Faculty of Electrical Technology and Engineering

DEVELOPMENT OF A MICROCONTROLLER-BASED HAPTIC AND AUDIO-TACTILE ASIA ATLAS GLOBE FOR VISUALLY IMPAIRED STUDENTS

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Bachelor of Electrical Engineering Technology (Industrial Automation & Robotics) with Honours

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A project report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Electrical Engineering Technology (Industrial Automation & Robotics)
with Honours

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2024

DECLARATION

I declare that this project report entitled "DEVELOPMENT OF A MICROCONTROLLER-BASED HAPTIC AND AUDIO-TACTILE ASIA ATLAS GLOBE FOR VISUALLY IMPAIRED STUDENTS" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature ---

Student Name ---

Date ---

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DEDICATION

To my dearest parents, Mohd Jamil Aris Bin Haron and Mariah Binti Sedik,

Words cannot fully express the depth of my gratitude for your unwavering support and boundless love. Your sacrifices, encouragement, and belief in me have been the bedrock upon which I have built my dreams. From the late-night study sessions to the moments of doubt, you have always been there, offering a comforting word and a guiding hand. This achievement is as much yours as it is mine. Thank you for being my greatest cheerleaders and my constant source of strength.

To my esteemed supervisor, Ts. Maslan Bin Zainon,

Your wisdom, patience, and guidance have been instrumental in the completion of this project. Your insightful feedback and unwavering support have not only shaped this work but have also profoundly influenced my academic journey. I am deeply grateful for the time and effort you have invested in me, and for the invaluable lessons you have imparted. Your mentorship has been a beacon of light, guiding me through the complexities of this project. Thank you for believing in my potential and for pushing me to achieve my best.

To my cherished friends,

Your friendship has been a source of joy and inspiration throughout this journey. The laughter, the late-night brainstorming sessions, and the unwavering support have made this experience truly memorable. You have been my pillars of strength, offering encouragement and a listening ear whenever I needed it. This accomplishment would not have been possible without your camaraderie and support. Thank you for standing by me through every challenge and for celebrating every success with me.

With heartfelt gratitude,
Maizatul Najwa Binti Mohd Jamil Aris

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ABSTRACT

Geography heavily relies on visual aids to convey various information. However, it faces significant challenges in meeting the educational needs of visually impaired students due to the lack of suitable learning resources. Traditional teaching tools like globes are inaccessible and impractical for this group. These globes lack the tactile features needed to distinguish geographical elements, especially the vast continent of Asia, known as the largest continent in the world. Additionally, these globes are easily displaced, making it difficult for visually impaired students to accurately identify countries, often requiring continuous verbal assistance from teachers. The primary objective of the current research initiative is to develop an innovative tactile globe that not only addresses these issues but also promotes inclusivity and ease of use for all students, particularly those with visual impairments, by enriching the learning experience in geography education. The design concept is based on a thorough analysis of identified challenges and relevant literature, offering a comprehensive solution to existing limitations. Key features of this design include a Raspberry Pi as the controller, a stepper motor as the moving mechanism that allows the globe to rotate along the x-axis, mimicking the Earth's rotation, specific buttons corresponding to different areas within the continent of Asia, integrated speakers for auditory feedback, and distinct indicators associated with each button to enhance usability. The selection of components and functions aligned with the research goals is crucial to ensure the development of a truly transformative educational tool. Experiments were conducted to evaluate the prototype, and post-experiment questionnaires were administered to volunteers consisting of both normal and disabled students to record their experiences. The questionnaire included five elements: usability, ease of use, attitude towards use, behavioral intention to use, and enjoyment. During the experiment, time data was collected to assess the system's effectiveness throughout the experiment. Survey results showed an average score of 4.7 for efficiency, 4.9 for ease of use, 4.6 for confidence, 5.0 for recommendation, and 5.0 for enjoyment. Calibration results also indicated that the motor took only 4.72 seconds to move from the origin to each area in the continent of Asia. Overall, this research project lays a solid foundation for the development and implementation of more effective learning tools for all students, regardless of their health status.

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ABSTRAK

Geografi sangat bergantung pada bantuan visual untuk menyampaikan pelbagai info. Namun, ia menghadapi cabaran besar dalam memenuhi keperluan pendidikan pelajar yang mengalami masalah penglihatan kerana ketiadaan sumber pembelajaran yang sesuai. Alat pengajaran tradisional seperti glob tidak dapat diakses dan tidak praktikal untuk golongan ini. Glob ini tidak mempunyai ciri taktil yang diperlukan untuk membezakan elemen-elemen geografi, terutamanya benua Asia yang luas, yang dikenali sebagai benua terbesar di dunia. Selain itu, glob ini mudah tergeser, menyebabkan kesulitan bagi pelajar yang mengalami masalah penglihatan untuk mengenal pasti negara-negara dengan tepat, sering memerlukan bantuan lisan daripada guru secara berterusan. Objektif utama inisiatif penyelidikan semasa adalah untuk menghasilkan glob taktil yang inovatif yang tidak hanya menangani masalah ini, tetapi juga menggalakkan inklusiviti dan memudahkan penggunaan untuk semua pelajar, terutamanya mereka yang mengalami masalah penglihatan, dengan memperkayakan pengalaman pembelajaran dalam pendidikan geografi. Konsep reka bentuk yang dibuat berdasarkan analisis menyeluruh terhadap cabaran yang dikenal pasti dan literatur yang relevan, dengan menawarkan penyelesaian komprehensif kepada batasan sedia ada. Ciri utama reka bentuk ini termasuk Raspberry Pi sebagai pengawal, stepper motor sebagai mekanisme bergerak yang membolehkan glob berputar mengikut paksi-x, meniru putaran Bumi, butang khusus yang berkorespondensi dengan kawasan-kawasan berbeza dalam benua Asia, pembesar suara terintegrasi untuk maklum balas auditori, dan penunjuk yang berbeza yang berkaitan dengan setiap butang untuk meningkatkan kebolehgunaan. Pemilihan komponen dan fungsi yang sejajar dengan matlamat penyelidikan adalah penting untuk memastikan pembangunan alat pendidikan yang benar-benar berubah. Eksperimen telah dijalankan untuk menilai prototaip, dan soal selidik pasca eksperimen telah diberikan kepada sukarelawan yang terdiri daripada pelajar normal dan kurang upaya untuk merekodkan pengalaman mereka. Soal selidik tersebut termasuk lima elemen: kegunaan, kemudahan penggunaan, sikap terhadap penggunaan, niat tingkah laku untuk menggunakan, dan keseronokan. Semasa eksperimen, data masa telah diambil untuk menilai keberkesanan sistem sepanjang eksperimen berlangsung. Hasil tinjauan menunjukkan skor purata 4.7 untuk keberkesanan, 4.9 untuk kemudahan penggunaan, 4.6 untuk keyakinan, 5.0 untuk cadangan, dan 5.0 untuk keseronokan. Hasil kalibrasi juga menunjukkan bahawa motor hanya mengambil masa 4.72 saat untuk bergerak dari asal ke setiap kawasan di benua Asia. Secara keseluruhannya, projek penyelidikan ini meletakkan asas yang kukuh untuk pembangunan dan pelaksanaan alat pembelajaran yang lebih berkesan untuk semua pelajar, tanpa mengira status kesihatan mereka.

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ACKNOWLEDGEMENTS

As I bring this Final Year Project to completion, I wish to take a moment to formally acknowledge the efforts and dedication I have invested throughout this journey. The process of conceptualizing, designing, and implementing this project has been both a challenge and a profound learning experience that has contributed significantly to my personal and academic growth.

This project required perseverance, critical thinking, and adaptability to overcome numerous obstacles along the way. I am proud of the commitment I have demonstrated in ensuring its successful completion. Through diligent research, thoughtful problem-solving, and consistent effort, I was able to achieve the objectives I set out to accomplish.

The challenges encountered during this process were invaluable in shaping my technical expertise and enhancing my time management and organizational skills. Each step of the project reinforced the importance of self-discipline, focus, and the ability to learn independently. This experience has been instrumental in preparing me for future academic and professional endeavours.

I am grateful for the opportunity to apply the knowledge and skills acquired during my studies to a meaningful project. This accomplishment represents a significant milestone in my academic journey, and it is a testament to the hard work and dedication I have consistently pursued.

This acknowledgment reflects my commitment to achieving excellence and serves as a reminder of the importance of resilience and self-reliance in overcoming challenges. I take great pride in having completed this project and am confident that the experience will continue to inspire and guide me in my future endeavours.

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LIST OF SYMBOLS

%	-	Percent
°C	-	Degree Celcius
μs	-	Microsecond
Ω	-	Ohm
±	-	Plus-minus

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LIST OF ABBREVIATIONS

3D	-	3 Dimension
WHO	-	World Health Organization
RGB	-	Red, Green, and Blue
GPIO	-	General Purpose Input/Output
V	-	Voltage
PWM	-	Pulse Width Modulation
RPi	-	Raspberry Pi
GHz	-	Gigahertz
kgf·cm	-	kilogram-force centimeter

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CHAPTER 1

INTRODUCTION

1.1 Background

Traditional educational methods have typically relied on teachers using instructional aids such as textbooks, videos, and visual materials. However, in the modern age, technological advancements like learning tablets and smart books have been introduced to improve both structured classroom teaching and independent learning. Despite these advancements, not all these innovations are accessible to students with visual impairments or blindness. For these students, specialized tools like audio map for geography, braille books for reading, and thermoform paper sheets for tactile exploration are crucial. However, many visually impaired students have limited experience with reading braille textbooks or tactile graphics [1], and the cost of these tools can be prohibitive. Furthermore, creating a single atlas for geography learning requires a significant amount of thermoform paper sheets due to their standardized and non-modifiable size. Accessible items like globes lack a control system and essential assistive features such as texture and color that could help students stay focused during the learning process. As a result, there are numerous limitations that obstruct a comprehensive learning experience for students under these conditions.

This study suggests the following strategies for designing a tactile globe: 1) 3D printing; 2) a globe control system; and 3) an audio feedback system. Utilizing materials that engage multiple senses can enhance the learning process. Three-dimensional (3D) terrain modelling has been a valuable tool in cartography and geology since the introduction of relief globes of Earth in 1752 [2]. Among these, 3D printing emerges as a promising method to improve the educational experience for visually impaired students. The use of 3D-printed map allows students to feel texture and shape, aiding in the recognition of map that might be visually difficult. The use of filaments of different colors and textures in the 3D-printing process can further assist students in distinguishing between states, recognizing state names, and understanding the spatial arrangement of states. The addition of an actuator that can rotate the globe, equipped with a refined control function, ensures systematic rotation and a return to its original position upon release. Incorporating audio functions to help students identify the regions assigned by the teacher enhances efficiency and enriches the learning experience. This literature review focuses on examining, investigating, and developing a 3D-modelled globe integrated with a proper control system and actuator, supplemented with an audio feedback system. The goal is to determine whether this setup aids students in studying the Asian region by identifying the regions on the globe, thereby enhancing their overall learning experience.

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1.2 Problem Statement

The existing globe model presents a series of challenges for visually impaired students due to its flat surfaces. The texture of the globe, which is crucial for helping students differentiate between regions, is insufficient and can lead to potential misunderstandings. Furthermore, the globe's rotation is not easily visible, which can cause students to lose their bearings when manipulating it. Teachers often find themselves having to repeatedly explain the various regions on the globe to the students, which can be a time-consuming and repetitive task. To alleviate these issues and lessen the burden on teachers, it is necessary to develop a project that delivers a product with the best possible interactive features for a globe. This product should be designed with the needs of visually impaired students in mind, providing them with a more accessible and user-friendly tool for learning about our world.

The goal is to create a globe that not only aids in geographical understanding but also enhances the overall learning experience by being interactive and engaging. This would not only benefit the students but also provide a valuable teaching aid for educators. The development of such a product requires careful consideration of the specific challenges faced by visually impaired students and the incorporation of features that address these challenges effectively.

The project aligns with SDG 4 (Quality Education) by providing visually impaired students with accessible learning tools, ensuring they receive a quality education comparable to their sighted peers. By developing a tactile globe with haptic and audio feedback, it introduces innovative educational resources tailored to their needs. In terms of SDG 9 (Industry, Innovation, and Infrastructure), the project incorporates advanced technologies like 3D printing, haptic feedback, and audio guidance, showcasing innovation in educational tools and contributing to resilient educational infrastructure that supports inclusive education. Addressing SDG 10 (Reduced Inequalities), the project tackles educational disparities faced by visually impaired students, promoting equal opportunities and empowering them to reduce inequalities in education. Finally, the project supports SDG 17 (Partnerships for the Goals) through collaborative efforts involving students, educators, and technology developers, highlighting the importance of partnerships in achieving educational goals and serving as a model for other institutions, fostering knowledge and resource sharing.

1.3 Project Objectives

The main objective of this project is:

a) To design and develop a microcontroller-based circuit and hardware of an atlas globe for visually impaired students.

b) To apply haptic and audio-tactile technologies for the atlas globe.

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c) To analyze the performance of the atlas globe in terms of its effectiveness as a teaching and learning tool.

1.4 Scope of Project

The scope of this project is applicable to the education sector, especially for students with visual impairments. The designed system aims to assist and facilitate students and teachers in learning world map more effectively during learning sessions. The design of a globe system that is easily accessible to students and teachers. Radial distribution network with balanced load condition.

a) A system that combines haptic and audio-tactile technology, enabling the learning process to be received accurately and clearly. Students can learn about regions in the Asian region through dedicated touch and hearing capabilities.

b) By focusing on the specific design and system of this globe and continuously analyzing its performance, this project aims to enhance the abilities and efficiency of students experiencing visual impairments while encouraging improvements in the education sector for these special students.

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1.5 Significance of Project

The findings of the study will help all students, especially those with visual impairments, understand the positions of countries in Asia. This study will provide the necessary information to comprehend the Asian atlas. By understanding the geographical locations of Asian countries, visually impaired students can develop a more comprehensive understanding of the world. Understanding the positions of countries in Asia is an essential first step in comprehending global geography. In the future, the use of globe technology in

Geography subjects, particularly for special education students, is expected to expand. Therefore, this study can provide crucial foundational knowledge on this matter.

1.6 Limitations of Project

In order to facilitate a more focused analysis of the topic, certain limitations have been introduced for the study. Some of these limitations include:

a) This project specifically focuses on Asian countries, which may limit students' knowledge level.
b) The atlas in this project is not entirely accurate because it prioritizes large islands, disregarding smaller ones to ensure the functionality of the globe system.
c) While the purpose of this globe is to assist individuals with disabilities, such as the visually impaired, it is not universally usable. For instance, those who have both visual and hearing impairments may face challenges.
d) The project utilizes a small-sized motor, which imposes restrictions on the globe's size and weight.
e) The project's rotation is confined to the x-axis only.

1.7 Report Organization

The report focuses on the creation of a haptic and audio tactile globe for visually impaired students and is structured into four key chapters. Chapter 1, the Introduction, emphasizes the necessity of accessible learning tools for blind students and proposes the idea of a 3D-printed tactile globe, equipped with audio feedback and a control system, as a potential solution.

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Chapter 2, the Literature Review, provides a comprehensive overview of the educational challenges faced by visually impaired students, especially in learning geography. It evaluates current tools, such as tactile map, and assesses the potential of new technologies, including audio guidance and 3D printing, to create a tactile globe that could significantly enhance these students' learning experiences. This chapter underscores the importance of such advancements by highlighting the limitations of existing educational aids.

Chapter 3, Methodology, offers an in-depth look at the design process, component selection, and system design for the tactile globe, detailing the use of a controller and other components.

Chapter 4 details the results and analysis derived from the initial testing of the system's components. These findings will serve as a critical reference for subsequent work in the project's second phase. The chapter emphasizes the outcomes achieved by the system and provides a comprehensive analysis of the collected data, offering valuable insights into the project's further advancement and refinement.

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Finally, Chapter 5 concludes the project by summarizing all efforts and work undertaken. It offers a concise overview of the entire process, emphasizing the key steps and outcomes achieved.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This section embarks on a thorough investigation and synthesis of the core concept and guiding philosophy behind the development of the Asia atlas globe project, which is custom-made for visually impaired students. To ensure a complete and holistic understanding, a systematic review of the literature was conducted. Various elements were considered, including the globe's design and texture, the division of regions, tactile engagement techniques for the visually impaired, and the applications of 3D printing technology. The primary platforms used for gathering pertinent articles were Google Scholar and the Digital Library. Key search terms such as "Visual Impairment," "Tactile Globe," "Education for Impaired Student," and "3D printing" were used to retrieve relevant literature. The search yielded 70 results from Google Scholar and 216 from the Digital Library. To streamline the selection process, criteria for inclusion and exclusion were applied. The exclusion method aimed to eliminate articles not directly related to the research topic, resulting in the identification of 26 highly relevant articles from each source. Subsequently, the comparison method was applied to encompass materials pertinent to various aspects of the project, including 3D printing, tactile perception of the blind, globe design, and computer-assisted learning. The chosen articles cover a spectrum of relevant topics, including the application of 3D printing technology, tactile sensitivity of the visually impaired, design considerations, and advancements in computer learning methodologies. The goal is to determine whether this setup aids students in studying the Asian region by identifying the regions on the globe, thereby enhancing their overall learning experience.

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2.2 Visual Impaired

Visual impairment significantly restricts a person's capacity to process visual information and carry out routine tasks. This condition can affect individuals of all ages, transcending boundaries of gender, social status, and intellectual capabilities. The causes of visual impairment or blindness can be multifaceted, often involving damage to the retina or optic nerve due to diseases, or complications within the optic nerve or brain itself. Disorders under the umbrella of visual impairment include a limited or incomplete field of vision, decreased visual acuity, impaired cognitive image processing, or reduced perception of colors and contrast. The World Health Organization (WHO) estimates that around 2.2 billion people globally are affected by some form of vision impairment or blindness, with nearly 1 billion experiencing moderate to severe impairments that could have been prevented or still need attention[3]. The WHO defines poor vision as having visual acuity between 10 and 30 percent. Visual acuity between 5 and 10 percent is classified as low vision [4]. The WHO also differentiates three levels of blindness: total blindness (no light perception), blindness (visual acuity less than 2%), and legal blindness (visual acuity between 2% and 5%). From 2016 to 2020, there was a significant increase in the number of students with special needs, rising from 2352 to 2651 students[3].

Research indicates that students with visual impairments encounter a multitude of challenges in accessing education, with limited resources and support systems exacerbating disparities in learning outcomes. This upward trend underscores the commitment of parents to provide educational opportunities for their children, recognizing that education is the key to a brighter future. Visual impairment can impact various aspects of academic performance, including reading comprehension, geographical awareness, mathematical reasoning, and information retention, thereby hindering their overall learning outcomes. Furthermore, disparities in access to specialized support services and assistive technologies contribute to

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inequalities in educational opportunities for visually impaired students, particularly in resource-constrained environments. Education for visually impaired students entails significant costs due to the need for additional devices to aid their limited vision. Over the years, various assistive devices have been developed to mitigate these challenges, including reading magnifiers, Braille textbooks, and reading assistance tools, aimed at facilitating their learning process and promoting equal access to education. By promoting inclusive education policies and expanding access to resources and support services, societies can empower visually impaired students to achieve their full potential and participate meaningfully in educational and social activities.

2.3 Learning Atlas and Geography in Special Education School

2.3.1 Teaching and Learning

In the realm of education, students typically learn to interpret traditional atlas for navigational purposes and to gain a broad understanding of geography. While these standard atlas learning techniques work well for most students, those with visual impairments necessitate tailored approaches to effectively access geographical knowledge. Special education schools address this need by using custom-made atlas equipped with Braille code for visually impaired students. These tactile atlases feature elevated patterns that symbolize geographic features and are sized in accordance with educational guidelines.

Moreover, these schools provide training to students to decode Braille, memorize patterns, and understand compass directions, all of which facilitate atlas navigation [5]. By harnessing their sense of touch, students memorize the shapes of Braille letters to decipher the details on the atlas. To further assist in navigation, tactile atlas incorporates arrows that guide students from the shapes of regions to their corresponding names, ensuring accurate location identification under the guidance of an instructor.

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Furthermore, the integration of technology, such as tactile atlas, 3D printed models, and auditory descriptions, provides additional support and engagement for visually impaired students. By employing these specific methods and utilizing specialized materials, special education schools aid visually impaired students in developing crucial spatial awareness skills. This not only helps them gain a comprehensive understanding of geography but also facilitates their educational success and participation in a wider range of academic activities. The ultimate goal is to foster an inclusive learning environment that caters to the unique needs of visually impaired students, empowering them to excel academically.

2.3.2 Supporting Materials

2.3.2.1 Tactile Map

Tactile graphics serve as an essential educational tool that significantly aids visually impaired students in their learning journey. Tactile graphics, also known as 2D raised-line graphics, offer an alternative to traditional text and visual diagrams, providing a valuable aid to visually impaired students [6]. Tactile atlas considerably enhances spatial awareness among these students, with a notable 85% reporting increased confidence in navigating unfamiliar areas [7]. Further studies tactile atlas contributes to boosting academic achievement by improving the understanding of geographic concepts by 30% compared to traditional methods [8]. Tactile graphics can be created using various methods like thermoforming, braille embossing, and using swell paper, offering tactile learning experiences for visually impaired learners. Thermoforming involves the process of heating plastic sheets to mold them into intricate shapes that students can physically explore, thereby enriching their educational experience.

Wiedel noted that while Braille has seen significant advancements, tactile graphics for the blind, such as atlas, have remained somewhat limited despite concerted efforts to

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improve these resources and a significant demand for them. He attributed these challenges to issues related to symbolization and reproduction [9]. However, these challenges have not deterred researchers and experts from persisting in their experiments with and production of customized tactile map. Over the past decade, developments in this field have accelerated. In 2016, a collaborative initiative in the Czech Republic involving the ELSA Centre, Teiresias Centre, and Seznam.cz was launched with the aim of enhancing accessibility and providing up-to-date tactile map in a quick and easy manner [9]. These maps enable students to visualize environmental landscapes. Tactile map feature symbols and textures to differentiate and represent various atlas elements. Due to the limited number of distinguishable textures, some land cover/usage categories have been grouped together [10]. This distinction is crucial for students to remember and not confuse with repeated textures when learning and interacting with the map. Some limitations of tactile map include their large size, necessitating the printing of entire regions on numerous sheets, which can make them difficult to manage and store. Despite these challenges, the continued development and use of tactile map remain a vital part of the educational journey for visually impaired students.

