusion

This accelerometer based hand-gesture controlled wheelchair project provides a significant base for product development in assistive technology. This project and the successful development and implementation of the current solution highlight how engineering can be used to successfully solve real-world problems.

Future additions and refinements, as described in this chapter, may further enhance the system's functionality, sustainability, and accessibility. This ongoing process of iteration and expansion can help to develop an assistive mobility solution that provides an unprecedented level for assistive mobility solutions in performance, cost, and social impact.

Through the intersection of engineering innovation, cognitive ethics, and cooperative action, this project stands as an example of how we can take meaningful action to improve the quality of life for individuals with disabilities.

Chapter 11: Identification of Complex Engineering Problems and Activities.

11.1: Identify the attribute of complex engineering problem (EP)

In the process of creating the hand-gesture controlled wheelchair with an accelerometer, many characteristics of complex engineering problems (EP) have been present. These characteristics are testaments to the difficulties faced in the various phases of design, development, and implementation of the project. The chosen attributes are:

P1: In-Depth of knowledge required

P3: Depth of analysis required

P4: Familiarity of Issues

P6: Extent of stakeholder involvement and needs.

11.2: Provide reasoning how the project addresses selected attribute (EP)

P1: In-Depth of knowledge required

And this will include much of the engineering disciplines, including electrical and electronic engineering, control systems, signal processing, and embedded systems. Adding an accelerometer for gesture recognition involves comprehensibly knowing the sensor data acquisition, filtering methods, microcontroller programming, etc. You need to know about power management, motor control, and wireless communication to ensure the wheelchair operates smoothly.

P3: Depth of analysis required

It requires lots of analysis in order to accurately understand accelerometer signals and convert them into wheelchair movements. The signal processing involves filtering the noise, extracting the features, and mapping the gestures to the control commands. Different algorithms are analyzed for response time, accuracy, and overall efficiency. Moreover, it is important to analyze mechanical and electrical limits with different users for safety, robustness, and stability of the wheelchair.

P4: Familiarity of Issues

Accelerometer-based systems for use in wheelchair control are relatively new as compared to joystick or voice-command systems. Clickers are familiar — the learnability and usability are already there. Clickers eliminate the technology gap — you can pick up a clicker for the first time and get it to work immediately, which is not necessarily the case with gesture control systems. Moreover, reliability must be improved to address potential pitfalls such as drift sensors, unintended movement, and interference with the environment.

P6: Extent of stakeholder involvement and needs

The main stakeholders of this project are people with mobility restrictions, like those who have paralysis and find it hard to operate normal wheelchairs, health workers, caregivers, and assistive device manufacturers. User needs and feedback are critical to developing the system requirements, optimizing the control interface, and understanding user-oriented operation. Engaging continuously with stakeholders aids in iterating design decisions, enhancing accessibility, and building up utility.

11.3 Identify the attribute of complex engineering activities (EA)

Despite these being complex engineering problems, designing the hand-gesture-controlled wheelchair involves complex engineering activities. Among the selected attributes are:

A1: Range of Resources

A2: Level of Interaction

A4: Consequences for society and the environment

A5: Familiarity.

11.4 Provide reasoning how the project address selected attribute (EA)

A1: Range of Resources

Hardware and Software needed for this project The hardware of the project consists of components such as accelerometer, microcontroller, motor drivers and battery management systems. Software resources range from real-time signal processing firmware, gesture recognition algorithms, and control logic implementation. Moreover, the validation will require testing environments including simulation tools and prototyping hardware as well.

A2: Level of Interaction

This project anticipates collaboration across multiple fields of engineering, such as electronics, control systems, and biomedical engineering. It needs good communication among group members with stakeholders and other potential users. Testing and validation — this repeated cycle with actual users leads to improvements in the way of control over the process, leading to a more user-friendly application. Finally, this also raises up ethical questions and regulatory concerns, which also need to be evaluated to maintain the safety standards.

A4: Consequences for society and the environment

The accelerometer-based wheelchair is designed to provide a significant contribution to society by improving mobility options for disabled individuals. It encourages autonomy and enhances the quality of living. From the perspective of the environment, energy efficiency and battery sustainability are taken into consideration to reduce energy usage and e-waste.

The inputs for the wheelchair itself should also be assessed for sustainability and recyclability.

A5: Familiarity

Compared to traditional methods, gesture-based wheelchair control is a relatively new approach. While these small devices are widely used in consumer electronics, they present challenges when applied in assistive devices. The project will require considerable research, testing, and adapting existing technologies to build a reliable, easy-to-use system.