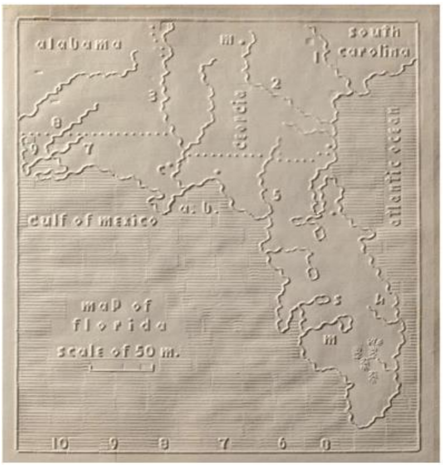

Figure 2.1 Atlas of Florida [11]

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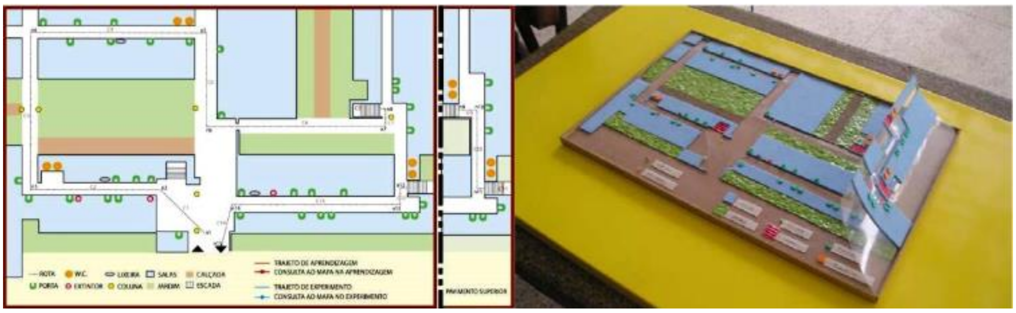

Figure 2.2 (a) schematic print of the tactile atlas (b) tactile atlas

2.3.2.2 3D Models

The combination of 3D models into tactile map signifies a substantial progression in accessibility for students with visual impairments. The efficacy of 3D models in augmenting the comprehension and utility of tactile map for individuals with visual impairments [12]. 3D map, which are three-dimensional representations, offer an easy depiction of shape, height, size, and depth comparisons of different objects relative to each other [13] .In the current technological era, the creation of 3D map has been simplified with the advent of 3D printing devices. A few years ago, the production of 3D models required significant costs and time. However, the emergence of 3D printers has made 3D modelling more accessible and affordable, as filament is available at various prices depending on the type and quality. In 3D printing, objects are printed layer by layer based on the settings of the slicing application. Filament is melted and deposited on the print bed one layer at a time, enabling the production of complex and customized objects depending on the user's creativity and using less material compared to traditional 3D manufacturing methods [14].

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Some of the advantages that can be observed by using 3D printing include lower production costs, accessibility, clear depiction of the height and depth of the object, electronic distribution and storage of files, reduced production time, and perfect scaling for representation of 3D objects [15]. These models provide tactile designs that can be explored by students through touch, enabling them to understand the characteristics of space more clearly. Additionally, the use of 3D models allows for the representation of complex structures, facilitating a more accurate understanding of geographical and architectural concepts. This approach aligns with the principles of Universal Design for Learning (UDL), ensuring that educational materials are accessible to diverse learners. Furthermore, the importance of incorporating multisensory elements, such as auditory labels or textures, to further enhance the effectiveness of tactile map with 3D models [16]. Map that can be printed in 3D incorporate elevated regions and adaptable designs to aid in orientation and direction-finding. These features enhance the user's ability to understand and navigate the represented terrain or area. The customizable patterns can be tailored to highlight specific points of interest or routes, providing a more personalized navigation experience. The raised areas give a tactile dimension to the atlas, offering an additional layer of information about the topography or layout. This makes these 3D printable map a versatile tool for navigation. [17]. Also using 3D icons, indications of elevation, and responsive sound elements. These components work together to create a multi-sensory experience. This involves the use of 3D models that provide a visual and spatial understanding of objects or environments. These models are enhanced with integrated audio features, which can offer additional information, feedback, or immersive experiences. The combination of visual 3D models with audio creates a multi-sensory interaction, enriching the user's engagement and comprehension [1]. The 3D symbols provide a visual representation of objects or information, height clues offer a sense of scale and topography, and the interactive audio can give real-time feedback or additional information, enhancing the overall user interaction and understanding [18]. 3D printed map with different textures allow students to easily distinguish each region and aid in easier memorization, similar to the concept of Braille code. This is an important feature to consider as visually impaired students primarily rely on their sense of touch for learning

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and memory. A few related projects supporting 3D printing for 3D model map are listed below:

Table 2.1: Tactile Graphic Research

Article	Method	Example of Work	Advantage / Disadvantage
[17] Taylor et al	The 3D printable map have raised areas and customizable patterns to help with navigation		1. Advantage: User can make their own map. 2. Disadvantage: Some people might struggle to use it if they don't have the right tech or skills.
[18] Holloway et al	Using 3D symbols, height clues, and interactive audio		1. Advantage: User can make their own map. 2. Disadvantage: harder to understand.
[1] Uttara Ghodke et al	Using 3D models integrated with audio		1. Advantage: make things clearer and give more information 2. Disadvantage: can be complex and might have issues with sound feedback.
[13] Brule et al	Using 3D printing to educate the impaired visual youth		1. Advantage: User can make their own map. 2. Disadvantage: Does not support multiple interactions simultaneously

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2.4 Assistive Technology to Learn Map and Geography

Research on assistive technology for visually impaired students in the context of learning map and geography reveals a variety of innovative strategies aimed at boosting spatial comprehension and geographic education. Tactile map serve as a fundamental tool, offering physical depictions of geographical data that students can explore through touch. These map often incorporate features such as raised surfaces and diverse textures to represent a variety of geographic and environmental elements, making them accessible for learners with blindness or visual impairments. The development of digital and hybrid interactive map further supports learning. Digital Interactive Map (DIMs) are displayed on flat surfaces like screens and can be interacted with via touch-sensitive interfaces. Hybrid Interactive Map (HIMs) merge digital components with physical models, providing a rich, multi-sensory experience that can include sound and even haptic feedback [19]. This fusion of physical and digital elements can aid visually impaired students in better understanding and remembering geographic information.

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In addition to these tactile and interactive solutions, assistive technologies such as talking globes and virtual reality headsets are increasingly being integrated into geography education for visually impaired students. These technologies provide verbal instructions and auditory descriptions of locations, enhancing the learning experience by relying on auditory cues rather than visual ones. Furthermore, GPS technology can offer real-time, location-based feedback, assisting with mobility and spatial orientation outside traditional learning environments. For educators, the incorporation of these assistive technologies into the classroom involves organizing accessible learning materials and classroom setups, using detailed verbal descriptions, and allotting sufficient time for exploration and interaction with tactile and digital aids [20]. The use of scent and texture can also be utilized to help establish a cognitive atlas of different locations and features. In summary, these advancements in assistive technology not only facilitate the inclusion of visually impaired students in geography lessons but also enrich their overall educational experience and foster independence.

2.4.1 Audio Guidance

Research indicates that audio guidance can significantly enhance the learning experience of map and geography for students with visual impairments. By offering auditory cues and descriptions of spatial layouts, audio guidance allows these students to grasp geographical concepts more effectively. A demonstrated that incorporating audio descriptions of map helped visually impaired students develop a better understanding of geographic features and spatial relationships [21]. Another research explored the effectiveness of interactive audio-tactile map in facilitating geographic learning for visually impaired students [9]. The research found that incorporating interactive elements, such as touch-sensitive surfaces and auditory feedback, allowed students to actively engage with geographic information and spatial concepts. By interacting with the audio-tactile map, students could explore geographic features, navigate routes, and conceptualize spatial relationships more intuitively.

Moreover, the study highlighted the importance of personalized audio descriptions tailored to individual learning needs, which enhanced the comprehensibility and relevance of the geographic content. Furthermore, audio guidance promotes independent navigation and spatial awareness, empowering visually impaired students to explore map and geographic environments with confidence [22]. For example, when the instructor asks the student to discover a country on the Asian region, the audio feedback system will output the name, history, and fascinating information about the country. This not only expands the general knowledge of the student but also eases the instructor's tasks, while improving the

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students' learning experience. Also, this refers to a system that employs Quick Response (QR) codes to retrieve information associated with labels in tactile graphics. Tactile graphics are images that use raised surfaces so that a person can feel them. They are used by individuals who are blind or visually impaired to understand graphical information. The system uses QR codes, which are a type of barcode that contains information about the item it is attached to. In this case, the QR codes are used to store information about the labels in the tactile graphics. When these codes are scanned using a suitable device, the stored information is retrieved, providing details about the corresponding label in the tactile graphic [23]. Researchers have applied different techniques to create their prototypes, such as integrating audio labels, utilizing smartphone or tablet-triggered codes, and employing talking tactile tablets as part of their methodology. The audio feedback system shown below is an example from previous projects.

Table 2.2: Audio Feedback System Research

Method	Example of Work
3D printed removable region pieces with PenFriend audio labels [1]	

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A system used to access label information in tactile graphics using QR codes [23]	

2.5 Computer Vision

Research into the use of computer vision technologies to aid visually impaired students in learning map and geography has shown significant promise. These technologies leverage advanced algorithms to interpret visual data and convert it into formats that are accessible to individuals with visual impairments. Explored the use of computer vision-based systems to assist visually impaired students in atlas learning [24]. By using object recognition and spatial analysis algorithms, the system provided real-time audio descriptions of geographic features and surroundings, enabling students to navigate map more effectively. The computer vision-based atlas learning system utilized cutting-edge object recognition algorithms to identify various geographic features, such as landmarks, roads, and bodies of water, from digital map [25]. Once identified, these features were translated into audio descriptions using natural language processing techniques.

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Additionally, the system used spatial analysis algorithms to provide context-aware information, such as distance and direction, to help visually impaired students navigate map more effectively. Moreover, according to Lei Shi, he spent around three years finding the proper method to produce interactive 3D models for blind children [26]. The reason to choose computer vision is that computer vision is low-cost, widely available with camera-enabled devices, and robust to ambient noise in public spaces like classrooms. This approach is friendly and easier for visually impaired students as it does not require any part assembly and allows them to have more freedom to explore using objects and RGB cameras.

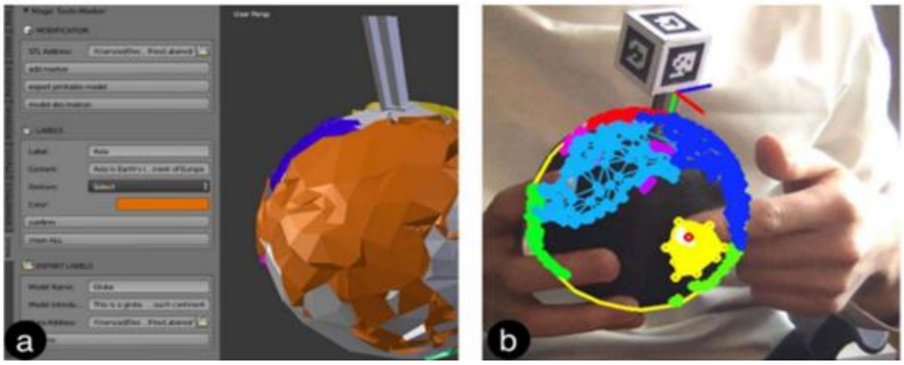

Figure 2.3 (a) "Markit" model (b) "Talkit"

The prototype described above facilitates interaction between camera devices and visually impaired students using a 3D model globe. The interaction process involves the creation of a "Markit" model, as depicted in Figure A, using software known as "Talkit," as illustrated in Figure B. This prototype incorporates an RGB camera and a microphone to incorporate audio annotations into 3D printed models. "Markit" offers a step-by-step procedure for any maker to generate I3Ms (Interactive 3D Models) with annotations, while "Talkit" is a computer application designed to enable blind users to access annotations from printed models using gestures and speech commands. Additionally, "Talkit" features an audio guide to assist visually impaired users in positioning the models to avoid occlusion issues [26]. The findings of the study indicated that the computer vision-based atlas learning system significantly improved the ability of visually impaired students to comprehend map and navigate geographic environments. The audio descriptions provided by the system were found to be accurate and informative, allowing students to gain a better understanding of spatial relationships and geographic layouts.

Overall, the research highlighted the potential of computer vision technologies to enhance accessibility and inclusivity in mapping education for visually impaired students.

By leveraging advanced algorithms and accessible devices, such systems can provide tailored support to help visually impaired students engage with map and geography more effectively, ultimately empowering them to participate more fully in educational activities related to spatial awareness and navigation.

2.6 Summary

Students with visual impairments often feel a sense of disconnection from the societal framework in which we exist, facing numerous barriers that hinder their smooth integration and active participation. Despite the commendable efforts in developing assistive technologies tailored to the needs of blind students, ongoing research efforts have uncovered inherent shortcomings within current systems. In response to these challenges, dedicated research initiatives have surfaced, aiming to innovate and refine existing methodologies. One such revolutionary shift involves the transition from traditional tactile map to more dynamic and immersive 3D model map, marking a significant advancement in enhancing accessibility and inclusivity within educational settings. This evolution not only signifies a departure from traditional learning methods but also represents a deep commitment to adopting advanced technologies to facilitate a more engaging and enriching educational experience for visually impaired students.

In tandem, researchers have delved into the potential of advanced features such as audio feedback mechanisms and computer vision technologies to further enhance the learning experience for visually impaired students. By leveraging the power of sound and real-time visual recognition, these tools provide invaluable support in navigating intricate map and understanding spatial relationships. Moreover, they pave the way for greater independence and autonomy, empowering students to explore and interact with their environment in meaningful ways. However, the journey towards educational equality and

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inclusivity does not end with the development of innovative technologies. It demands a concerted effort to ensure that these tools are accessible, adaptable, and responsive to the diverse needs of visually impaired students. This involves ongoing collaboration between researchers, educators, and the students themselves to co-create solutions that truly align with their lived experiences.

By embracing emerging technologies and pushing the boundaries of what is possible, can envision a future where every student, regardless of visual ability, has the opportunity to thrive and succeed in their educational journey.

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CHAPTER 3

METHODOLOGY

3.1 Overview

This research's methodology section outlines the systematic and theoretical framework used to create a tactile globe for visually impaired students. This chapter comprehensively discusses the tactile globe's design and development, including the product and the processes required for its effective operation. This section not only provides a succinct overview but also justifies the systematic approach and methods chosen for the study. It starts by explicitly stating the research objectives and discussing the research's importance, thereby affirming the design's relevance. The methodology then briefly discusses its alignment with the research objectives. The chapter proceeds by detailing the data collection methods employed, justifying their suitability in gathering the necessary data for the study. The tactile globe's design is informed by the previous chapter's findings, which suggested incorporating a mechanical system that can rotate the globe to specific locations and produce a sound upon arrival. This chapter seeks to elucidate the haptic tactile globe's design process, enhancing comprehension of its development and functionality.

3.2 Project Milestones

Prior to commencing the research methodology, the project establishes specific milestones. These milestones serve to illustrate the project plan's progression and facilitate time estimation for project completion. By identifying due dates for each milestone and creating a comprehensive project plan with a flowchart, the milestones are visually represented in Figure 3.1 for easy comprehension.

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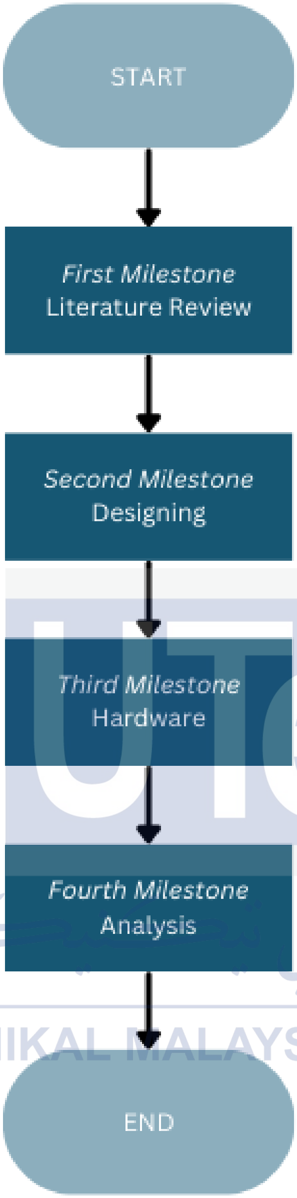

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Figure 3.1 Flow Chart of Methodology

3.2.1 First Milestone

After all project objectives have been defined, the next step is to complete the literature review. The literature review serves an important purpose, which is to provide a general overview of previous studies conducted by scholars or institutions. In this literature review, relevant ideas and information about the components used in this project, problem-solving methods previously attempted, and applied analysis techniques can be found. Literature reviews help understand the existing research landscape. By examining previous studies, one can benefit from others' experiences and avoid mistakes that may have been made before. Additionally, literature reviews help identify gaps in knowledge and outline areas that need focus in this project.

Figure 3.2 illustrates the flowchart of the literature review, encompassing these steps. By understanding previous research and drawing insights from it, the project can move forward effectively.

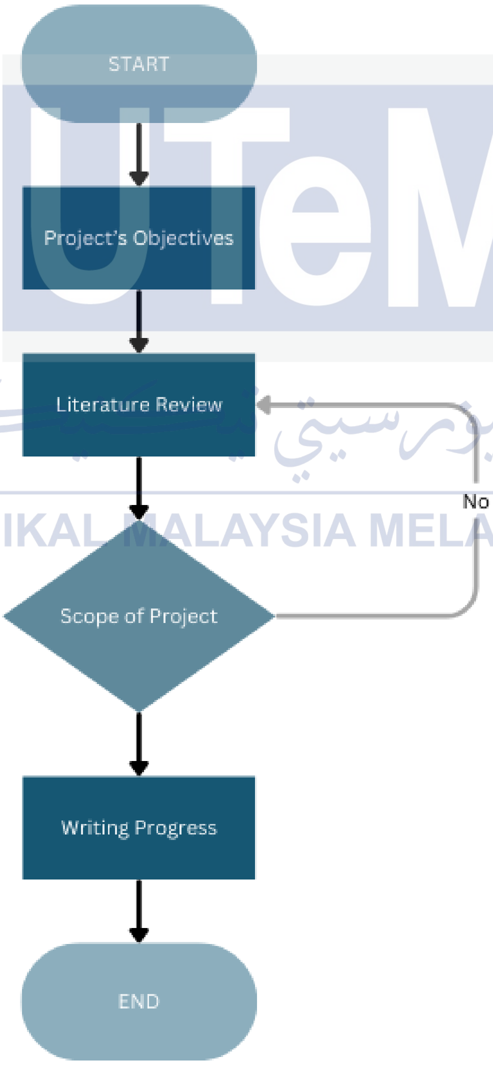

Figure 3.2 Flow Chart of Literature Review

3.2.2 Second Milestone

The tactile globe system's design is intended to enhance the learning experience of visually impaired students by improving their ability to understand and study global geography. The system is designed in such a way that when a student wants to explore a specific region, they can activate the globe through a button. This button commands the globe to rotate the desired region towards them, starting from the x-axis at a 0-degree angle. This rotation simulates the Earth's axial rotation, incorporating a circular motion to align with the natural movements of planets.

When the globe reaches the specified origin point, it provides auditory feedback describing the region, thereby confirming the student's selection. In addition, the system updates its coordinates to accurately calculate the position for future rotations, ensuring accuracy with each user interaction. This feature is controlled by a Raspberry Pi controller, which processes the rotation angles and activation commands. When a region button is pressed, it triggers a voice feedback system that not only confirms the action by announcing the region's name but also assists in orientational navigation for visually impaired students. The closed-loop feedback system ensures that the motor always knows its position. If external forces hinder movement, for example a student accidentally nudges the globe, the servo detects it and corrects accordingly. The feedback loop prevents misalignment due to disturbances, enhancing the overall reliability of the globe. Auditors' support is essential as it eliminates the need for students to physically locate the regions themselves, thereby simplifying the learning process and ensuring a more thorough understanding of the subject.

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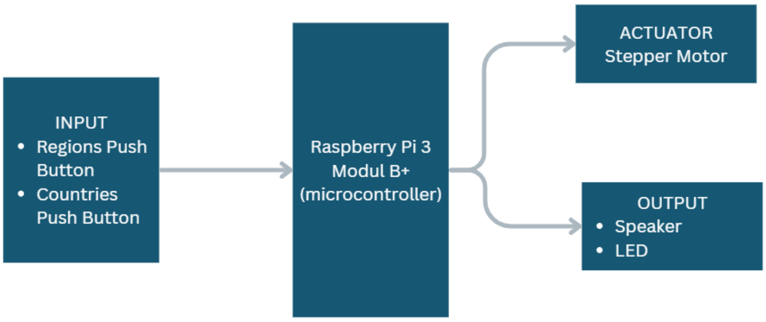

Figure 3.3 Block Diagram of Project System

Figure 3.3 and Figure 3.4 illustrates the block diagram and a flowchart that depict the project's systematic design, providing a visual representation of the operational workflow and the integration of components within the system.

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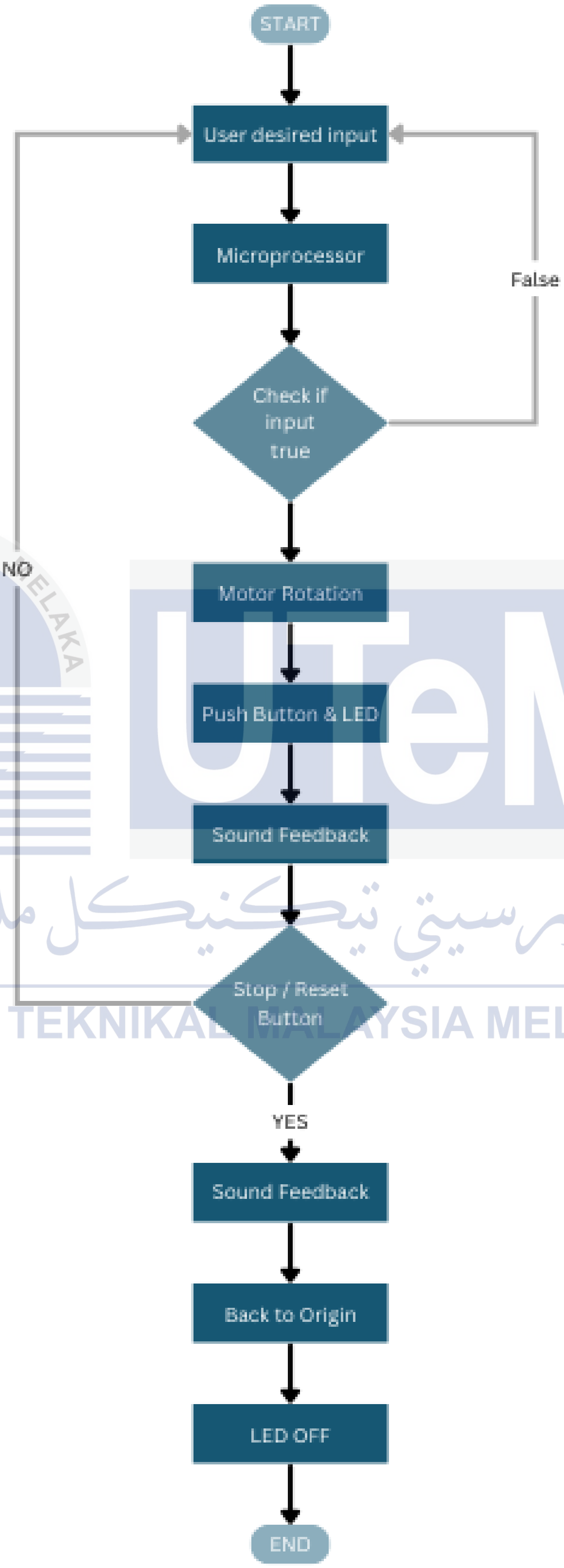

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Figure 3.4 Flow Chart of Project System

3.2.2.1 Software Development

This section provides an overview of the software that will be utilized in conjunction with the hardware component. It aims to explain the role and functionality of the software within the larger project context.