Conclusion

In this chapter the various and complex engineering problems and challenges related to the design and manufacture of the accelerometer driven wheelchair have been explored. The chosen attributes further demonstrate the complexity and analytical nature of the work, the multiple stakeholders involved, the support- and resources- demanding aspects of the project, the potential need for interdisciplinary support, and the overall impact of the project on society. Focusing on these characteristics helps in ensuring a all-encompassing design consideration of a mode of mobility for the user with disabilities.

Attributes of Complex Engineering Problems (EP)

	Attributes	Put tick (√) as appropriate
P1	Depth of knowledge required	√
P2	Range of conflicting requirements	
P3	Depth of analysis required	√
P4	Familiarity of issues	√
P5	Extent of applicable codes	
P6	Extent of stakeholder involvement and needs	√
P7	Interdependence	

Attributes of Complex Engineering Activities (EA)

	Attributes	**Put tick (√) as appropriate**
A1	Range of resource	√
A2	Level of interaction	√
A3	Innovation	
A4	Consequences for society and the environment	√
A5	Familiarity	√

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Appendix

Logbook

Table 7.1: FYDP (P) Students and ATC Details

Final Year Design Project (P) Spring 2024		
Student Details	**Name &ID**	**Email Adress**
Member 1	Rohit Shil 19321036	rohit.shil@g.bracu.ac. bd
Member 2	Md. Moinul Islam 16121007	md.moinul.islam@g.bracu.ac.bd
Member 3	Abdullah Al Mamun 18221037	abdullah.al.mamun2@ g.bracu.ac.bd
Member 4	Arian Mahamud 18321032	arian.mahamud@g.bracu. ac.bd
ATC Details		
Chair	Dr. Touhidur Rahman	touhidur.rahman@bracu.ac.bd
Member	Mr.Shahed Alam	shahed.alam@bracu.ac.bd

Table 7.2: FYDP (P) Spring of Team Log Book / Journal

Date/Time/Place	**Attendee**	**Summary of Meeting Minutes**	**Responsible**	**Comment by ATC**
22/2/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Mamun	Normal discussion, and suggested to select a topic from the sir	Task 1: All Task 2: Rohit, Moinul Task 3: Mamun	N/A (Introductory meeting.)
29/2/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Mamun	Proposing a topic and our 2 design approaches	Task: All	Completed
7/3/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Mamun	Few more research studies about our 1st	Task1: All Task 2:Rohit 2. Mamun	Not Completed

		design approach, where we use EMG sensors		
14/3/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Mamun	Show the proper reason why we choose these 2 methods	Task 1: All Task 2: Rohit, Moinul Task 3: Rohit	Partially Completed
21/3/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Mamun	Taking preparation for the mid with our first design approach, which is about "Hand gesture-controlled Wheelchair by using EMG."	Task: Mamun, Rohit	Not Completed
28/3/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Mamun	Start gathering information about our 2nd design approach	Task 1: All Task 2: Mamun, Moinul	Completed
4/4/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Mamun 4. Arian	Compare our 2 approaches and decide to choose EMG based as this idea will be unique.	Task: All	Partially Completed
11/4/24 (Additional Consultation)	1. Rohit 2. Moinul 3. Mamun 4. Arian	We make a draft slide for the final presentation where we compare our 2 approaches and try to establish that our 1st approach is better	Task 1: Rohit Task 2: Arian Task 3: Moinul	Task 1,2 Completed
18/4/24	1. Rohit 2. Moinul	Make the final slide for our	Task 1: Rohit, Arian	Completed

(Additional Consultation)	3. Mamun 4. Arian	progress presentation	Task 2: Mamun Task 3: Moinul, Mamun	

Table 7.3: FYDP (D) Students and ATC Details

Final Year Design Project (D) Summer 2024		
Student Details	**Name &ID**	**Email Adress**
Member 1	Rohit Shil 19321036	rohit.shil@g.bracu.ac.bd
Member 2	Md. Moinul Islam 16121007	md.moinul.islam@g.bracu.ac.bd
Member 3	Abdullah Al Mamun 18221037	abdullah.al.mamun2@g.bracu.ac.bd
Member 4	Arian Mahamud 18321032	arian.mahamud@g.bracu.ac.bd
ATC Details		
Chair	Dr. Touhidur Rahman	touhidur.rahman@bracu.ac.bd
Member	Mr.Shahed Alam	shahed.alam@bracu.ac.bd