Among all project aspects, coding and simulation hold paramount importance. These activities serve as the backbone of the entire monitoring system. By implementing effective code and conducting thorough simulations, we ensure the seamless operation and accurate monitoring of the system.

3.2.2.1.1 Proteus

Proteus software was chosen for designing the electrical circuit in this particular project due to its user-friendly interface and ease of use. Design engineers and technicians primarily utilize Proteus to create schematic drawings and electronic printed circuit boards, making it an essential tool in the field. Additionally, Proteus serves as a vast educational resource covering various aspects such as analogue and digital circuits, microcontroller and embedded system software, integrated microcontroller system experimentation, as well as unique experiments, graduation design, project development, and product design. The versatility of Proteus makes it a valuable asset in both educational and professional settings, providing a comprehensive platform for circuit design and analysis.

3.2.2.1.2 Python

Python is a versatile and popular programming language. Python comes preinstalled on Raspberry, so it’ll be ready to start from the get-go. Python has a vast ecosystem of libraries and modules that cover a wide range of applications. For Raspberry Pi, can find libraries for GPIO (General Purpose Input/Output), sensors, displays, cameras, and more.

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These libraries simplify hardware interactions, allowing focus on project logic rather than low-level details. Python is a computer programming language often used to build websites and software, automate tasks, and conduct data analysis. Python is a general-purpose language, meaning it can be used to create a variety of different programs and isn't specialized for any specific problems. This versatility, along with its beginner-friendliness, has made it one of the most used programming languages today. Python is commonly used for developing websites and software, task automation, data analysis, and data visualization.

3.2.2.1.2.1 Stepper Motor

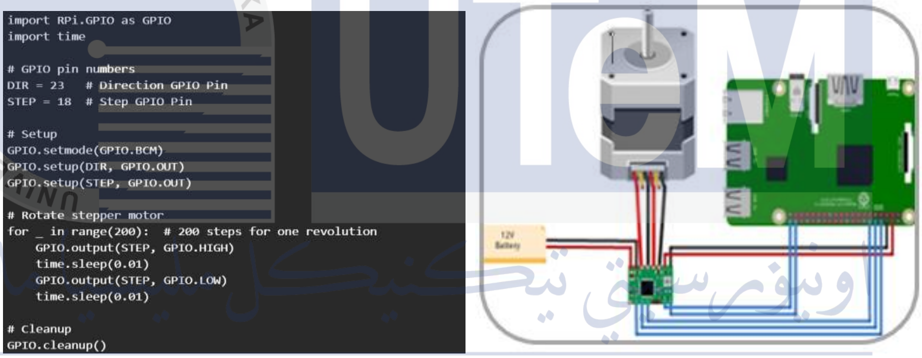

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Figure 3.5 Basic Coding and Circuit for Stepper Motor

Figure 3.5 shows the control of a stepper motor using a Raspberry Pi, which requires a stepper motor driver like the A4988. The driver serves as an interface between the Raspberry Pi and the motor, managing power requirements and control signals. The basic connections involve linking the motor power supply to the VMOT and GND pins of the driver, connecting the VDD and GND pins of the driver to the 3.3V and GND pins on the Raspberry Pi, and connecting the STEP and DIR pins of the driver to GPIO pins on the Raspberry Pi (e.g., GPIO 18 and GPIO 23, respectively). Additionally, the motor coils are connected to the driver through the 2B, 2A, 1A, and 1B pins.

The operation of the stepper motor is controlled through the DIR and STEP pins on the driver. The DIR pin determines the rotation direction of the motor, with its state (HIGH or LOW) indicating clockwise or counterclockwise rotation. The STEP pin controls the steps of the motor, with each pulse sent to this pin resulting in one step of the motor. The speed of the motor is regulated by the frequency of the pulses sent to the STEP pin; shorter delays between pulses lead to faster rotation. This setup allows precise control over the motor's movement, making it suitable for applications requiring accurate positioning.

The code begins by importing the necessary libraries and defining the GPIO pin numbers for the DIR and STEP signals. The GPIO pins are then configured as outputs. The motor is rotated by sending 200 pulses to the STEP pin, which corresponds to one full revolution of the motor. Each pulse consists of setting the STEP pin HIGH, waiting for a short delay, setting the STEP pin LOW, and waiting for another short delay. Finally, the GPIO pins are reset to their default state using the GPIO.cleanup() function.

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3.2.2.1.2.2 Push Button

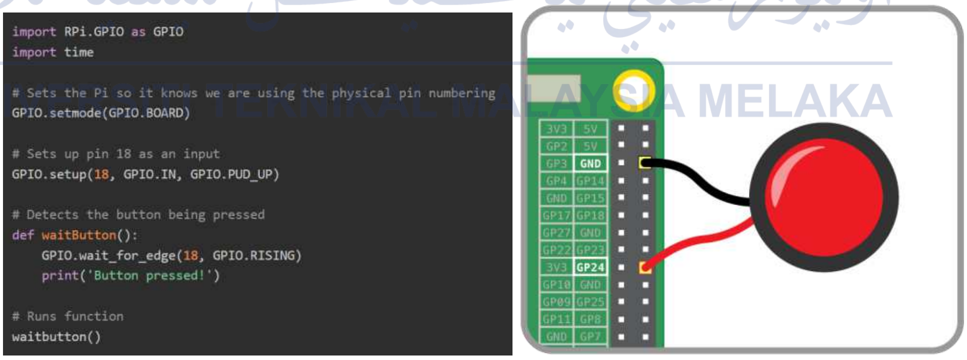

Figure 3.6 Basic Coding and Circuit for Push Button

In a push-button circuit designed for a Raspberry Pi, a tactile switch is connected to the GPIO pins as shown in Figure 3.6. This setup enables the detection of button presses through a Python script. Typically, one side of the push button is connected to a GPIO pin, such as pin 18, while the other side is connected to the 3.3V power supply via a resistor. This resistor serves to limit the current and protect the GPIO pin. When the button is not pressed, the input pin remains in a low state (0V). Pressing the button bridges the connection to the 3.3V power supply, shifting the pin's state to high (3.3V). A Python program can be written to utilize the RPi.GPIO library for reading the state of the button. The GPIO pin is initialized as an input and set to a default low state. The script continuously checks the pin's state, and a high reading indicates that the button has been pressed. This configuration allows for specific actions to be executed in the code in response to button presses, such as activating an LED or sending a digital signal. It is crucial to have the RPi.GPIO library installed to carry out such projects, and detailed guides are available for further instruction. This code is a basic example of how to set up a Raspberry Pi to respond to a physical button press. It demonstrates the use of GPIO pin configuration and edge detection to create a simple interactive hardware project. For the code to function as intended, the physical button must be correctly wired to the designated GPIO pin and the ground pin on the Raspberry Pi. Once set up, pressing the button will trigger the message output, signaling that the button press has been successfully registered by the program.

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3.2.2.1.2.3 LED

```
import RPi.GPIO as GPIO
import time

GPIO.setmode(GPIO.BCM)  # Set the pin numbering system to BCM
GPIO.setup(17, GPIO.OUT)  # Set GPIO17 as an output

try:
    while True:
        GPIO.output(17, GPIO.HIGH)  # Turn on the LED
        time.sleep(1)  # Wait for 1 second
        GPIO.output(17, GPIO.LOW)  # Turn off the LED
        time.sleep(1)  # Wait for 1 second
except KeyboardInterrupt:
    GPIO.cleanup()  # Clean up the GPIO pins when 'Ctrl+C' is pressed
```

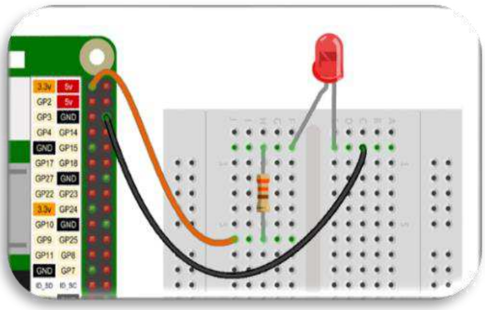

Figure 3.7 Basic Coding and Circuit for LED

Figure 3.7 shows an LED circuit connected to a Raspberry Pi requires an LED, a resistor, a breadboard, and jumper wires for assembly. The anode of the LED, which is the longer leg, connects to a GPIO pin such as GPIO17. The cathode, or shorter leg, attaches to one end of the resistor, while the other end of the resistor links to a ground pin on the Raspberry Pi. This configuration allows the LED to light up when the GPIO pin is set to high, with the resistor serving to limit the current and protect both the LED and the Raspberry Pi. A Python script can be written to control the LED, utilizing the RPi.GPIO library. The script sets the GPIO pin as an output and toggles it between high and low states, causing the LED to blink. It includes a loop that turns the LED on and off at one-second intervals, and a cleanup function to reset the GPIO pins when the program is interrupted, ensuring the pins are not damaged. This setup is essential for projects involving LED control, and the RPi.GPIO library must be installed prior to starting.

3.2.2.1.2.4 Speaker

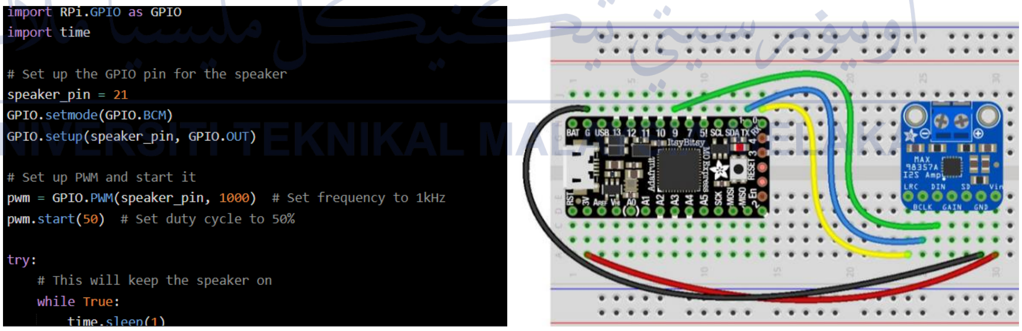

Figure 3.8 Basic Coding and Circuit for Speaker

A 5V speaker configuration with a Raspberry Pi typically involves an amplifier, such as the Adafruit MAX98357 I2S Class-D Mono Amp, to facilitate audio output. The amplifier's VIN is connected to the Raspberry Pi's 5V power, and its GND to the Raspberry Pi's ground. The DIN, BCLK, and LRCLK of the amplifier are connected to the Raspberry Pi's GPIO 21, GPIO 18, and GPIO 19, respectively. Basic control of the speaker can be achieved through a Python script that utilizes the Raspberry Pi's PWM capabilities. The script sets up a GPIO pin as an output for the speaker and initializes PWM on that pin with a frequency and duty cycle designed to generate a tone. The script runs in a loop to maintain the tone until manually interrupted, after which the PWM is stopped, and the GPIO pins are cleaned up to ensure a safe exit as shown in Figure 3.8. This basic setup is crucial for projects that require audio output from a speaker, and detailed instructions for such configurations are accessible for further guidance. It is imperative to power off the Raspberry Pi when connecting or disconnecting components to prevent any damage.

3.2.3 Third Milestone

Component selection in hardware development involves carefully choosing electronic components that meet specific requirements. This process includes evaluating and selecting components such as microcontrollers, motors, indicators, connectors, and other electrical and 3D printing parts. Factors like performance specifications, compatibility, cost, availability, reliability, and power consumption are considered. Thorough research, comparison of datasheets, and trade-offs ensure optimal selection. Proper component choice directly impacts the performance, functionality, and overall quality of a hardware system. Figure 3.9 illustrates the flowchart of the component selection.

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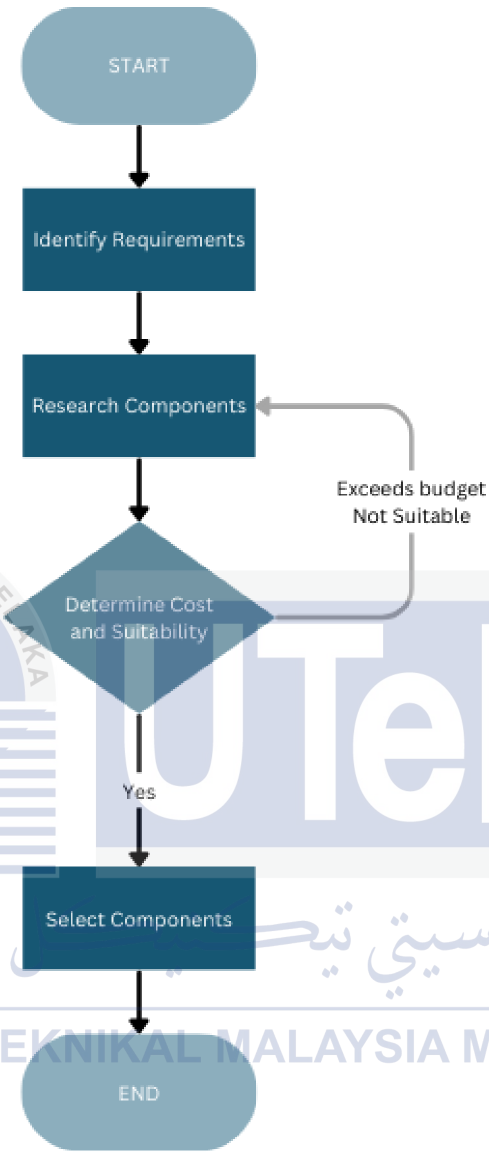

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Figure 3.9 Flow Chart of Component Selection

3.2.3.1 Raspberry Pi 3B+

In the context of system architecture, a microcontroller serves as the central processing unit, akin to the brain, orchestrating the operation of various electronic components within the tactile globe. This compact computing device facilitates programming and assembly, enabling seamless communication between the user and the system. When the user initiates a command, such as pressing a push-button, the Raspberry

Pi, a versatile single-board computer, processes the input and subsequently directs the connected electronic devices, such as motors, to execute specific actions.

Additionally, let's delve into the technical specifications of the Raspberry Pi 3 Model B+. This powerful board boasts a 64-bit quad-core processor clocked at 1.4GHz, dual-band wireless LAN (2.4GHz and 5GHz), Bluetooth 4.2/BLE support, Gigabit Ethernet via USB 2.0, and Power over Ethernet (PoE) capability using a separate PoE HAT. Its modular compliance certification ensures reliable wireless connectivity. Remarkably, the Raspberry Pi 3 Model B+ maintains compatibility with the mechanical footprint of both the Raspberry Pi 2 Model B and the original Raspberry Pi 3 Model B. Here are the specifications of Raspberry Pi 3 Model B+:

- Processor: Broadcom BCM2837B0, Cortex-A53 (ARMv8) 64-bit SoC running at 1.4GHz.
- Memory: 1GB LPDDR2 SDRAM.
- Wireless Connectivity: Dual-band 2.4GHz and 5GHz IEEE 802.11.b/g/n/ac wireless LAN, Bluetooth 4.2, and BLE.
- Ethernet: Gigabit Ethernet over USB 2.0 (maximum throughput 300 Mbps).
- GPIO: Extended 40-pin GPIO header.
- Video Output: Full-size HDMI.
- USB Ports: 4 USB 2.0 ports.
- Camera and Display Ports: CSI camera port for connecting a Raspberry Pi camera, DSI display port for connecting a Raspberry Pi touchscreen display.
- Audio: 4-pole stereo output and composite video port.
- Storage: Micro SD port for loading the operating system and storing data.
- Power Input: 5V/2.5A DC power input.
- Power-over-Ethernet (PoE) Support: Requires a separate PoE HAT.

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One standout feature of the Raspberry Pi is its GPIO (general-purpose input/output) pins, neatly arranged along the top edge of the board as shown in Figure 3.10. With a 40-pin GPIO header, these pins allow interfacing with external components. Even though the GPIO header remains unpopulated on models like the Raspberry Pi Zero and Raspberry Pi Zero W, it provides ample connectivity for up to push buttons, stepper motors, LEDs, and speaker outputs. This flexibility ensures scalability for future enhancements and additional functionalities. Below is the Figure 3.10 and Figure 3.11 of Raspberry Pi 3 Model B+ and the configuration of digital pin:

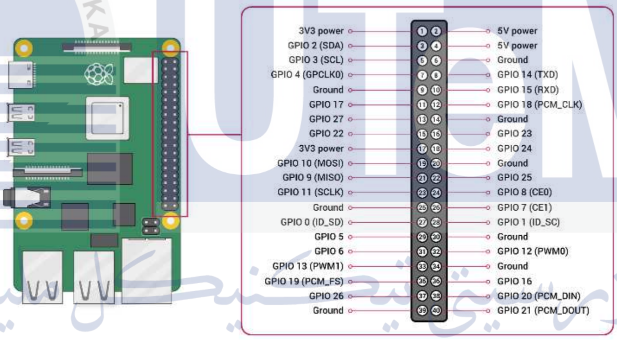

Figure 3.10 GPIO and the 40-pin header

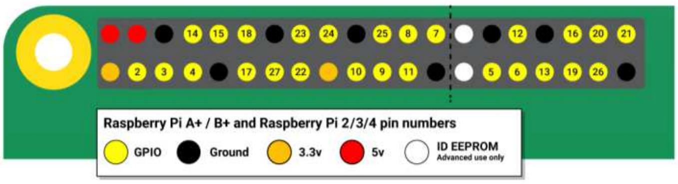

Figure 3.11 Any of the GPIO pins can be designated in software as an input or output pin and used for a wide range of purposes

The board features two 5V pins, two 3.3V pins, and several ground pins (GND) that cannot be reconfigured. The remaining pins serve as general-purpose 3.3V pins, where outputs are set to 3.3V and inputs are 3.3V-tolerant. When designated as output pins, a GPIO pin can be set to either high (3.3V) or low (0V). Conversely, when designated as an input pin, it can be read as either high (3.3V) or low (0V). The use of internal pull-up or pull-down resistors simplifies this process. Notably, GPIO2 and GPIO3 have fixed pull-up resistors, while other pins allow configuration through software. Beyond basic input and output functions, these GPIO pins offer versatility for various alternative purposes, with some functions available across all pins and others specific to certain pins as shown in Table 3.1.

Table 3.1: Other GPIO functions

PWM (pulse-width modulation)	Software PWM available on all pins Hardware PWM available on GPIO12, GPIO13, GPIO18, GPIO19
SPI	SPI0: MOSI (GPIO10); MISO (GPIO9); SCLK (GPIO11); CE0 (GPIO8), CE1 (GPIO7) SPI1: MOSI (GPIO20); MISO (GPIO19); SCLK (GPIO21); CE0 (GPIO18); CE1 (GPIO17); CE2 (GPIO16)
I2C	Data: (GPIO2); Clock (GPIO3) EEPROM Data: (GPIO0); EEPROM Clock (GPIO1)
Serial	TX (GPIO14); RX (GPIO15)

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3.2.3.2 Li-ion Battery

The BRC 18650 Ultrafire Rechargeable Li-ion Battery is marketed as a 3.7V 5000mAh battery, but its actual tested capacity is around 1200mAh. This discrepancy is common in many high-copy batteries, where the advertised capacity is significantly higher than the real-world performance. These batteries are often used in various devices such as flashlights, headlamps, and other portable electronics that require a reliable power source.

Here are the specifications for the BRC 18650 Ultrafire Rechargeable Li-ion Battery:

- Nominal Voltage: 3.7V
- Max. Charge Voltage: 4.2V

- Advertised Capacity: 5000mAh
- Actual Tested Capacity: Approximately 1200mAh
- Size: 18mm (diameter) x 65mm (length)
- Terminal Type: Button Top
- Shape: Cylindrical
- Rechargeable Times: Up to 1800 cycles
- Material: Lithium-ion (Li-ion)

Despite the lower actual capacity, these batteries can still be useful for low to moderate power applications. They are rechargeable, which makes them a cost-effective and environmentally friendly option compared to disposable batteries. However, users should be cautious and aware of the actual performance they can expect, especially if they need a battery for high-drain devices.

The construction of these batteries typically includes a protection circuit to prevent overcharging, over-discharging, and short-circuiting, which enhances their safety and longevity. However, the quality of these protection circuits can vary, especially in high-copy versions, so it's important to purchase from reputable sources to ensure safety and reliability. These batteries as a power supply for globe. Their rechargeable nature makes them a convenient and sustainable option for such applications, providing consistent power without the need for frequent battery replacements.

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Figure 3.12 BRC 18650 Ultrafire Rechargeable Li-ion Battery

3.2.3.3 Stepper Motor

The NEMA 17 stepper motor is a widely used type of stepper motor known for its precision and reliability. The term "NEMA 17" refers to the motor's frame size, which is standardized by the National Electrical Manufacturers Association (NEMA). Specifically, the NEMA 17 motor has a faceplate dimension of 1.7 x 1.7 inches (approximately 42 x 42 mm). This standardization ensures compatibility and interchangeability among different manufacturers and applications. The NEMA 17 stepper motor is a hybrid motor, combining features of both permanent magnet and variable reluctance stepper motors. It consists of a rotor, which is a permanent magnet with 50 teeth, and a stator, which is an electromagnet with 48 teeth arranged in four pairs. When the stator coils are energized in a specific sequence, the rotor aligns with the magnetic field, causing it to rotate in discrete steps. Each step corresponds to a fixed angle, typically 1.8 degrees, meaning the motor requires 200 steps to complete one full revolution.

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The NEMA 17 stepper motor operates on a rated voltage of 4V and draws a current of 1.2A per phase. It provides a holding torque of approximately 3.2 kg-cm, making it suitable for applications requiring precise control and high torque. The motor's step angle accuracy is typically within ±5%, ensuring reliable positioning in various applications. Due to its precision and torque, the NEMA 17 stepper motor is commonly used in a variety of applications, including 3D printers, CNC machines, and laser cutters. Its ability to provide accurate and repeatable movements makes it ideal for tasks that require precise positioning and control. Additionally, the motor's compact size and high torque make it a popular choice for robotics and automation projects.

The NEMA 17 stepper motor has several key specifications that define its performance. These include a phase resistance of 3.3 ohms, an inductance of 4 mH, and a rotor inertia of 35 g-cm². The motor's shaft diameter is typically 5 mm, with a shaft length of 22 mm. The motor's length can vary depending on the specific model, but it generally falls within the range of 33 mm. The NEMA 17 stepper motor is a versatile and reliable component widely used in precision applications. Its standardized dimensions, combined with its hybrid construction, allow it to deliver high torque and accurate positioning. Table 3.2 shows the detailed specifications for the NEMA 17 stepper motor:

Table 3.2: Specification NEMA 17 Stepper Motor

Electrical Specifications	• Rated Voltage: 12V DC • Current: 1.2A per phase at 4V • Step Angle: 1.8 degrees (200 steps per revolution) • Number of Phases: 4
Mechanical Specifications	• Holding Torque: 3.2 kg-cm • Motor Length: 1.54 inches (approximately 39 mm) • Shaft Diameter: 5 mm • Shaft Length: 22 mm • Phase Resistance: 3.3 ohms • Inductance: 4 mH • Rotor Inertia: 35 g-cm²
Environmental Specifications	• Operating Temperature: -10 to 40 °C • Additional Features • Lead Wires: 4-wire, 8-inch leads • Mounting: Standard NEMA 17 faceplate dimensions (42 x 42 mm)

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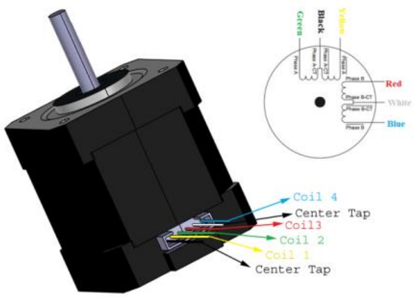

Figure 3.13 NEMA 17 Stepper Motor Configuration

The motor features six wires, connected to two split windings, which is typical for unipolar stepper motors as shown in Figure 3.13. The first winding consists of Black, Yellow, and Green wires, with Black serving as the center tap and Yellow and Green as the coil ends. The second winding includes Red, White, and Blue wires, with White as the center tap and Red and Blue as the coil ends. During operation, the center taps of the windings (Black and White) are usually connected to the positive supply, while the two ends of each winding are alternately grounded through a drive circuit. According to Figure 3.13, the sequence of the stator poles in the motor is A, B, A', B'. Based on the input received, the Raspberry Pi calculates the required rotation angle and sends control signals to the motor. This motor then rotates the globe to align the selected region in front of the user.

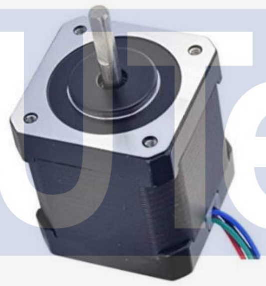

Figure 3.14 NEMA 17 Stepper Motor

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3.2.3.4 Speaker

The speaker acts as a conduit for information, allowing students to engage with content through both touch and sound. Tactile feedback from physical interaction meets its auditory counterpart, creating a holistic learning experience. For visually impaired students, this audio feedback is invaluable. It aligns with the tactile cues they receive from the globe, reinforcing their understanding of geographical concepts. By providing audible information, the speaker bridges the gap, ensuring that no student is left in silence when exploring the world. Portable subwoofer computer speakers, powered by a high-power 3.5mm Aux-in connection and USB 5V, are used for this project because it easily can connect directly to Raspberry Pi. When a button corresponding to a specific region is pressed on the control panel, the speaker provides audio feedback by announcing the name of that region. Additionally, when a student interacts with the tactile globe's surface, the speaker delivers audio output feedback, identifying the country associated with that location. This audio feedback serves as a valuable aid for visually impaired students, providing audible information that aligns with the tactile feedback they receive from the globe.

Figure 3.15 Portable Subwoofer Computer Speakers

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The specifications for a generic portable subwoofer computer speaker system with a high-power 3.5mm Aux-in connection and USB power typically include:

- Speaker Type: 2.0 or 2.1 channel
- Frequency Response: Often ranges from 80 Hz to 20,000 Hz
- Power Rating: Can vary, common ratings are 10W RMS (20W Peak), with some models offering up to 30W RMS (60W Peak)
- Dimensions: Compact size for easy placement on a desk or alongside a monitor
- Inputs: Standard 3.5mm analog input, USB-C for power and/or audio, Bluetooth connectivity for wireless audio streaming
- Additional Features: Some models may include customizable EQ settings, waterproof or dustproof design, and built-in controls for volume and bass levels.

3.2.3.5 Push Button

The tactile globe represents an innovative educational tool designed to enhance students' understanding of geography and global regions. It incorporates a thoughtful combination of technology and accessibility features, making it suitable for a diverse range of learners. The primary purpose of the tactile globe is to provide a tangible and interactive experience for visually impaired students. Rather than relying solely on traditional map or digital displays, students can physically engage with the globe.

The push buttons play a crucial role in achieving this goal. Each button corresponds to a specific geographical area, such as a countries and region. When a student presses a tactile self-locking push button, it triggers a stepper motor. This motor precisely rotates the globe to align with the selected region. This dynamic movement allows students to explore different parts of the world effortlessly. These buttons serve as indicators and selectors. They are strategically placed at the control panel. The tactile self-locking mechanism ensures that once a button is pressed, it remains in place until the student selects another region.

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Unlike the self-locking buttons, the tactile momentary push button operates differently. When a student presses the globe's surface, this button activates. It triggers an output voice, which provides information about the countries on that region the student has pressed. The voice output includes details such as the country's name. This auditory feedback enriches the learning experience.

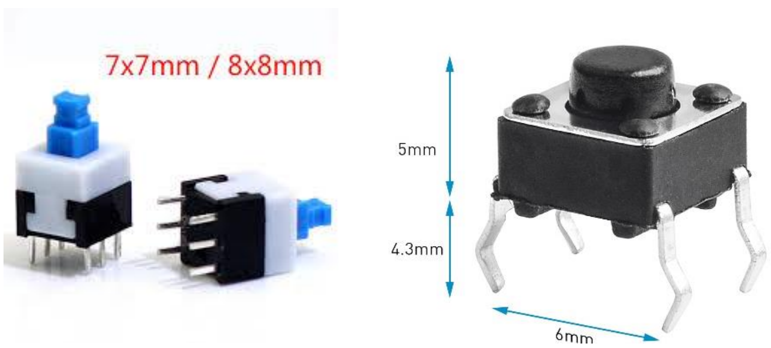

Figure 3.16 Tactile Self-Locking and Momentary Push Button

To enhance accessibility, the push buttons feature Braille code on their surfaces. Visually impaired users can run their fingers over the Braille labels to identify the purpose of each button. This thoughtful design ensures inclusivity and eliminates confusion. The tactile globe fosters curiosity and engagement. Students can explore the world's diversity firsthand. By combining tactile, auditory, and visual elements, the project caters to various learning styles. Here are the specifications for both Tactile Self-Locking and Tactile Momentary Push Buttons:

Tactile Self-Locking Push Button

- Dimensions: 7mm x 7mm
- Temperature Range: -40 to +70°C
- Rated Load: 0.3A at 60V AC or 1.5A at 25V AC
- Contact Resistance: ≤0.02Ω
- Actuation Force: 100-350g
- Insulation Resistance: ≥100MΩ
- Life: 100,000 button presses

Tactile Momentary Push Button

- Power Rating: Maximum 50mA at 24V DC
- Insulation Resistance: 100MΩ at 100V
- Operating Force: 2.55±0.69 N
- Contact Resistance: Maximum 100mΩ
- Operating Temperature Range: -20 to +70°C

Below are two distinct types of push buttons, each serving a specific purpose:

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Table 3.3: The usage of Tactile Self-Locking and Tactile Momentary Push Button in this project

Tactile Self-Locking	Tactile Momentary	Braille Code
East Asia	1. Republic of China, CHN 2. Mongolia, MNG 3. Japan, JPN 4. North Korea, PRK 5. South Korea, KOR 6. Macao, MAC 7. Taiwan, TWN 8. Hong Kong, HKG	1. 2. 3. 4. 5. 6. 7. 8.
West Asia	1. Turkey, TUR 2. Saudi Arabia, SAU 3. Armenia, ARM 4. Azerbaijan, AZE 5. Bahrain, BHR 6. Georgia, GEO 7. Iraq, IRQ 8. Iran, IRN 9. Palestine, PSE 10. Kuwait, KWT 11. Lebanon, LBN 12. Oman, OMN 13. Qatar, QAT 14. Cyprus, CYP 15. Syria, SYR 16. United Arab Emirates, ARE 17. Yemen, YEM 18. Jordan, JOR	1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15. 16. 17. 18.
Central Asia	1. Kazakhstan, KAZ 2. Kyrgyzstan, KGZ 3. Tajikistan, TJK 4. Turkmenistan, TKM 5. Uzbekistan, UZB	1. 2. 3. 4. 5.
South Asia	1. Bangladesh, BGD 2. Bhutan, BTN 3. India, IND 4. Maldives, MDV 5. Nepal, NPL 6. Pakistan, PAK 7. Sri Lanka, LKA	1. 2. 3. 4. 5. 6. 7.

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Southeast Asia	1. Indonesia, IDN 2. Singapore, SGP 3. Malaysia, MYS 4. Thailand, THA 5. Laos, LAO 6. Myanmar, MMR 7. Cambodia, KHM 8. Brunei Darussalam, BRN 9. Vietnam, VNM 10. Philippines, PHL	1. ⠊⠙⠝ 2. ⠎⠛⠏ 3. ⠍⠽⠎ 4. ⠞⠓⠁ 5. ⠇⠁⠕ 6. ⠍⠍⠗ 7. ⠅⠓⠍ 8. ⠃⠗⠝ 9. ⠧⠝⠍ 10. ⠏⠓⠇

Table 3.4: Braile Code for Each Tactile Self-Locking Push Button

Text	Braile Code
START	⠎⠞⠁⠗⠞
STOP	⠎⠞⠕⠏
EAST	⠑⠁⠎⠞
WEST	⠺⠑⠎⠞
CENTER	⠉⠑⠝⠞⠑⠗
SOUTH	⠎⠕⠥⠞⠓
SOUTHEAST	⠎⠕⠥⠞⠓⠑⠁⠎⠞

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3.2.3.6 LED

This project involves the use of Light Emitting Diodes (LEDs), specifically 5mm wired LEDs. These LEDs serve as indicators on a tactile globe. As described in the Abstract section, this innovative globe is designed to be user-friendly for all students, especially for students with visual impairments.

To enhance engagement and foster curiosity among all students, LEDs have been incorporated into the globe. These LEDs are strategically placed next to push buttons, each corresponding to a specific country. When a student presses the surface of the tactile globe, the LEDs illuminate, providing a visual representation. The LEDs function similarly to speakers, creating a dynamic learning experience.

Figure 3.17 LED 5mm

3.2.3.7 MCP20317

The Raspberry Pi hardware features a limited number of digital I/O pins. However, the addition of an MCP23017 I/O expander chip allows for the incorporation of 16 extra general-purpose pins as shown in Figure 3.18. The MCP23017, designed for I2C bus applications, comprises two 8-bit ports (PORTA and PORTB) that can be configured in either 8-bit or 16-bit modes.

By utilizing the MCP23017, an additional 16 pins can be added to the microcontroller. These pins can serve as input, output, input with a pull-up, or open drain. Furthermore, the MCP23017 supports external pin interrupts, eliminating the need for continuous polling. It operates within a voltage range of 2.7V to 5.5V, making it suitable for both 3.3V and 5V setups. Each I/O pin can sink/source up to 20mA.

To set the I2C address, connect the ADDR0-2 pins to either power or ground. This flexibility allows for up to 8 unique addresses on a single I2C bus, enabling a total of 128 I/O pins across multiple MCP23017 chips. Here are the specifications for the MCP23017:

- Interface: I2C
- I/O Pins: 16-bit input/output port expander
- Interrupt Output: Yes, with interrupt output
- Cascadable: Up to 8 devices on one bus
- Current: 25mA sink/source capability per I/O
- I2C Bus Frequency: Supports 100kHz, 400kHz, and 1.7MHz

- Operating Voltage: 1.8V to 5.5V
- Temperature Range: -40°C to +125°C

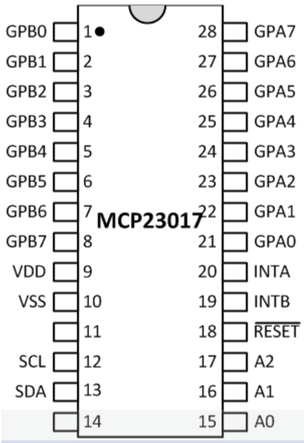

Figure 3.18 16-port digital I/O expander with an I2C interface

To power the MCP23017, connect the VDD pin to the +5V voltage rail and the VSS pin to the ground rail. Connect the SCL and SDA pins on the MCP23017 to the I2C pins on the Raspberry Pi hardware as shown in Figure 3.19. Set the I2C device address of the MCP23017 to ‘0x20’ by grounding the A0, A1, and A2 pins. Can safely connect the SDA and SCL pins directly to the Raspberry Pi hardware because there are resistors on the Raspberry Pi that pull these two signal lines to +3.3V.

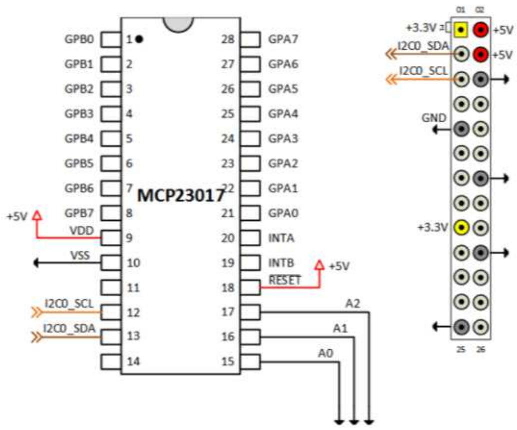

Figure 3.19 Connect MCP23017

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3.2.3.8 Materials for 3D Printing

Acrylonitrile Butadiene Styrene (ABS) filament, a commonly used thermoplastic material in 3D printing, is meticulously manufactured from a specialty bulk-polymerized ABS resin. This unique resin formulation has significantly lower volatile content compared to traditional ABS resins, resulting in a safer and more pleasant printing experience. When using ABS filament for 3D printing, users immediately notice its exceptional print quality, characterized by precise layer adhesion and minimal warping. Moreover, ABS exhibits remarkable mechanical properties. Its commendable impact resistance makes it an ideal choice for creating durable mechanical parts. Whether designing intricate robotics components or crafting functional prototypes, ABS performs exceptionally well. Furthermore, ABS can withstand temperatures of approximately 100°C without compromising its structural integrity, making it suitable for heat-resistant applications.

ABS filament enables educators to create tactile globes with raised features, providing a tangible representation of geographical elements. Students can explore landforms and oceans through touch. This tactile experience enhances their understanding of spatial relationships. Educators can customize ABS tactile globes to align with specific curriculum requirements. For example, adding braille labels for countries and other geographic details. This customization ensures that the tactile globe caters to specific learning objectives.

ABS is a robust material, resulting in durable and long-lasting tactile globes. These globes can withstand frequent handling without breaking or losing their shape. Creating ABS tactile globes in-house using 3D printers is cost-effective compared to purchasing pre-made tactile map or globes. Schools and educational institutions can produce customized globes without significant expenses.

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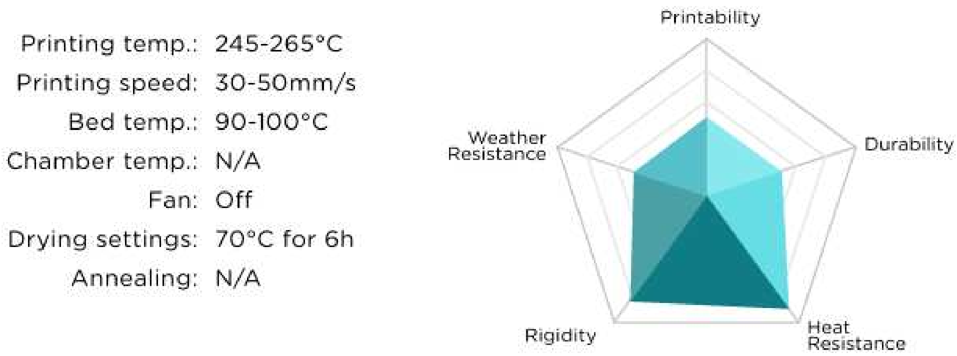

Figure 3.20 Printing Settings and Material Properties

3.2.4 Fourth Milestone

The analysis focuses on the early development of an Asia atlas based on haptic and audio-tactile microcontrollers for visually impaired students. It involves several crucial stages. In the initial phase, designing the electrical circuit and wiring schematic is necessary. This includes determining the required electronic components and connecting them correctly. The electrical circuit must comply with design specifications and meet functional requirements. Additionally, the wiring needs to be studied to ensure reliability and efficiency. Beyond circuitry and wiring, the overall project design also encompasses mechanical and ergonomic elements. The holistic design should consider aesthetics, usability, and efficiency. Once the design phase is complete, programming the microcontroller to control the Atlas becomes essential. This involves configuring leg movements and responses to audio feedback. Data will be evaluated to ensure the system delivers the expected output. If system performance is weak, reassessment and improvement of previous achievements are necessary.

3.3 Concept Design of The Product

The globe with features a surface atlas of the Asian region, will be connected to a stepper motor. This motor is responsible for rotating the globe to bring the correct region to the front for the student. Push buttons located on the control panel and on the globe, itself are used to input commands from the user into the system. The globe and control panel are connected with a connector to enhance the stability of the globe as shown at Figure 3.21. The control panel section serves as a housing for the controller and covers the circuits as a safety measure to prevent any electrical components from being damaged, which could pose a hazard to the user.

To elaborate, this educational device is designed to aid students in learning geography interactively. The stepper motor allows for precise control of the globe's rotation, ensuring that students can easily find and study different regions, specifically Asia in this case. The push buttons provide a tactile interface for students to engage with the globe, making the learning experience more hands-on. The connector not only secures the globe in place but also ensures it remains stable during operation, preventing any accidents due to the globe tipping over. Lastly, the control panel's dual function as housing protects internal electronics and provides an additional layer of safety for users, safeguarding against potential electrical hazards.

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Figure 3.21 3D Project Design

3.4 Procedure of Project

The conductor will introduce and explain the functions of each button on the control panel to the volunteers. Volunteers will be briefed on how to operate the globe and the testing procedure.

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Part 1: Finding Countries without a Blindfold:

i) Volunteers will begin the test by pressing the appropriate button on the control panel to move the globe to the specified region.

ii) Volunteers will search for the following countries without a blindfold:

Table 3.5: Selected Countries in Each Region

East Region	West Region	Central Region	South Region	Southeast Region
Mongolia	Cyprus	Uzbekistan	Bhutan	Malaysia

iii) The time taken by volunteers to identify each country will be recorded.

Part 2: Finding Countries with a Blindfold:

i) Before starting **Part 2**, volunteers will be blindfolded.

ii) Volunteers will repeat the same process as in **Part 1**, but this time with their eyes covered.

iii) The search time will be recorded in comparison with **Part 1**.

Part 3: Volunteer Evaluation:

i) Once the test is completed, volunteers are requested to complete a feedback form to evaluate the experiment as shown at Table 3.6.

Table 3.6: Post-Experiment Questions / Volunteer Evaluation

Question Based on Technology Acceptance Model (TAM)	1 Strongly Disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly Agree
1. Does the tactile globe improve the efficiency of the learning process for visually impaired students?					
2. Are the instructions for using the tactile globe clear and easy to use?					
3. Do you feel confident in using the tactile globe for teaching geography?					
4. Would you recommend the tactile globe to others?					
5. Do students enjoy using it?					

The above process will be repeated for five sets, with volunteers completing both parts in each set. After completing all sets, volunteers will be asked to fill out a feedback form. The feedback form will be used to evaluate the experiment and the volunteers'

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experience. This procedure aims to assess the volunteers' ability to identify countries with and without sight, as well as to collect feedback on the overall experimental process.

3.5 Summary

The methodology section details the creation of an interactive atlas for visually impaired students, focusing on Asia. It involves selecting a Raspberry Pi to process information, stepper motors to create physical movement, tactile buttons for user input, LEDs for visual guidance, and a speaker to provide audio cues. The components were chosen for their reliability and cost-effectiveness. The setup is designed to be user-friendly, allowing students to engage with the atlas through touch and sound, enhancing their learning experience. The Raspberry Pi coordinates the functions, the motors adjust atlas features, the buttons trigger interactions, the LEDs signal active areas, and the speaker narrates details. 3D printed elements add a tangible aspect to the atlas, making geographical features discernible by touch. This approach aims to deliver an educational tool that is both informative and accessible.

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CHAPTER 4

RESULTS AND DISCUSSION

4.1 Overview

This chapter embarks on an in-depth exploration of data analysis, beginning with a thorough examination of survey methodology and the subsequent analysis of results. It delves into the intricate processes involved in data collection, highlighting the various methods employed to gather accurate and reliable data. By utilizing a range of analytical techniques, this chapter aims to extract meaningful insights from the collected data.

A comprehensive outlook is adopted to uncover patterns and correlations within the survey results, providing valuable input for research, decision-making, and strategic planning. This chapter not only focuses on the technical aspects of data analysis but also emphasizes the importance of understanding the context and nuances of the data. It addresses the complexities of survey design, including question formulation, sampling strategies, and data validation, to ensure the integrity and relevance of the findings.

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Furthermore, this chapter lays the foundation for a holistic exploration of data interpretation, guiding readers through the process of transforming raw data into actionable knowledge. By examining the relationships between different variables and identifying key trends, it enhances the overall understanding of the subject matter. The insights gained from this analysis are intended to inform and support strategic initiatives, contributing to more informed and effective decision-making. This chapter sets the stage for a comprehensive and nuanced exploration of data analysis, emphasizing the critical role of survey methodology and data interpretation in achieving meaningful and impactful results.

4.2 Haptic And Audio-Tactile Asia Atlas Globe Construction

4.2.1 Drawing Result

Figure 4.1 described an innovative educational device, a microcontroller-based haptic and audio-tactile atlas globe, specifically for visually impaired students to facilitate their learning of Asian geography. This project was built using SolidWorks software and was ingeniously designed to utilize tactile sensations and auditory signals to impart geographical knowledge, thus enriching the educational journey of these students by eliminating the reliance on visual cues.

The schematic diagram illustrated a notable feature, a radius measuring R150.00 mm, which was emblematic of the Earth's spherical form. Additionally, it specified a true radius of R9.00 mm, which presumably represented a unique topographical detail or a prominent feature on the atlas's surface. The diagram also included precise linear dimensions, such as 400.00 mm and 300.00 mm, suggesting the atlas's overall scale or the intervals between specific features depicted on it. An angular measurement of 26.27° was also present, potentially signifying the globe's axial inclination or its orientation concerning a base or support structure.

The design included specific measurements for the parts that connected the globe to the control panel. These were detailed as circles with radii measuring R30.00 mm and R43.20 mm. The overall dimensions of the control panel were given as 300.00 mm x 400.00 mm x 87.56 mm. This provided a clear picture of the size and space the control panel would occupy. For the interactive elements of the control panel, like the START and STOP buttons, the dimensions were set at 37.60 mm x 37.60 mm. Other buttons, designated for different regions, were sized at 68.00 mm x 27.60 mm. A thoughtful addition to the design was the inclusion of Braille Code on each button, allowing users to identify the button's function by touch.

The design directive "DEBURR AND BREAK SHARP EDGES" was a safety feature, ensuring that all edges were smooth to the touch and did not pose a risk to users. This attention to detail highlighted the care taken to make the control panel user-friendly and safe. Here are the specifications separated into globe and control panel parts:

Globe Parts as shown in Figure 4.1

- Radius of the globe: R150.00 mm (emblematic of Earth's spherical form).
- True radius: R9.00 mm.
- Linear dimensions: 400.00 mm and 300.00 mm.
- Angular measurement: 26.27° (potentially signifies the globe's axial inclination or orientation).

Control Panel Parts as shown in Figure 4.5

- Circles with radii: R30.00 mm and R43.20 mm.
- Control panel dimensions: 300.00 mm x 400.00 mm x 72.00 mm.
- START and STOP buttons: 37.60 mm x 37.60 mm.
- Buttons for different regions: 67.60 mm x 27.60 mm.