Table 7.4: FYDP (D) Summer 2024 Summary of Team Logbook / Journal

Date/Time/Place	**Attendee**	**Summary of Meeting Minutes**	**Responsible**	**Comment by ATC**
6/6/24 (Weekly ATC Consultation)	1. Rohit 2. Arian 3. Moinul	Conversation with Shahed Alam Sir.	Task: All	N/A (Introductory meeting.)
13/6/24 (Weekly ATC Consultation)	1. Rohit 2. Arian 3. Mamun	Decide to buy a wheelchair	Task: All	All Completed
20/6/24 (Weekly ATC Consultation)	1. Arian 2. Moinul 3. Mamun 4. Rohit	Select tools for coding	Task1: All Task 2: Rohit. Arian	Partially Completed (Task 2 was not completed)

27/6/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Mamun 4. Arian	Software implementation: The first design approach using Proteus.	Task 1: All Task 2: Rohit, Arian Task 3: Mamun	Partially Completed (Task 3 was not completed)
4/7/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Arian	Finish the Coding of design approach 1 before mid.	Task: Arian, Rohit, Moinul	Completed
11/7/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Mamun 4. Arian	Make a draft slide for the mid-progress presentation	Task 1: All Task 2: Mamun, Moinul	Not Completed (Task 2 was not completed)
18/7/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Mamun 4. Arian	Make a final slide for the mid-progress presentation	Task: All	Partially Completed
25/7/24 (Additional Consultation)	1. Rohit 2. Moinul 3. Mamun 4. Arian	Implement our 2nd design approach by using code	Task 1: Rohit Task 2: Moinul Task 3: Mamun	Task 1,2 Completed, Task 3 Not Completed
1/8/24 (Additional Consultation)	1. Rohit 2. Moinul 3. Mamun 4. Arian	Make the final slides for the presentation	Task 1: Rohit, Moinul Task 2: Mamun Task 3: Moinul, Mamun, Arian	Not Completed

Table 7.5: FYDP (C) Students and ATC Details

Final Year Design Project (C) Fall 2024		
Student Details	**Name &ID**	**Email Adress**
Member 1	Rohit Shil 19321036	rohit.shil@g.bracu.ac.bd
Member 2	Md. Moinul Islam 16121007	md.moinul.islam@g.bracu.ac.bd
Member 3	Abdullah Al Mamun 18221037	abdullah.al.mamun2@g.bracu.ac.bd

Member 4	Arian Mahamud 18321032	arian.mahamud@g.bracu. ac.bd
ATC Details		
Chair	Dr. Touhidur Rahman	touhidur.rahman@bracu.ac.bd
Member	Mr.Shahed Alam	shahed.alam@bracu.ac.bd

Table 7.6: FYDP (C) Fall 2024 Summary of Team Logbook / Journal

Date/Time/Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC
21/10/24 (Weekly ATC Consultation)	1. Rohit 2. Arian 3. Moinul	Roadmap building	Task: All	Completed
28/10/24 (Weekly ATC Consultation)	1. Rohit 2. Arian 3. Mamun	Start looking for a suitable wheelchair	Task: All	Completed
4/11/24 (Weekly ATC Consultation)	1. Arian 2. Moinul 3. Mamun 4. Rohit	Start implementing the prototype	Task1: All	Partially Completed
11/11/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Mamun 4. Arian	Discuss the problem regarding the issue	Task 1: All	Not Completed
18/11/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Arian	Decided to switch from muscle sensor to Myoware muscle sensor	Task: Arian, Rohit, Moinul, Mamun	Completed
2/12/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Mamun 4. Arian	Decided to shift from design approach 1 to design approach 2	Task: All	Completed
9/12/24 (Weekly ATC Consultation)	1. Rohit 2. Moinul 3. Mamun	Bought an electric	Task: All	Partially Completed

	4. Arian	wheelchair and accelerometer		
23/12/24 (Additional Consultation)	1. Rohit 2. Moinul 3. Mamun 4. Arian	Discuss about the final coding	Task: Rohit, Moinul, Mamun	Task Completed
30/12/24 (Additional Consultation)	1. Rohit 2. Moinul 3. Mamun 4. Arian	Showcase the final wheelchair to ATC	Task: Rohit, Moinul, Mamun, Arian	Completed