Figure 4.1 Project Design

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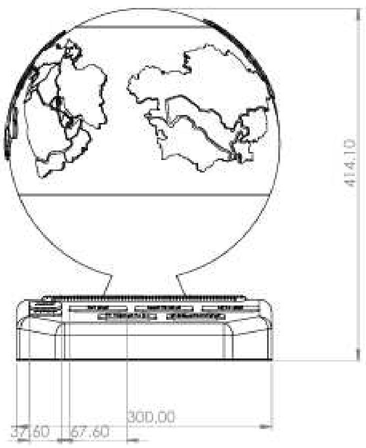

Figure 4.2 Front View

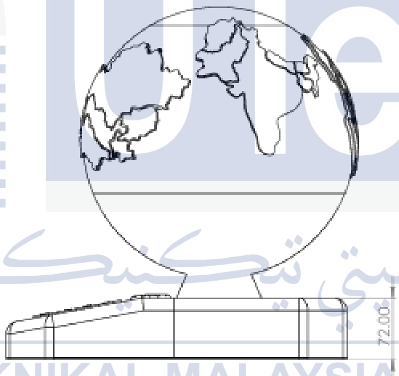

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Figure 4.3 Side View

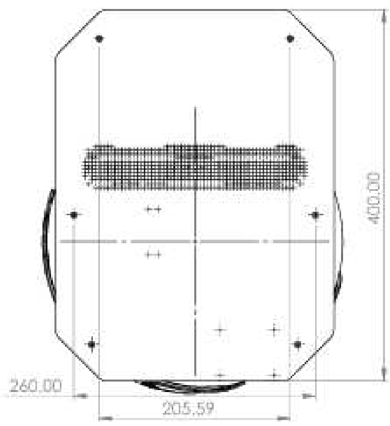

Figure 4.4 Bottom View

Figure 4.5 Control Panel Design

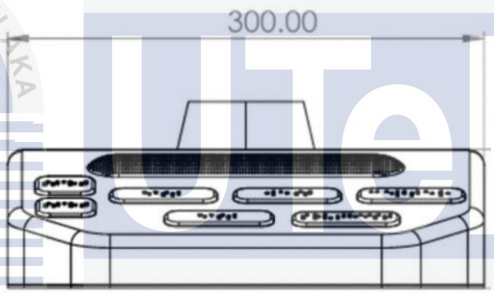

Figure 4.6 Front View

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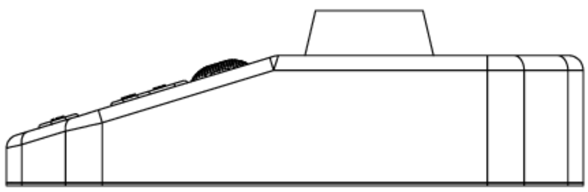

Figure 4.7 Side View

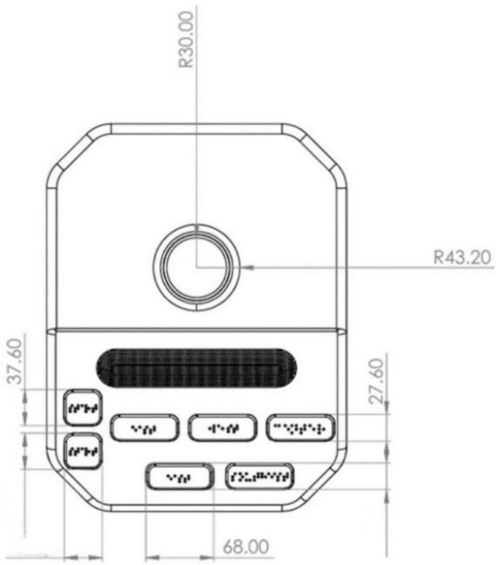

Figure 4.8 Top View

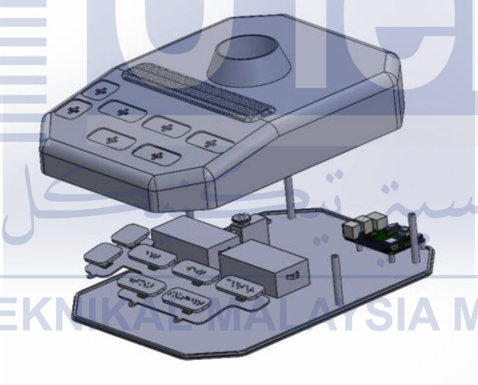

Figure 4.9 Inside Control Panel Design

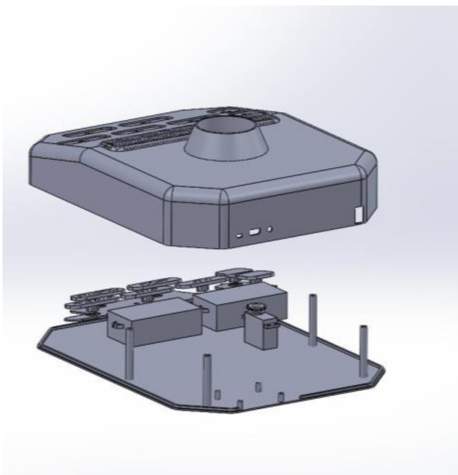

Figure 4.10 Back View Inside Control Panel Design

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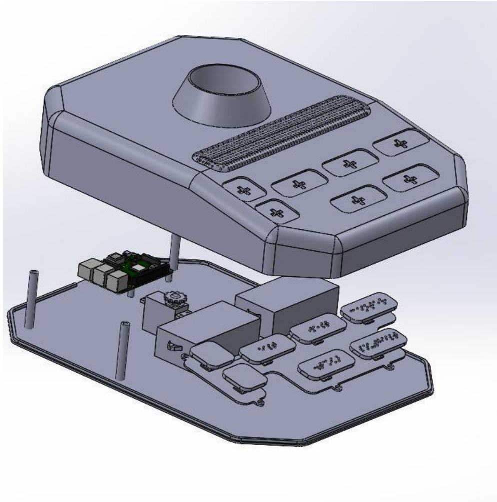

Figure 4.11 Side View Inside Control Panel Design

4.2.2 Hardware Result

4.2.2.1 Overall Hardware

The project "Development of A Microcontroller-Based Haptic and Audio-Tactile Asia Atlas Globe for Visually Impaired Students" utilized several key hardware components to create an interactive learning tool. The Raspberry Pi 3 Model B+ served as the central controller for the project. This powerful microcontroller ensured smooth operation and coordination of all connected devices.

For precise control of the globe's rotation, the project utilized a NEMA 17 stepper motor. This motor operated on a rated voltage of 12V DC, with a current of 1.2A per phase at 4V. The stepper motor ensured that the globe could be accurately positioned based on user input.

Audio feedback was provided by a speaker, which announced the name and details of the selected region. The speaker played pre-recorded audio files, enhancing the interactive experience for visually impaired students.

User input was facilitated by push buttons, which allowed users to select different regions on the globe as shown in Figure 4.12 and Figure 4.13. There were two types of push buttons used: tactile self-locking push buttons and tactile momentary push buttons. The self-locking buttons remained in place once pressed, while the momentary buttons provided immediate feedback when pressed and served as the primary input method for the user.

To expand the number of input and output connections, the project included an MCP23017 I/O expander chip. This chip added 16 extra general-purpose pins to the Raspberry Pi, operating within a voltage range of 2.7V to 5.5V and supporting external pin interrupts. The I/O expander allowed for more complex interactions and additional components to be connected to the system.

The globe itself was 3D printed using ABS filament, providing a durable and tactile surface. Different textures were used to represent various regions, allowing visually impaired students to explore and differentiate between them. The 3D printed globe rotated based on user input, aligning the selected region in front of the user for tactile exploration.

These components worked together seamlessly to provide an accessible and engaging way for all students, especially visually impaired students, to study the Asia atlas.

Figure 4.12 Front View of Project

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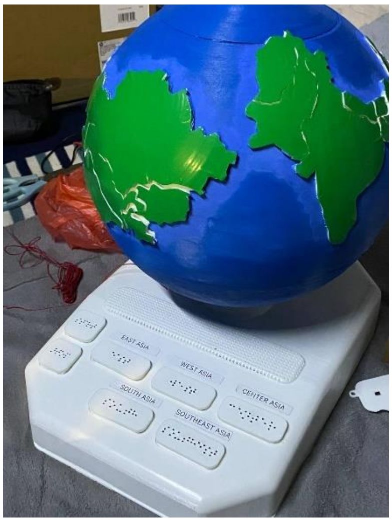

Figure 4.13 Side View of Project

4.2.2.2 Wiring

The wiring process in the tactile globe system is meticulously designed to integrate all components seamlessly and ensure smooth communication and operation. This involves connecting the Raspberry Pi as the central processing unit to input devices (push buttons), output devices (LEDs and speakers), the stepper motor for movement, and the MCP23017 I/O expander for GPIO extension. Each connection is carefully planned to optimize functionality and reduce interference.

The Raspberry Pi acts as the system's core, orchestrating all operations. Its 40-pin GPIO header provides interfaces for input and output connections. Power for the Raspberry Pi is supplied through a 5V DC source, while its GPIO pins control peripherals like the stepper motor, LEDs, and speaker. GPIO pins configured as outputs send control signals to the stepper motor driver and LEDs, while those configured as inputs receive signals from the push buttons. The use of these GPIO pins ensures efficient communication between the Raspberry Pi and other components. To overcome the limited number of GPIO pins on the Raspberry Pi, the MCP23017 I/O expander is used. This chip adds 16 additional GPIO pins to the system via I2C communication. The MCP23017 is powered by connecting its VDD pin to the 3.3V output of the Raspberry Pi and its VSS pin to the ground. The SDA (data) and SCL (clock) pins on the MCP23017 connect to the I2C pins on the Raspberry Pi, enabling seamless data transmission. The additional GPIO pins provided by the MCP23017 are used to manage the LEDs and push buttons, allowing for a more extensive and flexible wiring setup. Pins on the MCP23017 can be configured as inputs for detecting button presses or as outputs for controlling the LEDs.

The stepper motor, which is responsible for rotating the globe, is driven using a dedicated motor driver such as the A4988. This motor driver acts as an intermediary between the Raspberry Pi and the motor, translating control signals into precise movements. The motor driver is powered by connecting its VMOT pin to a 12V power source and its GND pin to the common ground. Logic power for the motor driver is provided by the Raspberry Pi's 3.3V or 5V pin. The DIR (direction) and STEP (pulse) pins on the driver are connected to GPIO pins on the Raspberry Pi to control the motor's rotation direction and step size, respectively as shown in Figure 4.16. The motor's coils are wired to the driver's output terminals (1A, 1B, 2A, 2B) to enable movement.

The push buttons, which serve as input devices for user commands, are connected either directly to the Raspberry Pi's GPIO pins or via the MCP23017 as shown in Figure 4.15. Each button is wired between a GPIO pin and the ground, with a pull-up resistor to maintain a stable high logic level when the button is not pressed. This configuration ensures accurate signal detection when a button is pressed, minimizing the chances of false inputs.

The LEDs provide visual feedback to users and are connected to the GPIO pins of either the Raspberry Pi or the MCP23017. The anode of each LED is connected to a GPIO pin through a current-limiting resistor (typically 220Ω to 330Ω) to prevent excessive current flow. The cathode is connected to the ground. By toggling the GPIO pin's state between HIGH and LOW, the LEDs can be turned on or off as required, offering visual confirmation of operations. The speaker as shown in Figure 4.14, which delivers audio feedback, is connected to the Raspberry Pi through an amplifier. The amplifier is powered by connecting its VIN pin to the Raspberry Pi's 5V pin and its GND pin to the common ground. The audio signal from the Raspberry Pi is sent to the amplifier through GPIO pins configured for I2S communication (DIN, BCLK, and LRCLK). The amplifier then drives the speaker, producing sound with adequate clarity and volume for user feedback.

Proper wiring practices were followed throughout the system to ensure stable operation and minimize interference. Power lines were routed separately from signal lines to prevent electromagnetic interference, and decoupling capacitors were used to stabilize voltage for sensitive components like the motor driver. A common ground was established across all components to maintain consistent voltage levels, reducing the risk of signal mismatches. Cable management was another important aspect of the wiring process. Wires were labelled and organized using cable ties to make the system more manageable and easier to troubleshoot. This structured wiring approach ensures the reliability and durability of the tactile globe system, facilitating efficient operation and user interaction.

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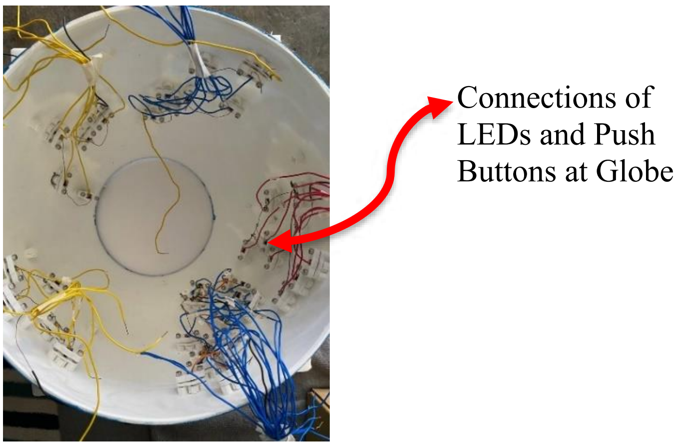

Figure 4.14: Wiring in Globe

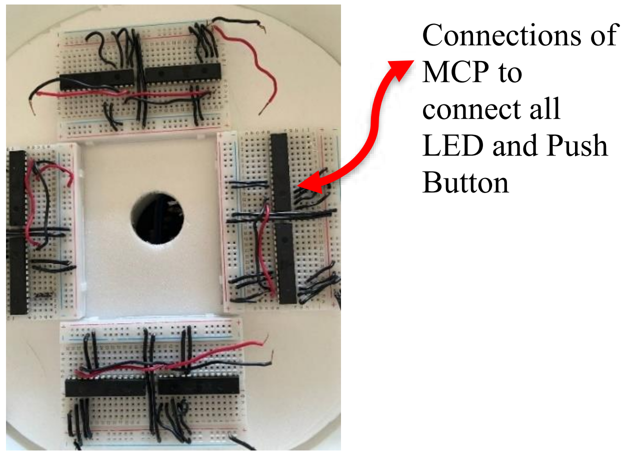

Figure 4.15: Wiring for MCP

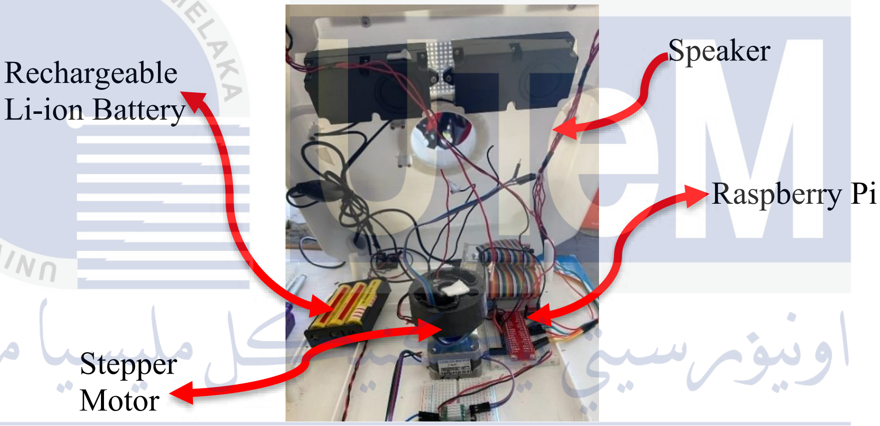

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Figure 4.16 Wiring in Control Panel

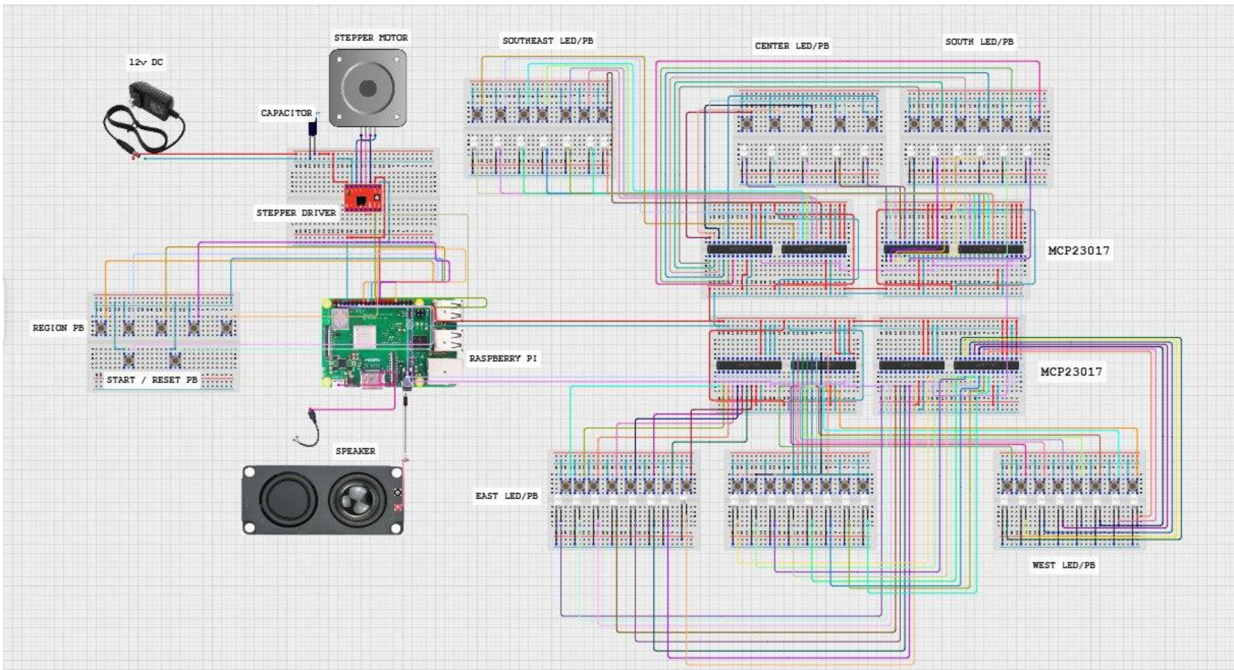

Figure 4.17 Overall Circuit Diagram

4.3 Data Analysis

In the current session, a detailed exposition of the outcomes stemming from the implemented methodologies is set forth. This detailed exposition includes an array of simulation outcomes, the evolution and progression in project development, and the insights gained from rigorous analytical evaluations. These results were meticulously derived in alignment with the foundational goals and the breadth of work initially established. The comprehensive analysis and all associated results have been executed with the deliberate intention to meet the project's aims and remain within the parameters of the defined work scopes.

4.3.1 Effectiveness of Components

4.3.1.1 Stepper Motor Performance

4.3.1.1.1 Accuracy Test

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The accuracy test is designed to measure how precisely the stepper motor can align the globe to predefined target positions. This test is crucial for evaluating the performance and reliability of the stepper motor in achieving accurate positioning, which is essential for applications requiring high precision.

To conduct the accuracy test, the globe was rotated to ten different predefined positions. These positions were evenly spaced at intervals of 360 degrees, resulting in target positions at 0°, 72°, 144°, 216°, 288°, and 360° as shown in Table 4.1. Each rotation was carefully controlled to ensure consistency in the movement of the globe.

After each rotation, a protractor was used to measure the actual position reached by the globe. This measurement process was carried out meticulously to ensure accuracy. The deviation between the actual position and the target position was then calculated for each trial. This deviation, measured in degrees, provided a quantitative assessment of the stepper motor's precision.

Table 4.1: Data Table for Accuracy Test

Target Position (°)	Actual Position (°)	Deviation (°)
0	0.5	0.5
72	72.5	0.5
144	143.9	-0.1
216	215.7	-0.3
288	288.4	0.4
360	359.6	-0.4

- Mean $= \dfrac{Sum\ of\ deviations}{Number\ of\ Data\ Points}$

  Mean $= \left(\dfrac{0.5+0.5+(-0.1)+(-0.3)+0.4+(-0.4)}{6}\right) = 0.1$

- Standard Deviation $= \dfrac{\sqrt{\sum(X_i - Mean)^2}}{n}$

  Standard Deviation $=$

$$\frac{\sqrt{(0.5-0.1)^2+(0.5-0.1)^2+(-0.1-0.1)^2+(-0.3-0.1)^2+(0.4-0.1)^2+(-0.4-0.1)^2}}{6} = 0.15$$

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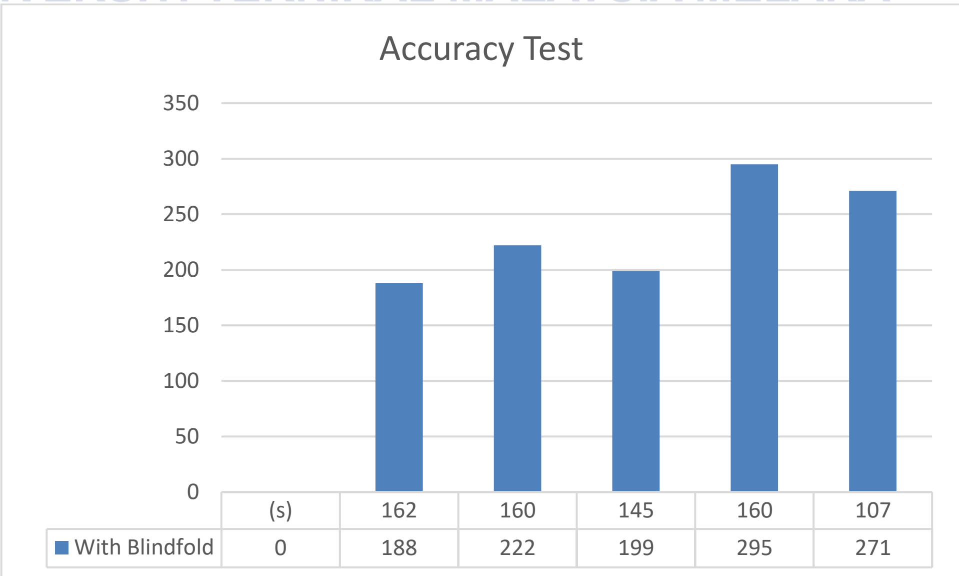

Figure 4.18 Chart for Accuracy Test

Conducting this accuracy test ensures that the stepper motor meets the required standards of precision and reliability as shown in Figure 4.17. The results of this test will inform further development and optimization efforts, contributing to the enhancement of the stepper motor's performance in practical applications.

4.3.1.1.2 Speed Test

The speed test is a critical evaluation designed to measure the time taken by the stepper motor to complete a full 360° rotation under standard operating conditions. This test is essential for understanding the motor's performance in terms of speed and consistency, which are crucial factors in many practical applications.

To conduct the speed test, the stepper motor was commanded to perform ten full rotations, each consisting of a complete 360° turn. This repetitive operation was chosen to ensure a comprehensive assessment of the motor's speed and to identify any variations in performance over multiple trials. During each trial, a stopwatch was used to record the time taken for the motor to complete the full rotation. The use of a stopwatch allowed for precise measurement of the rotation time, ensuring the accuracy of the test results. Each trial was conducted under the same standard operating conditions to maintain consistency and reliability in the data collected.