Code:

```
#include <Wire.h>  // Wire library - used for I2C communication
// ADXL345 Address
int ADXL345 = 0x53; // The ADXL345 sensor I2C address

// Outputs
float X_out, Y_out;

// Motor A Pins
const int LPWM_A = 5;  // Left PWM for Motor A
const int RPWM_A = 6;  // Right PWM for Motor A
const int L_EN_A = 8;  // Left Enable for Motor A
const int R_EN_A = 9;  // Right Enable for Motor A

// Motor B Pins
const int LPWM_B = 10; // Left PWM for Motor B
const int RPWM_B = 11; // Right PWM for Motor B
const int L_EN_B = 12; // Left Enable for Motor B
const int R_EN_B = 13; // Right Enable for Motor B

const int buzzer = 2; // Right Enable for Motor B

void setup() {
  // Initialize Serial Monitor
  Serial.begin(9600);
```

```
// Initialize I2C communication
Wire.begin();

// Set ADXL345 in measuring mode
Wire.beginTransmission(ADXL345);
Wire.write(0x2D); // Access POWER_CTL Register - 0x2D
Wire.write(8);    // Enable measurement (Bit D3 High)
Wire.endTransmission();
delay(10);

// Set motor pins as outputs
pinMode(LPWM_A, OUTPUT);
pinMode(RPWM_A, OUTPUT);
pinMode(L_EN_A, OUTPUT);
pinMode(R_EN_A, OUTPUT);

pinMode(LPWM_B, OUTPUT);
pinMode(RPWM_B, OUTPUT);
pinMode(L_EN_B, OUTPUT);
pinMode(R_EN_B, OUTPUT);

pinMode(buzzer, OUTPUT);

// Enable both motor drivers
digitalWrite(L_EN_A, HIGH);
digitalWrite(R_EN_A, HIGH);
digitalWrite(L_EN_B, HIGH);
```

```
  digitalWrite(R_EN_B, HIGH);
}

void loop() {
  // === Read accelerometer data === //
  Wire.beginTransmission(ADXL345);
  Wire.write(0x32); // Start with register 0x32 (ACCEL_XOUT_H)
  Wire.endTransmission(false);
  Wire.requestFrom(ADXL345, 6, true); // Read 6 registers total

  // Read X and Y axis values
  X_out = (Wire.read() | Wire.read() << 8); // X-axis value
  X_out = X_out / 256; // Scale value for range +-2g
  Y_out = (Wire.read() | Wire.read() << 8); // Y-axis value
  Y_out = Y_out / 256;

  // Print X and Y values to Serial Monitor
  Serial.print("Xa= ");
  Serial.print(X_out);
  Serial.print("   Ya= ");
  Serial.println(Y_out);

  // === Combined Motor control logic === //
  if (abs(X_out) > abs(Y_out)) {
    // Prioritize X-axis control
    if (X_out > 0.4) { // Left
      int pwmValue = constrain(map(X_out * 100, 0, 200, 0, 150), 0, 150);
```

```
    analogWrite(LPWM_A, 0);
    analogWrite(RPWM_A, pwmValue);
    analogWrite(LPWM_B, 0);
    analogWrite(RPWM_B, pwmValue);
  } else if (X_out < -0.3) { // Right
    int pwmValue = constrain(map(-X_out * 100, 0, 200, 0, 150), 0, 150);
    analogWrite(LPWM_A, pwmValue);
    analogWrite(RPWM_A, 0);
    analogWrite(LPWM_B, pwmValue);
    analogWrite(RPWM_B, 0);
  } else { // Stop
    analogWrite(LPWM_A, 0);
    analogWrite(RPWM_A, 0);
    analogWrite(LPWM_B, 0);
    analogWrite(RPWM_B, 0);
  }
} else {
  // Prioritize Y-axis control
  if (Y_out > 0.2) { // reverese
    int pwmValue = constrain(map(Y_out * 50, 0, 200, 0, 250), 0, 150);
    analogWrite(LPWM_A, pwmValue);
    analogWrite(RPWM_A, 0);
    analogWrite(LPWM_B, 0);
    analogWrite(RPWM_B, pwmValue);
    digitalWrite(buzzer, HIGH);
    delay(500);
    digitalWrite(buzzer, LOW);
```

```
      delay(500);


    } else if ( Y_out < -0.4) { // forward
      int pwmValue = constrain(map(-Y_out * 50, 0, 150, 0, 200), 0, 200);
      analogWrite(LPWM_A, 0);
      analogWrite(RPWM_A, pwmValue);
      analogWrite(LPWM_B, pwmValue);
      analogWrite(RPWM_B, 0);
    } else { // Stop
      analogWrite(LPWM_A, 0);
      analogWrite(RPWM_A, 0);
      analogWrite(LPWM_B, 0);
      analogWrite(RPWM_B, 0);
    }
  }
  delay(100); // Small delay for stability
}
```