The recorded times for each of the ten rotations as shown in Table 4.2, were then analysed to determine the average time taken for a full 360° rotation. Additionally, any deviations or inconsistencies in the rotation times were noted, providing insights into the motor's performance stability during repetitive operations.

Table 4.2: Data Table for Speed Test

Trial	Rotation Time (s)
1	3.95
2	4.05
3	5.00
4	4.50
5	4.86
6	5.00
7	5.16
8	4.98
9	4.90
10	4.80

- Mean $= \frac{Sum\ of\ deviations}{Number\ of\ Data\ Points}$

  Mean $= \left(\frac{3.95+4.05+5.00+4.50+4.86+5.00+5.16+4.98+4.90+4.80}{10}\right) = 4.72$

- Standard Deviation $= \frac{\sqrt{\sum(X_i - Mean)^2}}{n} = 0.4$

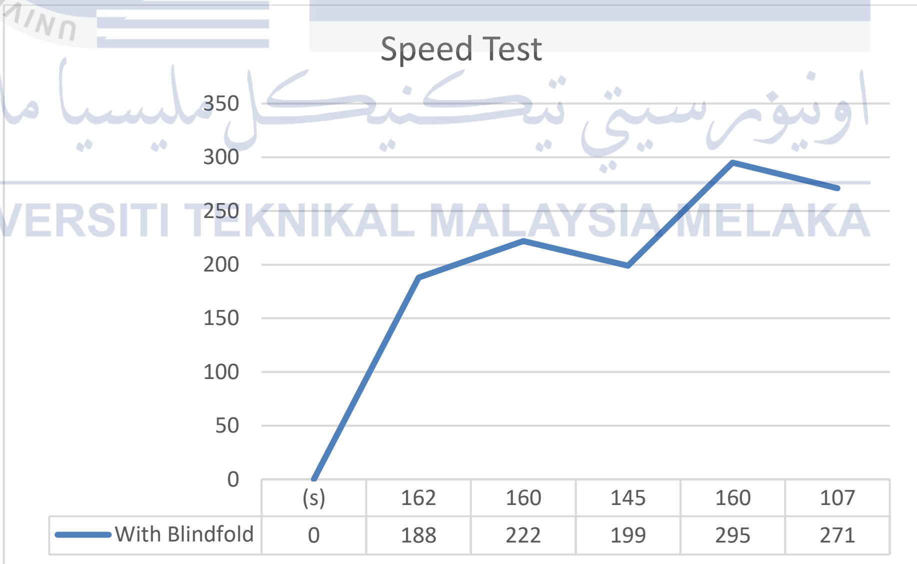

Figure 4.19 Chart for Speed Test

The speed test provides valuable insights into the stepper motor's capabilities, highlighting its strengths and identifying any areas that may require further optimization. The results in Figure 4.18 shown this test contribute to a comprehensive understanding of the motor's performance, supporting informed decision-making in its application and development.

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4.3.1.2 Auditory Feedback

4.3.1.2.1 Accuracy And Clarity

The accuracy and clarity of the auditory feedback system are critical to ensure it effectively conveys information to the user. This testing phase is essential for evaluating how well the system performs in real-world scenarios, where clear and accurate communication is paramount. To conduct the accuracy and clarity testing, ten different audio messages were pre-recorded and played through the speaker. These messages were carefully selected to represent a range of typical use cases, ensuring a comprehensive assessment of the system's performance. The messages varied in length, complexity, and content to provide a robust evaluation.

Five volunteers participated in the evaluation process. Each volunteer listened to the audio messages and assessed them based on two key criteria: clarity and accuracy. Clarity refers to how clear and understandable the message was, while accuracy pertains to whether the message content was consistent with the expected output.

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Table 4.3: Data Table for Clarity and Accuracy Testing

Countries	Volunteer 1	Volunteer 2	Volunteer 3	Volunteer 4	Volunteer 5	Average Rating (Clarity)	Average Rating (Accuracy)
China	5	5	5	4	5	4.8	5.0
Hong Kong	5	5	5	4	4	4.6	4.8
Azerbaijan	4	5	3	4	5	4.2	4.4
Palestine	5	5	5	5	5	5.0	5.0
Lebanon	5	4	5	5	4	4.6	4.8
Kyrgyzstan	4	4	3	4	3	3.6	3.4
Turkmenistan	5	4	4	5	5	4.6	4.8
Sri Lanka	5	5	5	5	5	5.0	5.0
Bhutan	5	5	5	5	5	5.0	5.0
Thailand	5	5	5	5	5	5.0	5.0
Laos	5	5	4	5	5	4.8	5.0

4.3.1.2.2 Delay Measurement

The button press delay test is designed to measure the time interval between pressing a button and hearing the corresponding audio message. This test is crucial for evaluating the responsiveness of the auditory feedback system, ensuring that it provides timely and accurate feedback to the user. To conduct this test, a stopwatch with millisecond precision was used to measure the delay. The test involved pressing a button and recording the time taken for the corresponding audio message to be heard. This process was repeated for a total of 20 button presses to ensure a comprehensive assessment of the system's responsiveness. Each button press was carefully timed, with the stopwatch started at the moment the button was pressed and stopped as soon as the audio message was heard as shown in Table 4.4. This precise measurement allowed for an accurate calculation of the delay for each trial. The recorded delays were then documented for further analysis. Timely feedback is crucial for ensuring a positive user experience. In many applications, users rely on immediate auditory feedback to confirm their actions and make informed decisions. Delays in feedback can lead to confusion, frustration, and reduced efficiency. Therefore, ensuring that the auditory feedback system responds promptly to user input is essential for maintaining user satisfaction and effectiveness.

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Table 4.4: Data Table for Delay Measurement

Trial	Rotation Time (s)
1	0.43
2	0.46
3	0.49
4	0.50
5	0.48
6	0.50
7	0.51
8	0.46

9	0.44
10	0.46
11	0.48
12	0.50
13	0.51
14	0.44
15	0.52
16	0.43
17	0.44
18	0.48
19	0.50
20	0.41

- Mean $= \frac{Sum\ of\ all\ values}{Number\ of\ values}$

  Mean $= 0.47$

- Variance $= \frac{\sum(X_i - Mean)^2}{n}$

  Variance $= (0.43 - 0.47)^2 = 0.0019$

  Repeating for all values, the total variance is 0.000883

- Standard Deviation $= \sqrt{\sum(X_i - Mean)^2}$

  Standard Deviation $= \sqrt{0.000883} = 0.0297$

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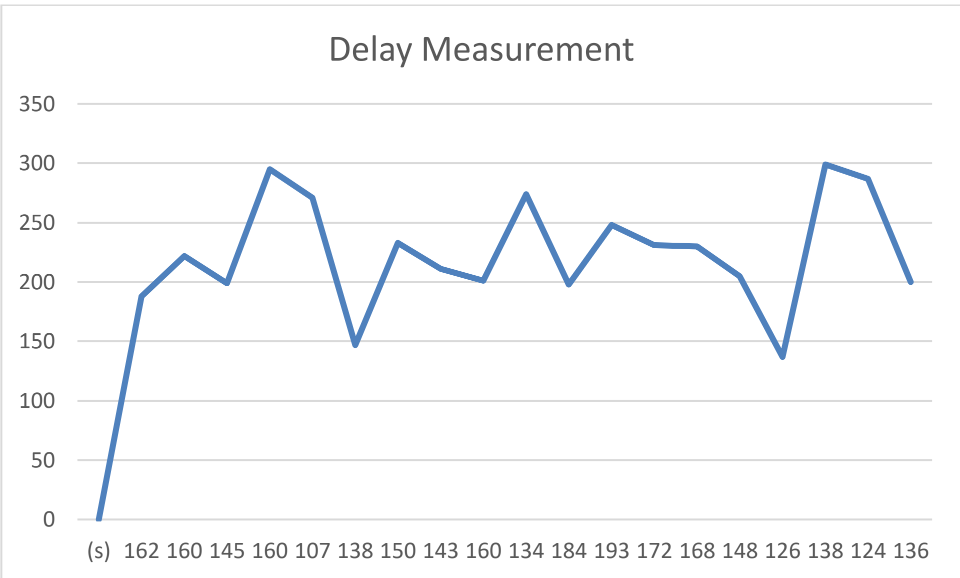

Figure 4.20: Chart for Delay Measurement

The button press delay test is a critical evaluation that ensures the auditory feedback system provides timely and accurate feedback to users. The insights gained from this test shown in Figure 4.19 are essential for optimizing the system's performance and ensuring a positive user experience.

4.3.1.3 System Reliability

To thoroughly evaluate the reliability of the tactile globe system, data was collected over a continuous 50-hour operational period. This extended monitoring period was chosen to ensure a comprehensive assessment of the system's performance under sustained use. During this time, all critical system components, including the Raspberry Pi, MCP, stepper motor, LEDs, push buttons, and speakers, as shown in Table 4.6 were closely monitored for any instances of failure or malfunction.

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Throughout the 50-hour period, the system was subjected to regular operational tasks to simulate typical usage conditions. Each component's performance was continuously tracked to identify any deviations from normal functionality. The monitoring process was designed to capture both minor glitches and significant failures, providing a detailed picture of the system's reliability as shown in Table 4.5.

These metrics are critical for assessing the robustness of the system and its ability to recover from unexpected issues.

a) **Failure Instances:** The total number of malfunctions that occurred during the 50-hour operational period was recorded. This data point provides an overview of the system's reliability and highlights any components that may be prone to failure.

b) **Downtime:** The time (in seconds) during which the system or individual components were non-operational was meticulously documented. This metric helps in understanding the impact of each failure on the overall system performance.

c) **Recovery Time:** The time (in seconds) required to restore the system to full functionality after a failure was also recorded. This data point is essential for evaluating the efficiency of the recovery process and the system's resilience.

The analysis of the collected data as shown in Table 4.5 involves examining the frequency of failure instances, the total downtime, and the average recovery time. By identifying components with higher failure rates or longer recovery times, targeted improvements can be made to enhance the system's overall reliability. Additionally, the insights gained from this evaluation can inform future design and development efforts, ensuring that the tactile globe system meets the highest standards of performance and reliability.

Table 4.5: Data Table for System Reliability

Failure Instance	Time of Failure (h:mm)	Component Affected	Downtime (s)	Recovery Time (s)	Failure Cause
1	3.14	Stepper Motor	125	55	Rotation Overload
2	8.46	Speaker	35	10	Signal delay
3	14.19	LED	40	20	Connection Loose
4	22.15	Integrated System	200	95	Power fluctuation
5	33.10	Stepper Motor	200	120	Globe Misalignment
6	47.25	Push Button	10	5	Faulty Signal Input

1. Calculating Mean Downtime and Recovery Time

a) Mean Downtime: Average duration the system or a component remains non-operational.

- Mean Downtime = $\frac{Total\ Downtime}{Number\ of\ Failures}$
- Total Downtime = 125 + 35 + 40 + 200 + 200 + 10 = 610s

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- Mean Downtime= $\frac{610}{6}$ = 101.67s

b) Mean Recovery Time: Average time required to restore functionality.

- Mean Recovery Time = $\frac{Total\ Recovery\ Time}{Number\ of\ Failures}$
- Total Recovery Time = 55 + 10 + 20 + 95 + 120 + 5 = 305s
- Mean Recovery Time = $\frac{305}{6}$ = 50.83s

2. Visualizing Failures

Table 4.6: Data Table of the Frequency And Duration of System Failures

Component Affected	Number of Failures	Mean Downtime (s)	Mean Recovery Time (s)
Stepper Motor	2	163	88
Speaker	1	35	10
LED	1	40	20
Integrated System	1	200	95
Push Button	1	10	5

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3. Comparing System Reliability to Expected Standards

- Total Uptime: 50 hours = 180,000s
- Total Downtime: 101.67s
- System Uptime Percentage:

Uptime = $\left(\frac{Total\ Uptime - Downtime}{Total\ Uptime}\right) \times 100$

= $\left(\frac{180000-101.67}{180000}\right) \times 100$ = 99%

The system exceeded the expected uptime of 99%, demonstrating strong reliability.

In summary, the reliability evaluation of the tactile globe system provides valuable insights into its performance under continuous operation. By monitoring and analysing key metrics such as failure instances, downtime, and recovery time, it is possible to assess the system's robustness and identify areas for improvement. This comprehensive evaluation is essential for ensuring that the tactile globe system delivers consistent and reliable performance, meeting the needs and expectations of its users.

4.3.2 Data Analysis

4.3.2.1 Time Taken to Identify Countries

To thoroughly evaluate the usability and effectiveness of the tactile globe, a series of tests were conducted involving volunteers who were tasked with identifying specific countries on the globe. The evaluation was designed to assess the performance of the tactile globe under two distinct conditions: with and without visual feedback.

1. **Without a Blindfold:** In this condition, volunteers were allowed to use both tactile and visual feedback to locate and identify countries on the tactile globe. This setup aimed to simulate a typical usage scenario where users can rely on multiple sensory inputs to enhance their accuracy and speed in identifying countries.
2. **With a Blindfold:** In the second condition, volunteers were blindfolded and had to rely solely on tactile and auditory feedback to locate and identify countries. This condition was designed to test the effectiveness of the tactile globe for users who are visually impaired or in situations where visual feedback is not available.

For each condition, the time taken by volunteers to identify specific countries was recorded in seconds. The recorded times for each attempt were analyzed to identify patterns and trends in the volunteers' performance. The average time taken to identify countries in each condition was calculated, providing a measure of the tactile globe's effectiveness under different sensory inputs. Additionally, any significant variations in the times were noted, offering insights into the challenges faced by volunteers in each condition. The analysis aimed to uncover any factors that might influence the usability of the tactile globe, such as the design of the tactile features, the clarity of auditory feedback, and the overall user experience. By understanding these factors, it is possible to identify areas for improvement and optimize the tactile globe for better performance.

Table 4.7: Data Table for Time Taken to Identify Countries

Volunteer ID	Country	Without Blindfold (s)	With Blindfold (s)	Difference (s)
V1	Mongolia	162	188	26
	Cyprus	160	222	62
	Uzbekistan	145	199	54
	Bhutan	160	295	135
	Malaysia	107	271	164
V2	Mongolia	138	147	9
	Cyprus	150	233	83
	Uzbekistan	143	211	68
	Bhutan	160	201	41
	Malaysia	134	274	140
V3	Mongolia	184	198	14
	Cyprus	193	248	55
	Uzbekistan	172	231	59
	Bhutan	168	230	62
	Malaysia	148	205	57
V4	Mongolia	126	137	11
	Cyprus	138	299	161
	Uzbekistan	124	287	162
	Bhutan	136	200	64
	Malaysia	122	157	35
V5	Mongolia	143	220	77
	Cyprus	135	140	6
	Uzbekistan	264	290	26
	Bhutan	134	259	125
	Malaysia	126	246	120
V6	Mongolia	175	180	5
	Cyprus	186	148	38
	Uzbekistan	196	221	25
	Bhutan	184	291	107
	Malaysia	140	150	10

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V7	Mongolia	174	184	156
	Cyprus	184	159	25
	Uzbekistan	165	121	44
	Bhutan	134	238	104
	Malaysia	133	227	94
V8	Mongolia	191	197	6
	Cyprus	173	167	6
	Uzbekistan	184	186	2
	Bhutan	167	123	44
	Malaysia	175	242	67
V9	Mongolia	199	292	93
	Cyprus	187	174	13
	Uzbekistan	168	279	111
	Bhutan	92	224	132
	Malaysia	171	182	11
V10	Mongolia	188	266	78
	Cyprus	172	236	64
	Uzbekistan	197	165	32
	Bhutan	179	246	67
	Malaysia	142	215	73

Table 4.8: Table for Mean and Standard Deviation for Each Parts

Category	Mean (s)	Standard Deviation (s)
Without Blindfold	153.48	22.96
With Blindfold	224.68	50.58
Difference	71.19	39.26

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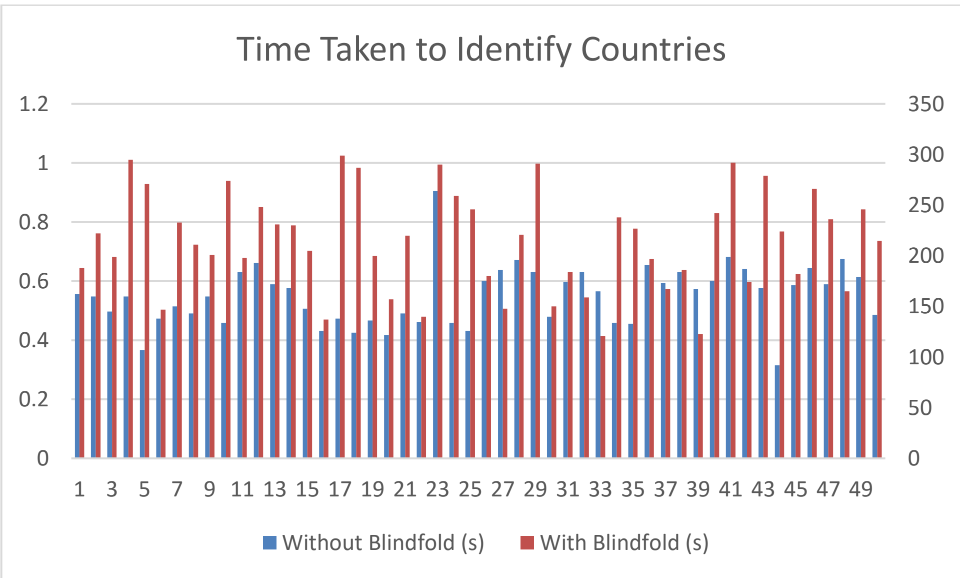

Figure 4.21: Chart for Time Taken to Identify Countries

The procedure is designed to simulate real-world usage of the tactile globe while collecting comprehensive data on its performance and usability. Table 4.7 and Table 4.8 shown by dividing the experiment into multiple phases (with and without blindfolds) and collecting user feedback, the study ensures a holistic evaluation of the system. This systematic approach provides valuable insights into how the tactile globe meets the needs of its target audience and its potential to enhance the educational experience for visually impaired students.

4.3.2.2 Volunteer Evaluation

To evaluate user acceptance of the tactile globe, a structured feedback form was developed based on the Technology Acceptance Model (TAM). This form focused on key aspects such as perceived usefulness, ease of use, intention to recommend, and overall satisfaction. Participants were asked to rate their experiences using a 5-point Likert scale .

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A total of 10 volunteers as shown in Table 4.9, including visually impaired students and educators, participated in the testing. Their feedback was collected immediately after the usability testing, ensuring fresh and unbiased responses.

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Table 4.9: Data Table for Feedback Responses

Volunteer ID	Q1 Efficiency	Q2 Ease of Use	Q3 Confidence	Q4 Recommendation	Q5 Enjoyability
V1	5	5	4	5	5
V2	5	5	5	5	5
V3	5	5	5	5	5
V4	4	5	5	5	5
V5	5	5	4	5	5
V6	5	4	5	5	5
V7	4	5	5	5	5
V8	4	5	5	5	5
V9	5	5	4	5	5
V10	5	5	4	5	5

Table 4.10: Summary Table for Descriptive Statistics

Question	Mean	Median	Mode
Q1 Efficiency	4.7	5.0	5
Q2 Ease of Use	4.9	5.0	5
Q3 Confidence	4.6	5.0	5
Q4 Recommendation	5.0	5	5
Q5 Enjoyability	5.0	5	5

The tactile globe received high scores for efficiency, ease of use, and enjoyability, with most participants rating these aspects 4 or 5 as shown in Table 4.9. This positive feedback highlights the overall satisfaction of users with the tactile globe, indicating that it performs well in key areas that contribute to a positive user experience.

A detailed factor analysis was conducted to identify the primary factors influencing the acceptance of the tactile globe. The analysis revealed that usability and effectiveness are the most significant factors. Usability refers to how easy and intuitive the tactile globe is to use, while effectiveness measures how well it helps users achieve their learning objectives. These factors are crucial for ensuring that the tactile globe meets the needs of its users, particularly visually impaired students who rely on tactile and auditory feedback for learning.

The evaluation of the tactile globe demonstrates its success in providing an efficient, easy-to-use, and enjoyable learning tool for visually impaired students as shown in Table 4.10. The insights gained from the factor analyses provide valuable guidance for future improvements and optimizations. By focusing on usability, effectiveness, and enjoyability, the tactile globe can continue to meet the needs of its users and support their educational journey.

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4.4 Summary

In this section, the chapter examines the effectiveness of the device's components, including tests on the stepper motor's accuracy and speed, the clarity of auditory feedback, and the system's overall reliability. Volunteer evaluations were conducted to measure the time taken to identify countries with and without visual feedback. The system's reliability was monitored over 50 hours, assessing failure instances, downtime, and recovery time.

The chapter concludes with a summary of the outcomes of the haptic and audio-tactile atlas globe project. It highlights the early results, and the challenges faced, such as technical hurdles and resource limitations that caused delays. This chapter provides a comprehensive analysis of the project, emphasizing the importance of survey methodology, data interpretation, and the innovative design of the educational device.

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CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In the grand tapestry of educational advancements, the development of a microcontroller-based haptic and audio-tactile atlas stands out as a monumental stride in the realm of special education, particularly for visually impaired students in Malaysia. This pioneering project has been crafted with precision to meet its foundational objectives, revolutionizing the way visually impaired students interact with and understand the geographical complexities of the Asian region. The atlas is not merely a tool for education; it is a gateway to a world that these students have had limited means to explore. The challenges faced by visually impaired students in grasping the spatial intricacies of geography are profound. Traditional methods of teaching often fall short in conveying the rich tapestry of landscapes, borders, and cultural landmarks that define Asia. This atlas globe, through its innovative use of haptic feedback and audio descriptions, provides an experience that transcends visual limitations. It allows students to 'feel' the size of each country and region, and to 'hear' the information, thus offering a more comprehensive understanding of the atlas. The extended sentences and detailed descriptions within the atlas are designed to cater to the unique learning needs of visually impaired students, providing context, scale, and a sense of orientation that is often missing from conventional study materials. By incorporating these elements, the atlas not only aids in the study of geography but also enhances cognitive development, spatial reasoning, and memory retention.

The project successfully achieved its primary objectives, demonstrating significant advancements in the design and development of educational tools for visually impaired

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students. The first objective was to design and develop a microcontroller-based circuit and hardware for an atlas globe tailored to the needs of visually impaired students. This goal was met through the meticulous selection and integration of key hardware components. The Raspberry Pi 3 Model B+ served as the central controller, ensuring smooth operation and coordination of all connected devices. The project also incorporated a NEMA 17 stepper motor for precise control of the globe's rotation, allowing accurate positioning based on user input. The globe itself was 3D printed using ABS filament, providing a durable and tactile surface that visually impaired students could explore. The successful development of this hardware laid a strong foundation for the subsequent application of haptic and audio-tactile technologies.

The second objective focused on applying haptic and audio-tactile technologies to the atlas globe. This was achieved by integrating multi-sensory feedback mechanisms that enhanced the interactive experience for visually impaired students. The globe featured tactile self-locking and momentary push buttons, allowing users to select different regions. These buttons were connected to the Raspberry Pi and served as the primary input method. Additionally, a speaker provided audio feedback, announcing the name and details of the selected region. This combination of haptic feedback and audio descriptions enabled students to 'feel' the size of each country and region and 'hear' the information, offering a comprehensive understanding of the atlas. The inclusion of Braille on the buttons further ensured accessibility for visually impaired users.

The final objective was to analyse the performance of the atlas globe in terms of its effectiveness as a teaching and learning tool. This was accomplished through a series of tests and evaluations involving visually impaired students. The results indicated a significant improvement in the students' ability to recognize and locate different regions. These findings highlighted the atlas globe's effectiveness in enhancing the learning process, improving cognitive development, spatial reasoning, and memory retention for visually impaired students.

In conclusion, the project successfully met its objectives, resulting in the creation of an innovative and effective educational tool for visually impaired students. The atlas globe not only provided a means for these students to learn geography but also demonstrated the potential of technology to create inclusive educational environments. The success of this project paves the way for further innovations and improvements, ensuring that visually impaired students have the tools they need to succeed in their educational journey.

5.2 Potential for Commercialization

The introduction of a microcontroller-based haptic and audio-tactile Asia atlas globe into Malaysia's educational framework presents a substantial opportunity for progress, particularly for visually impaired students. The nation is witnessing an increase in visually impaired individuals pursuing higher education, with the government endorsing their integration into mainstream colleges and universities. Malaysia's educational ethos is centered on inclusivity, striving to afford visually impaired students equitable educational opportunities akin to their sighted counterparts. This commitment is exemplified by the existence of dedicated educational institutions for the blind, including two primary and one secondary school that offer both residential and national schooling options.

Technologies such as haptic feedback and audio-tactile interfaces are poised to revolutionize the educational experiences of visually impaired students, granting them a more profound comprehension of their surroundings. These innovations are instrumental in aiding cognitive mapping and orientation, which are vital for the autonomy and mobility of visually impaired individuals. The advent of cost-effective, and adaptable tools like the Asia atlas globe stands to bolster the spatial awareness of these students.

The path to commercialization necessitates a thorough understanding of the educational sector's needs regarding such assistive tools, ensuring the atlas is both accessible and affordable. Partnerships with educational entities and support organizations for the visually impaired, such as the Malaysian Association for the Blind, are crucial for garnering insights that will inform the atlas's development and distribution. Moreover, financial backing and endorsements from both governmental and private sectors are essential to propel the product into the marketplace and guarantee its long-term viability.

In essence, the creation and commercialization of a microcontroller-based haptic and audio-tactile Asia atlas globe could serve as a pivotal educational asset for visually impaired students in Malaysia. It is in harmony with the nation's goals for an inclusive education system and has the potential to enhance the academic outcomes and overall well-being of this student demographic. The triumph of such an initiative hinge on comprehensive market research, strategic alliances, and supportive governmental policies.

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5.3 Future Works

For future improvements the primary goal will be to enhance the current globe developed during the PSM:

a) Develop additional modules or versions of the globe that cover other regions and regions. This would provide a more comprehensive learning tool and broaden students' knowledge beyond Asia.

b) Incorporate more detailed 3D printing technology and advanced mapping software to include smaller islands and more precise geographical features. This would improve the accuracy of the atlas while maintaining functionality.

c) Integrate multi-sensory feedback mechanisms, such as vibrations or tactile signals, to assist users with both visual and hearing impairments. Additionally, consider developing a companion app that provides visual and auditory information through alternative devices.

d) Use a more powerful motor that can handle larger and heavier globes. This would allow for the creation of a bigger globe, providing more space for detailed geographical features and enhancing the overall user experience.

e) Implement a dual-axis rotation system, allowing the globe to rotate on both the x-axis and y-axis. This would enable users to explore the globe more freely and gain a better understanding of geographical relationships.

By addressing these limitations, the project can become a more versatile and effective educational tool for visually impaired students and potentially benefit a wider audience.

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REFERENCES

[1] Uttara Ghodke, Lena Yusim, Sowmya Somanath & Peter Coppin, 2019, THE CROSS SENSORY GLOBE Co-Designing a 3D Audio-Tactile Globe Prototype for Blind and LowVision Users to Learn Geography

[2] HOROWITZ, S., & SCHULTZ, P. (2014). PRINTING SPACE: USING 3D PRINTING OF DIGITAL TERRAIN MODELS IN GEOSCIENCES EDUCATION AND RESEARCH. JOURNAL OF GEOSCIENCE EDUCATION, 62, 138–145. HTTPS://DOI.ORG/10.5408/13-031.1]

[3] WORLD REPORT ON VISION. (N.D.). HTTPS://WWW.WHO.INT/DOCS/DEFAULT SOURCE/DOCUMENTS/PUBLICATIONS/WORLD-VISION-REPORT-ACCESSIBLE.PDF

[4] Flaxman, S. R., Bourne, R. R. A., Resnikoff, S., Ackland, P., Braithwaite, T., Cicinelli, M. V., Das, A., Jonas, J. B., Keeffe, J., Kempen, J. H., Leasher, J., Limburg, H., Naidoo, K., Pesudovs, K., Silvester, A., Stevens, G. A., Tahhan, N., Wong, T. Y., Taylor, H. R., & Bourne, R. (2017). Global Causes Of Blindness And Distance Vision Impairment 1990–2020: A Systematic Review And Meta-Analysis. The Lancet Global Health, 5(12), E1221–E1234. Https://Doi.Org/10.1016/S2214-109x(17)30393-5

[5] Feucht, F. C., & Holmgren, C. R. (2018). Developing Tactile Map For Students With Visual Impairments: A Case Study For Customizing Accommodations. Journal Of Visual Impairment & Blindness, 112(2), 143–155. Https://Doi.Org/10.1177/0145482x1811200203

[6] Butler, M., Holloway, L., Marriott, K., & Goncu, C. (2016). Understanding The Graphical Challenges Faced By Vision-Impaired Students In Australian Universities. Higher Education Research & Development, 36(1), 59–72. Https://Doi.Org/10.1080/07294360.2016.1177001

[7] Davidson, M. (2023, May 29). Understanding Data Selection In Tactile Atlasping: An Inclusive Design Approach. Openaccess.Wgtn.Ac.Nz. Https://Openaccess.Wgtn.Ac.Nz/Articles/Thesis/Understanding_Data_Selection_In_Tactile_Atlasping_An_Inclusive_Design_Approach/23255276/1

[8] Wabiński, J., Mościcka, A., & Kuźma, M. (2020). The Information Value Of Tactile Map: A Comparison Of Map Printed With The Use Of Different Techniques. The Cartographic Journal, 1–12. Https://Doi.Org/10.1080/00087041.2020.1721765

[9] Vincent Van Altena, Daan Rijnberk, Marieke Kuijer, Jansen, J., Min, E., Aafke Van Welbergen, Visser, T., Van, & Nauta, J. (2023). Tailoring Tactile Map Based On Blind Users' Needs. Proceedings Of The Ica, 5, 1–7. Https://Doi.Org/10.5194/Ica-Proc-5-22-2023

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

[10] Kim, C. (2016). Land Use Classification And Land Use Change Analysis Using Satellite Images In Lombok Island, Indonesia. Forest Science And Technology, 12(4), 183–191. Https://Doi.Org/10.1080/21580103.2016.1147498

[11] Duggan, T. (2017). Depicting And Charting The Southern Coastline Of Anatolia - Record Of The Later Toponyms Of Phaselis: Palyopoli-Paleopolis, Tekiroba, Gironda-Phionda-Fironda-Fionda - The 1812 Report Of Rapid Coastal Erosion - The (Doubtful) Islands And Evidence Leading Towards A Date For The Collapse Of The Upper Courses Of The Inner Harbour Arm At Ancient Phaselis, Antalya. Phaselis: Disiplinlerarasi Akdeniz Araştirmalari Dergisi, 3, 1–48. Https://Doi.Org/10.18367/Pha.17001

[12] Phutane, M., Wright, J., Castro, B. V., Shi, L., Stern, S. R., Lawson, H. M., & Azenkot, S. (2022). Tactile Materials In Practice: Understanding The Experiences Of Teachers Of The Visually Impaired. Acm Transactions On Accessible Computing, 15(3). Https://Doi.Org/10.1145/3508364

[13] Brulé, E., Bailly, G., Brock, A., Valentin, F., Denis, G., & Jouffrais, C. (2016). Mapsense: Multi-Sensory Interactive Map For Children Living With Visual Impairments. Https://Inria.Hal.Science/Hal-01263056/Document

[14] Ford, S., & Minshall, T. (2019). Invited Review Article: Where And How 3d Printing Is Used In Teaching And Education. Additive Manufacturing, 25(25), 131–150. Https://Doi.Org/10.1016/J.Addma.2018.10.028

[15] Shahrubudin, N., Lee, T. C., & Ramlan, R. (2019). An Overview On 3d Printing Technology: Technological, Materials, And Applications. Procedia Manufacturing, 35, 1286–1296. Https://Doi.Org/10.1016/J.Promfg.2019.06.089

[16] Minhat, M. (2020). Enhancing The Usability Of Tactile Atlas For The Visually Impaired. Journal Of Engineering And Science Research, 4(4), 12–19. Https://Doi.Org/10.26666/Rmp.Jesr.2020.4.3

[17] Taylor, B., Dey, A., Siewiorek, D., & Smailagic, A. (2016). Customizable 3d Printed Tactile Map As Interactive Overlays. Proceedings Of The 18th International Acm Sigaccess Conference On Computers And Accessibility. Https://Doi.Org/10.1145/2982142.2982167

[18] Holloway, L., Marriott, K., & Butler, M. (2018). Accessible Map For The Blind. Proceedings Of The 2018 Chi Conference On Human Factors In Computing Systems. Https://Doi.Org/10.1145/3173574.3173772

[19] Ducasse, J., Marc J.-M. Macé, Serrano, M., & Christophe Jouffrais. (2016). Tangible Reels. Https://Doi.Org/10.1145/2858036.2858058

[20] Parsons, D., Inkila, M., & Lynch, J. (2019). Navigating Learning Worlds: Using Digital Tools To Learn In Physical And Virtual Spaces. Australasian Journal Of Educational Technology. Https://Doi.Org/10.14742/Ajet.3675

[21] Siekierska, E., Labelle, R., Brunet, L., Mccurdy, B., Pulsifer, P., Rieger, M. K., & O'neil, L. (2003). Enhancing Spatial Learning And Mobility Training Of

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Visually Impaired People-A Technical Paper On The Internet-Based Tactile And Audio-Tactile Atlasping. The Canadian Geographer/Le G?Ographe Canadien, 47(4), 480–493. Https://Doi.Org/10.1111/J.0008-3658.2003.00037.X

[22] Brock, A. M. (2013). Touch The Atlas! Acm Sigaccess Accessibility And Computing, 105, 9–14. Https://Doi.Org/10.1145/2444800.2444802

[23] Baker, C. M., Milne, L. R., Drapeau, R., Scofield, J., Bennett, C. L., & Ladner, R. E. (2016). Tactile Graphics With A Voice. Acm Transactions On Accessible Computing, 8(1), 1–22. Https://Doi.Org/10.1145/2854005

[24] Kumar, N., & Jain, A. (2022). A Deep Learning Based Model To Assist Blind People In Their Navigation. Journal Of Information Technology Education: Innovations In Practice, 21, 095-114. Https://Doi.Org/10.28945/5006

[25] Chiang, Y.-Y., Leyk, S., & Knoblock, C. A. (2014). A Survey Of Digital Atlas Processing Techniques. Acm Computing Surveys, 46(2), Article 21. Doi: 10.1145/2557423

[26] Shi, L., Lawson, H., Zhang, Z., & Azenkot, S. (2019). Designing Interactive 3d Printed Models With Teachers Of The Visually Impaired. Proceedings Of The 2019 Chi Conference On Human Factors In Computing Systems. Https://Doi.Org/10.1145/3290605.3300427

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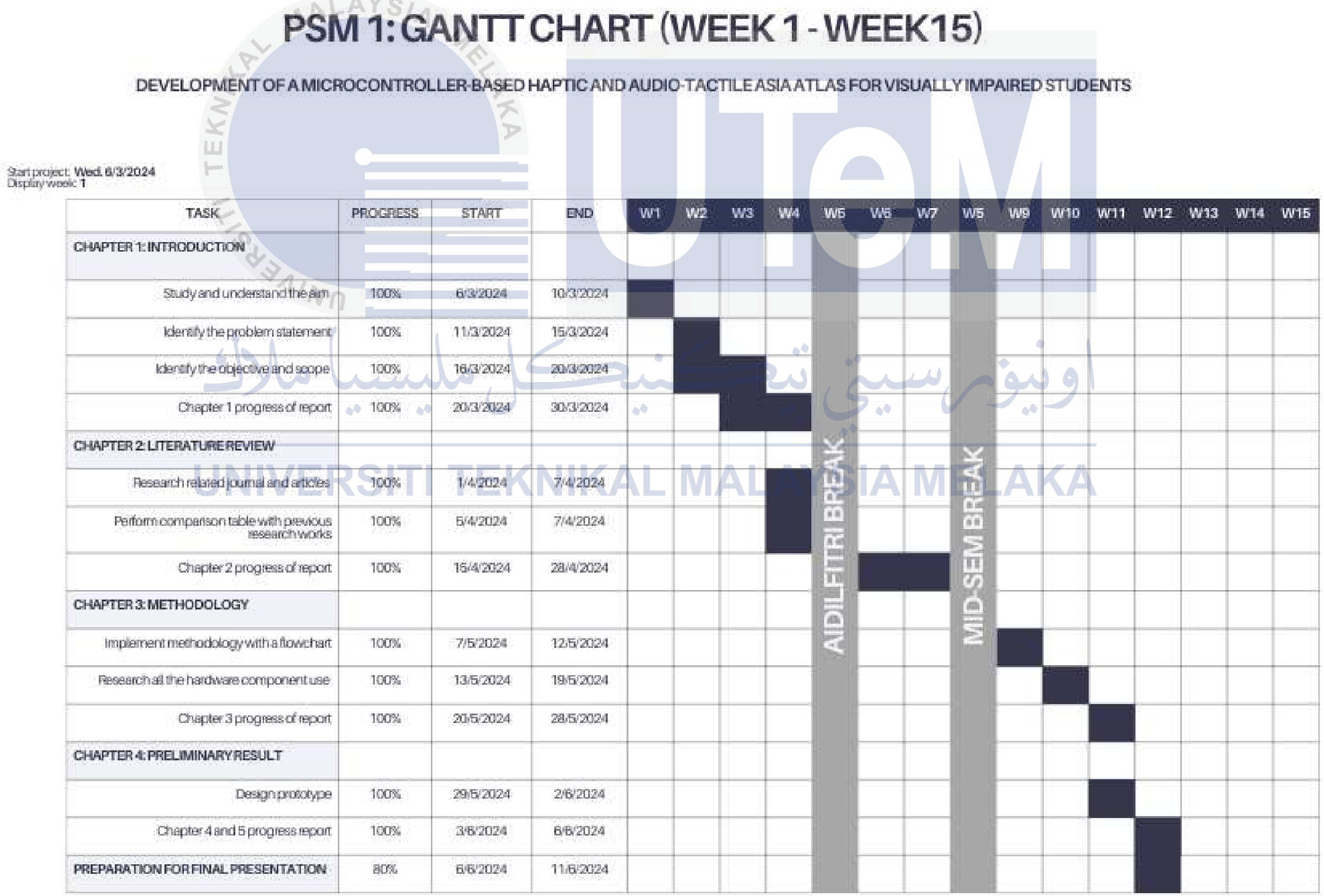
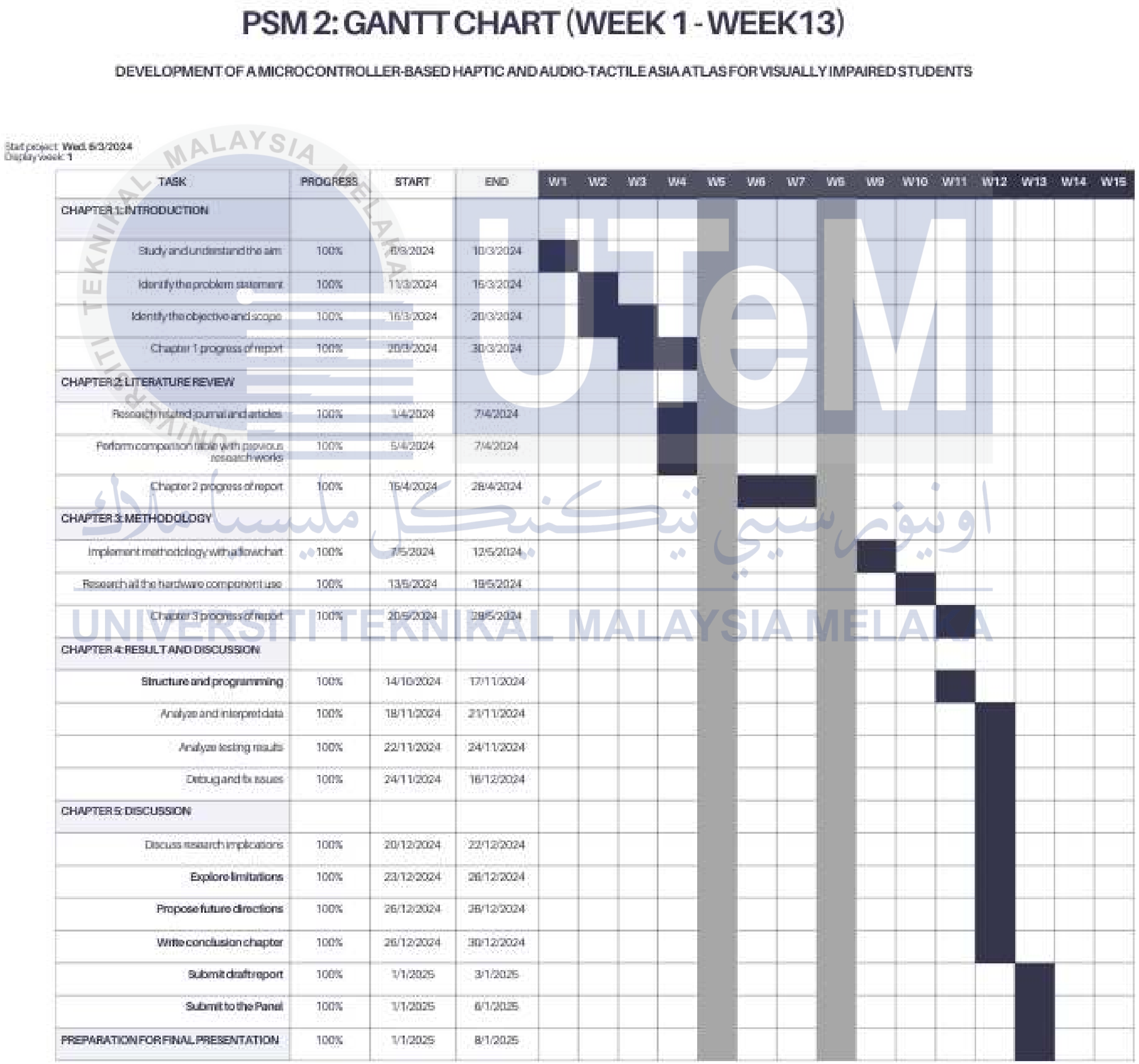
APPENDICES

APPENDIX I: Gantt Chart PSM 1



APPENDIX II: Gantt Chart PSM 2



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```
import RPi.GPIO as GPIO
import time
import os
from adafruit_mcp230xx.mcp23017 import MCP23017
from adafruit_mcp230xx.digital_inout import Direction
from digitalio import Pull
import board
import busio

# Initialize I2C
i2c = busio.I2C(board.SCL, board.SDA)
mcp1 = MCP23017(i2c, address=0x20)
mcp2 = MCP23017(i2c, address=0x21)
mcp3 = MCP23017(i2c, address=0x22)
mcp4 = MCP23017(i2c, address=0x23)
mcp5 = MCP23017(i2c, address=0x24)
mcp6 = MCP23017(i2c, address=0x25)
mcp7 = MCP23017(i2c, address=0x26)
mcp8 = MCP23017(i2c, address=0x27)

# GPIO setup
STEP = 26                              # STEP pin on A4988
DIR = 19                               # DIR pin on A4988
button_pins = [23, 24, 25, 12, 16]     # GPIO pins for buttons
reset_button_pin = 27                  # GPIO pin for reset button
system_control_pin = 22                # GPIO pin for start/stop button


# Motor and Angle Configuration
steps_per_revolution = 200  # For 17HS2408 (1.8° step angle)
microstepping = 16  # A4988 configured for 1/16 microstepping
steps_per_degree = steps_per_revolution * microstepping / 360

# Define Angles for Buttons
angles = {
    button_pins[0]: 2,  # Button 1 -> 20°
    button_pins[1]: 7,  # Button 2 -> 40°
    button_pins[2]: 12,
    button_pins[3]: 16,
    button_pins[4]: 20,
}

# Initialize Global Variables
current_angle = 0


# Initialize GPIO
GPIO.setmode(GPIO.BCM)
GPIO.setup([STEP, DIR], GPIO.OUT)

GPIO.setup(reset_button_pin, GPIO.IN, pull_up_down=GPIO.PUD_UP)
GPIO.setup(system_control_pin, GPIO.IN, pull_up_down=GPIO.PUD_UP)

for pin in button_pins:
    GPIO.setup(pin, GPIO.IN, pull_up_down=GPIO.PUD_UP)
```

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```
system_locked = False

# LED groups for mcp1, mcp2,mcp3,mcp4
led_groups = [
 [mcp1.get_pin(i) for i in range(0, 8)],   #group 1/east asia
 [mcp2.get_pin(i) for i in range(0, 16)],  #group 2/west asia
 [mcp3.get_pin(i) for i in range(0, 5)], #group 3/central asia
 [mcp3.get_pin(i) for i in range(8, 14)],   #group 4/south asia
 [mcp4.get_pin(i) for i in range(0, 7)],  #group 5/southeast asia
 ]

#country button at region
country_buttons1 = [mcp5.get_pin(i) for i in range(0, 8)] #east asia
country_buttons2 = [mcp6.get_pin(i) for i in range(0, 16)] #west asia
country_buttons3 = [mcp7.get_pin(i) for i in range(0, 5)] #central asia
country_buttons4 = [mcp7.get_pin(i) for i in range(8, 14)] #south asia
country_buttons5 = [mcp8.get_pin(i) for i in range(0, 7)] #southeast asia


for group in led_groups:
    for led in group:
        led.direction = Direction.OUTPUT
        led.value = False

for button in country_buttons1:
    button.direction = Direction.INPUT
    button.pull = Pull.UP

for button in country_buttons2:
    button.direction = Direction.INPUT
    button.pull = Pull.UP

for button in country_buttons3:
    button.direction = Direction.INPUT
    button.pull = Pull.UP

for button in country_buttons4:
    button.direction = Direction.INPUT
    button.pull = Pull.UP

for button in country_buttons5:
    button.direction = Direction.INPUT
    button.pull = Pull.UP

country_sounds1=[
    "espeak -v en+f5 -s 165 -p 60 'Republic of China'",
    "espeak -v en+f5 -s 165 -p 60 'Mongolia'",
    "espeak -v en+f5 -s 165 -p 60 'Japan'",
    "espeak -v en+f5 -s 165 -p 60 'North Korea'",
    "espeak -v en+f5 -s 165 -p 60 'South Korea'",
    "espeak -v en+f5 -s 165 -p 60 'Macau'",
    "espeak -v en+f5 -s 165 -p 60 'Taiwan'",
    "espeak -v en+f5 -s 165 -p 60 'Hong Kong'"
    ]                                #east asia

country_sounds2 = [
    "espeak -v en+f5 -s 165 -p 60 'Turkey'",
```

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```
    "espeak -v en+f5 -s 165 -p 60 'Saudi Arabia'",
    "espeak -v en+f5 -s 165 -p 60 'Armenia'",
    "espeak -v en+f5 -s 165 -p 60 'Azerbaijan'",
    "espeak -v en+f5 -s 165 -p 60 'Bahrain'",
    "espeak -v en+f5 -s 165 -p 60 'Georgia'",
    "espeak -v en+f5 -s 165 -p 60 'Iraq'",
    "espeak -v en+f5 -s 165 -p 60 'Iran'",
    "espeak -v en+f5 -s 165 -p 60 'Palestine'",
    "espeak -v en+f5 -s 165 -p 60 'Kuwait'",
    "espeak -v en+f5 -s 165 -p 60 'Lebanon'",
    "espeak -v en+f5 -s 165 -p 60 'Oman'",
    "espeak -v en+f5 -s 165 -p 60 'Qatar'",
    "espeak -v en+f5 -s 165 -p 60 'Cyprus'",
    "espeak -v en+f5 -s 165 -p 60 'Syria'",
    "espeak -v en+f5 -s 165 -p 60 'United Arab Emirates'",
    "espeak -v en+f5 -s 165 -p 60 'Yemen'",
    "espeak -v en+f5 -s 165 -p 60 'Jordan'"
    ]                               #west asia

country_sounds3 = [
    "espeak -v en+f5 -s 165 -p 60 'Kazakhstan'",
    "espeak -v en+f5 -s 165 -p 60 'Kyrgyzstan'",
    "espeak -v en+f5 -s 165 -p 60 'Tajikistan'",
    "espeak -v en+f5 -s 165 -p 60 'Turkmenistan'",
    "espeak -v en+f5 -s 165 -p 60 'Uzbekistan'"
    ]                               #central asia

country_sounds4 = [
    "espeak -v en+f5 -s 165 -p 60 'Bangladesh'",
    "espeak -v en+f5 -s 165 -p 60 'Bhutan'",
    "espeak -v en+f5 -s 165 -p 60 'India'",
    "espeak -v en+f5 -s 165 -p 60 'Maldives'",
    "espeak -v en+f5 -s 165 -p 60 'Nepal'",
    "espeak -v en+f5 -s 165 -p 60 'Pakistan'",
    "espeak -v en+f5 -s 165 -p 60 'Sri Lanka'"
    ]                               #south asia

country_sounds5 = [
    "espeak -v en+f5 -s 165 -p 60 'Indonesia'",
    "espeak -v en+f5 -s 165 -p 60 'Malaysia'",
    "espeak -v en+f5 -s 165 -p 60 'Thailand'",
    "espeak -v en+f5 -s 165 -p 60 'Laos'",
    "espeak -v en+f5 -s 165 -p 60 'Myanmar'",
    "espeak -v en+f5 -s 165 -p 60 'Vietnam'",
    "espeak -v en+f5 -s 165 -p 60 'Philippines'"
    ]                               #southeast asia

def check_system_control():
    global system_locked
    if GPIO.input(system_control_pin) == GPIO.LOW:
        time.sleep(0.2)
        if GPIO.input(system_control_pin) == GPIO.LOW:
            system_locked = not system_locked
            if system_locked:
                turn_off_all_leds()
                os.system("espeak -v en+f5 -s 165 -p 60 'system is
locked.'")
                time.sleep(0.05)
```

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```
                os.system("espeak -v en+f5 -s 165 -p 60 'map is off'")
            else:
                os.system("espeak -v en+f5 -s 165 -p 60 'system is
unlocked.'")
                time.sleep(0.05)
                os.system("espeak -v en+f5 -s 165 -p 60 'map is on'")

def turn_off_all_leds():
    for group in led_groups:
        for led in group:
            led.value = False

def turn_on_led_group(*group_indices):
    turn_off_all_leds()
    for group_index in group_indices:
        if 0 <= group_index < len(led_groups):
            for led in led_groups[group_index]:
                led.value = True

def turn_on_single_led(button_index, mcp_group):

    turn_off_all_leds()
    if 0 <= button_index < len(mcp_group):
        led = mcp_group[button_index]
        led.value = True


# Motor Control Functions
def rotate(angle, direction="forward"):

    steps = int(angle * steps_per_degree)
    GPIO.output(DIR, GPIO.HIGH if direction == "forward" else GPIO.LOW)
    for _ in range(steps):
        GPIO.output(STEP, GPIO.HIGH)
        time.sleep(0.02)  # Pulse width (1ms)
        GPIO.output(STEP, GPIO.LOW)
        time.sleep(0.02)  # Delay between steps

def move_to_angle(target_angle):

    global current_angle
    angle_difference = target_angle - current_angle
    if angle_difference > 0:
        direction = "forward"
    else:
        direction = "backward"
        angle_difference = -angle_difference  # Make the angle difference
positive

    rotate(angle_difference, direction=direction)
    current_angle = target_angle




def play_sound1():
    os.system("espeak -v en+f5 -s 165 -p 60 'East asia'")
    time.sleep(1)
```

```
    os.system("espeak -v en+f5 -s 165 -p 60 'Please press the country
map'")

def play_sound2():
    os.system("espeak -v en+f5 -s 165 -p 60 'west asia'")
    time.sleep(1)
    os.system("espeak -v en+f5 -s 165 -p 60 'Please press the country
map'")

def play_sound3():
    os.system("espeak -v en+f5 -s 165 -p 60 'Central asia'")
    time.sleep(1)
    os.system("espeak -v en+f5 -s 165 -p 60 'Please press the country
map'")

def play_sound4():
    os.system("espeak -v en+f5 -s 165 -p 60 'south asia'")
    time.sleep(1)
    os.system("espeak -v en+f5 -s 165 -p 60 'Please press the country
map'")

def play_sound5():
    os.system("espeak -v en+f5 -s 165 -p 60 'southeast asia'")
    time.sleep(1)
    os.system("espeak -v en+f5 -s 165 -p 60 'Please press the country
map'")

def play_country_sound1(index):
    os.system(country_sounds1[index])

def play_country_sound2(index):
    os.system(country_sounds2[index])

def play_country_sound3(index):
    os.system(country_sounds3[index])

def play_country_sound4(index):
    os.system(country_sounds4[index])

def play_country_sound5(index):
    os.system(country_sounds5[index])

def play_startup_sound():
    os.system("espeak -v en+f5 -s 165 -p 60 'Please select region'")

def check_buttons():
    global current_angle

    if GPIO.input(button_pins[0]) == GPIO.LOW:
        target_angle = angles[button_pins[0]]
        move_to_angle(target_angle)
        turn_on_led_group(0)
        play_sound1()
    elif GPIO.input(button_pins[1]) == GPIO.LOW:
        target_angle = angles[button_pins[1]]
        move_to_angle(target_angle)
        turn_on_led_group(1)
        play_sound2()
```

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```
    elif GPIO.input(button_pins[2]) == GPIO.LOW:
        target_angle = angles[button_pins[2]]
        move_to_angle(target_angle)
        turn_on_led_group(2)
        play_sound3()
    elif GPIO.input(button_pins[3]) == GPIO.LOW:
        target_angle = angles[button_pins[3]]
        move_to_angle(target_angle)
        turn_on_led_group(3)
        play_sound4()
    elif GPIO.input(button_pins[4]) == GPIO.LOW:
        target_angle = angles[button_pins[4]]
        move_to_angle(target_angle)
        turn_on_led_group(4)
        play_sound5()


# Function to Check Reset Button
def check_reset_button():

    global current_angle
    if GPIO.input(reset_button_pin) == GPIO.LOW:  # Reset button pressed
        rotate(current_angle, direction="backward")  # Move back to 0°
        current_angle = 0


def check_country_buttons1(): #east asia
    for index, button in enumerate(country_buttons1):
        if not button.value:
            turn_on_single_led(index, [mcp1.get_pin(i) for i in
range(0,8)])
            play_country_sound1(index)

def check_country_buttons2(): #west asia
    for index, button in enumerate(country_buttons2):
        if not button.value:
            turn_on_single_led(index,[mcp2.get_pin(i) for i in
range(0,16)])
            play_country_sound2(index)

def check_country_buttons3(): #central asia
    for index, button in enumerate(country_buttons3):
        if not button.value:
            turn_on_single_led(index, [mcp3.get_pin(i) for i in
range(0,5)])
            play_country_sound3(index)

def check_country_buttons4(): #south asia
    for index, button in enumerate(country_buttons4):
        if not button.value:
            turn_on_single_led(index, [mcp3.get_pin(i) for i in
range(8,14)])
            play_country_sound4(index)

def check_country_buttons5(): #southeast asia
    for index, button in enumerate(country_buttons5):
        if not button.value:
```

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```
            turn_on_single_led(index, [mcp4.get_pin(i) for i in
range(0,7)])
            play_country_sound5(index)


print("Press any button to control the servo, LEDs, and sound.")
play_startup_sound()

try:
    while True:
        check_system_control()  # Check the system control button
        if not system_locked:
          check_buttons()
          check_reset_button()
          check_country_buttons1()
          check_country_buttons2()
          check_country_buttons3()
          check_country_buttons4()
          check_country_buttons5()
        time.sleep(0.1)
except KeyboardInterrupt:
    print("Program terminated.")
finally:
    GPIO.cleanup()
```

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APPENDIX IV: Raspberry Pi 3 Model B+

Overview

Raspberry Pi 3 Model B+ has a 64-bit quad-core processor running at 1.4GHz, dual-band 2.4GHz and 5GHz wireless LAN, Bluetooth 4.2/BLE, Gigabit Ethernet over USB 2.0, and PoE capability via a separate PoE HAT. The dual-band wireless LAN comes with modular compliance certification.

Raspberry Pi 3 Model B+ maintains the same mechanical footprint as both Raspberry Pi 2 Model B and Raspberry Pi 3 Model B. Specification

Processor:	Broadcom BCM2837B0, Cortex-A53 64-bit SoC @ 1.4GHz
Memory:	1 GB
Connectivity:	• 2.4 GHz and 5 GHz IEEE 802.11b/g/n/ac wireless LAN, Bluetooth 4.2, BLE • Gigabit Ethernet over USB 2.0 (maximum throughput 300Mbps) • 4 × USB 2.0 interface
Video and sound:	• 1 x full size HDMI • MIPI DSI display port • MIPI CSI camera port • 4 pole stereo output and composite video port
Multimedia:	H.264, MPEG-4 decode (1080p30); H.264 encode (1080p30); OpenGL ES 1.1, 2.0 graphics
SD card support:	Micro SD format for loading operating system and data storage
Input Power:	• 5V/2.5A DC via micro USB connector • 5V DC via GPIO header

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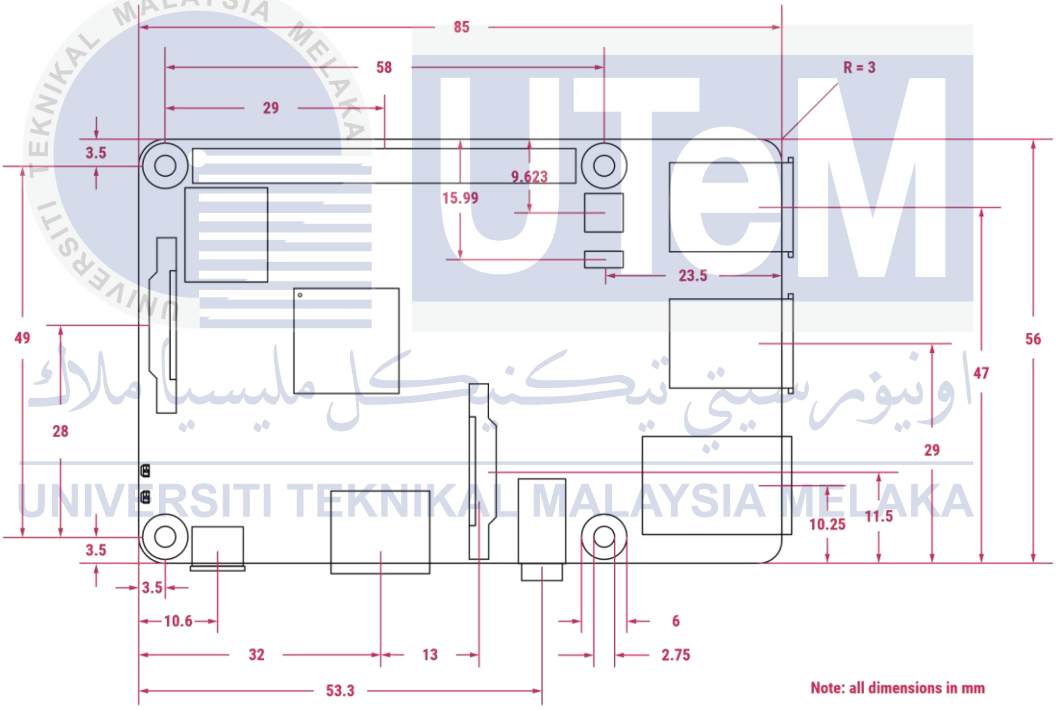
• Power over Ethernet (PoE)-enabled (requires separate PoE HAT)

Operating temperature: 0-50°C

Production lifetime: Raspberry Pi 3 Model B+ will remain in production until at least January 2028

Compliance: For a full list of local and regional product approvals, please visit pip.raspberrypi.com

Physical specification



WARNINGS

- This product should only be connected to an external power supply rated at 5V/2.5 A DC. Any external power supply used with Raspberry Pi 3 Model B+ shall comply with relevant regulations and standards applicable in the country of intended use.
- This product should be operated in a well-ventilated environment, and if used inside a case, the case should not be covered.
- Whilst in use, this product should be placed on a stable, flat, non-conductive surface, and should not be contacted by conductive items.
- The connection of incompatible devices to the GPIO connection may affect compliance, result in damage to the unit, and invalidate the warranty.

- All peripherals used with this product should comply with relevant standards for the country of use and be marked accordingly to ensure that safety and performance requirements are met. These articles include but are not limited to keyboards, monitors, and mice when used in conjunction with the Rapsberry Pi.
- The cables and connectors of all peripherals used with this product must have adequate insulation so that relevant safety requirements are met.

SAFETY INSTRUCTIONS

To avoid malfunction or damage to this product, please observe the following:

- Do not expose to water or moisture, or place on a conductive surface whilst in operation.
- Do not expose to heat from any source; Raspberry Pi 3 Model B+ is designed for reliable operation at normal ambient temperatures.
- Do not expose the printed circuit board to high-intensity light sources (e.g. xenon flash or laser) whilst in operation.
- Take care whilst handling to avoid mechanical or electrical damage to the printed circuit board and connectors.
- Whilst it is powered, avoid handling the printed circuit board, or only handle it by the edges to minimise the risk of electrostatic discharge damage.

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APPENDIX V: MCP23017

Features

• Configurable Interrupt Source:

- AEC-Q100 Qualified - Interrupt-on-change from configured register
- 16-Bit Remote Bidirectional I/O Port (Pins GPA7, GPB7 are output only for **MCP23017**): defaults or pin changes

• Polarity Inversion Register to Configure the Polarity of the Input Port Data - I/O pins default to input

- High-Speed I2C Interface (**MCP23017**): • External Reset Input
- Low Standby Current: 1 µA (max.)
  - 100 kHz
  - 400 kHz • Operating Voltage:
  - 1.7 MHz - 1.8V to 5.5V @ –40°C to +85°C

• High-Speed SPI Interface (**MCP23S17**): - 2.7V to 5.5V @ –40°C to +85°C

- 10 MHz (maximum) - 4.5V to 5.5V @ –40°C to +125°C

- Three Hardware Address Pins to Allow Up to Eight Devices On the Bus

Packages

- Configurable Interrupt Output Pins: • 28-pin QFN, 6 x 6 mm Body
  - Configurable as active-high, active-low or • 28-pin SOIC, Wide, 7.50 mm Body open-drain • 28-pin SPDIP, 300 mil Body

• INTA and INTB Can Be Configured to Operate • 28-pin SSOP, 5.30 mm Body Independently or Together

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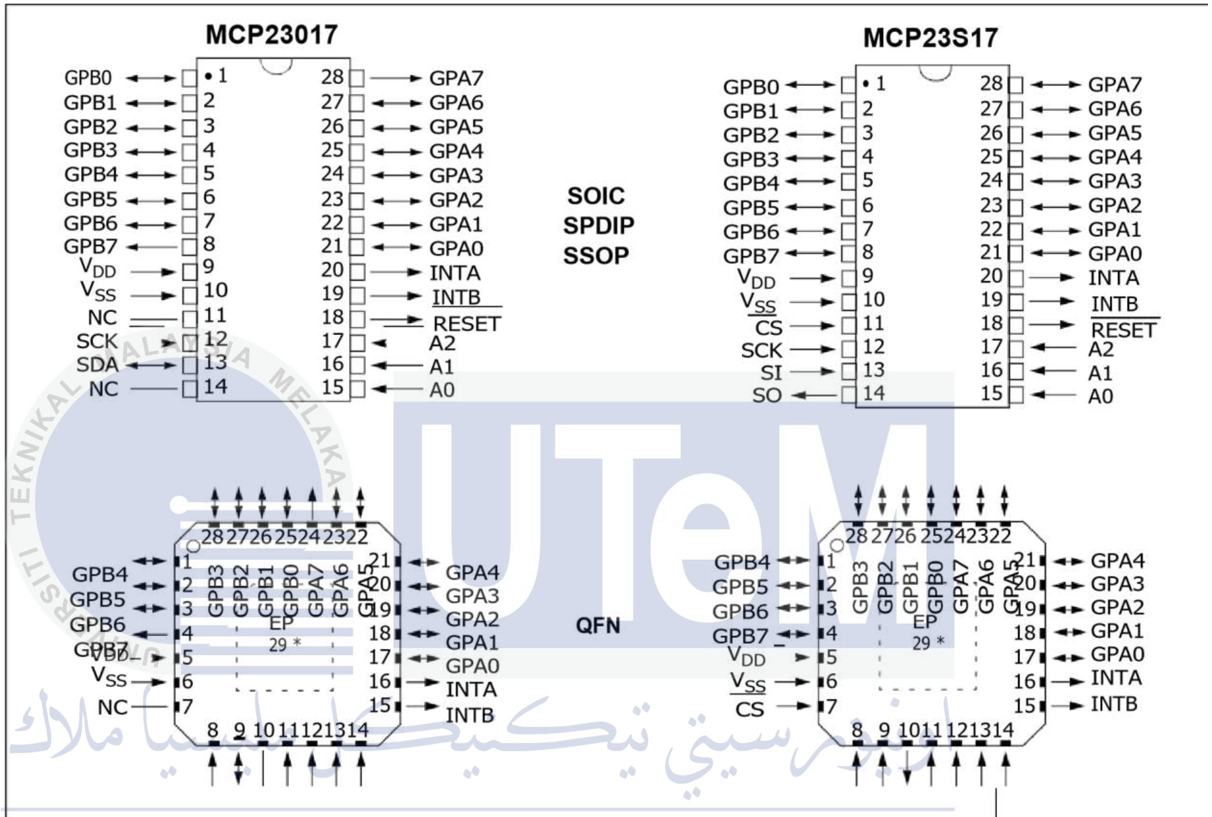
Package Types



* Includes Exposed Thermal Pad; see Table 2-1.

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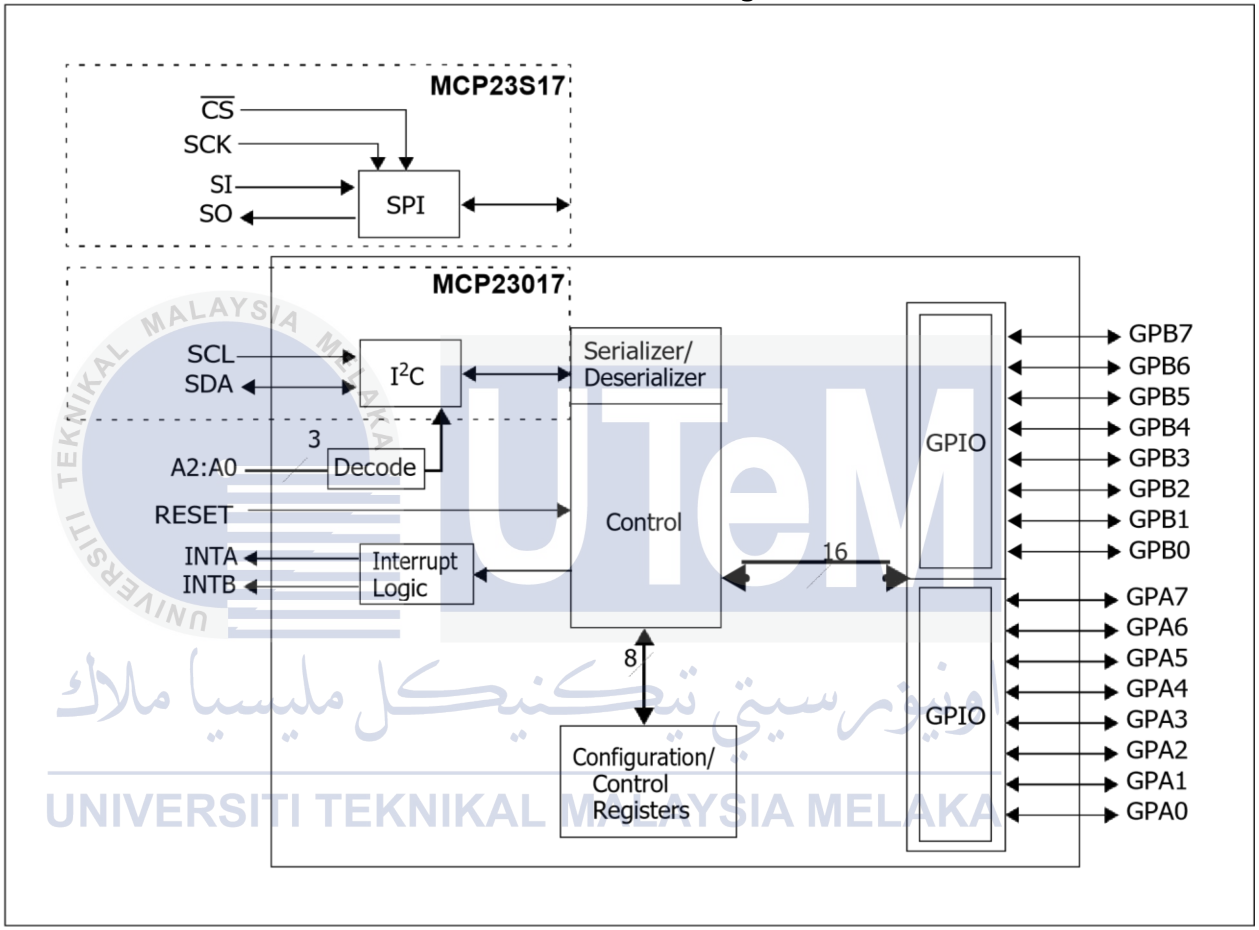
Functional Block Diagram



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