SIGN SPEAK
SMART KEYPAD FOR MUTE PEOPLE COMMUNICATION

A PROJECT REPORT

EE19611-INNOVATION AND DESIGN THINKING FOR ELECTRICAL ENGINEERS

Submitted By

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in partial fulfilment for the award of the degree of

BACHELOR OF ENGINEERING

in

ELECTRICAL AND ELECTRONICS ENGINEERING

RAJALAKSHMI ENGINEERING COLLEGE THANDALAM,

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MAY 2025

BONAFIDE CERTIFICATE

Certified that this report **"SIGN SPEAK SMART KEYPAD FOR MUTE PEOPLE COMMUNICATION"** is the bonafide work of **VIJAYRAM S (220901116)** and **MARAN ELANTHIRAIAN (220901125)** who carried out the work under my supervision. Certified further that to the best of my knowledge the work reported herein does not form part of any other thesis or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

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Signature of the Supervisor with date

Signature Examiner-1

Signature Examiner-2

ABSTRACT

Communication is essential for expressing thoughts and emotions, yet speech-impaired individuals face challenges that lead to dependency and social isolation. The lack of affordable assistive tools worsens this issue. This project introduces a Smart Keypad with Voice Assistant to empower speech-impaired users. It features a T9 text input method, processed by an Arduino microcontroller, which generates voice output using pre-recorded audio files stored on an SD card. The device includes character deletion and message confirmation for enhanced usability. Additionally, it supports multi-language voice output, including Tamil, English, and other regional languages, ensuring inclusivity. Designed to be portable, user-friendly, and cost-effective, this innovative solution bridges communication gaps. It enables users to express themselves independently, enhancing their social participation and improving their quality of life by promoting self-reliance.

ACKNOWLEDGEMENT

We wish to express our deep sense of gratitude to our guide **Dr. D. SHYAM,** Associate Professor, Department of Electrical and Electronics Engineering, for providing an opportunity to work on this project **"SIGN SPEAK SMART KEYPAD FOR MUTE PEOPLE COMMUNICATION"**. We are also thankful for his enthusiastic guidance and encouragement in completing the project.

We extend our thanks to project coordinator **Dr. R. ESSAKI RAJ,** Professor, Department of Electrical and Electronics Engineering, for his kind cooperation.

We express our sincere thanks to **Dr. C. KAMALAKANNAN,** Professor and Head, Department of Electrical and Electronics Engineering, for his guidance and support during this project.

We express our sincere thanks to **Dr. S. RAMAREDDY**, Dean, Department of Electrical and Electronics Engineering, for his guidance and support during this project.

We express our sincere thanks to **Dr. M. SUBBIAH**, Emeritus Professor, Department of Electrical and Electronics Engineering, for his guidance and support during this project.

We express our thanks to **Dr. S.N. MURUGESAN,** Principal, Rajalakshmi Engineering College and management for his support and the facilities provided to complete our project on time.

We also express our gratitude to our parents and friends for their moral support and valuable suggestions during the course of the project.

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LIST OF ABBREVATIONS

ARDUINO UNO R3	Arduino board, version Uno (1), Revision 3.
MP3TF16	MP3 audio module with TF card (up to 16GB) support.
4x4 Keypad	Keypad with 16 keys arranged in 4 Rows and 4 Columns
SPEAKER	Sound Producing Electronic Audio Knowledge Enhancement Resource
SD CARD	Secure Digital Card
LCD DISPLAY	Screen that uses liquid crystals to visually display information.
AAC	Augmentative and alternative communication
HCI	Human Computer Interaction

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Communication is vital for human connection, yet individuals with speech impairments face significant barriers in expressing themselves. The “SIGN SPEAK” addresses this challenge by offering a portable, user-friendly device that enables effective communication through voice synthesis, customizable keypads, and multilingual support. It adapts to user behavior, enhancing personalization and efficiency. This innovation promotes independence, inclusion, and dignity, helping users participate more fully in social, educational, and professional activities. More than just a tool, it represents a step toward a more accessible society. This report details the motivation, design, and impact of this transformative solution.

1.2 STANDARDFORD DESIGN THINKING APPROCH

This project thoughtfully applies the Design Thinking approach to develop an offline, T9 keypad-based communication device tailored for mute individuals.

It begins with the **Empathize phase**, where the focus is on understanding the emotional, social, and practical struggles mute individuals face in daily life. Communication is a basic human need, and for someone who cannot speak, expressing even simple thoughts can become a significant challenge. Most existing solutions are either expensive, require constant internet access, or involve modern touch-based interfaces that may not be user-friendly or familiar to all, especially in rural or low-income areas.

In the **Define phase**, these insights are narrowed down into a clear problem statement: mute individuals need a simple, low-cost, offline, and multilingual tool to communicate easily and effectively. Based on this, the Ideate phase leads to the creation of a practical concept—a compact device that uses a familiar T9 keypad for text input. This keypad allows users to construct words using multi-press logic and select sentences or phrases. The system is designed to output natural, pre-recorded voice messages in English or Tamil, making the interaction feel more human and understandable.

Moving into the **Prototype phase**, the idea is brought to life using components like an Arduino microcontroller, a 4x4 T9-style keypad, a DFPlayer Mini module for audio playback, a speaker, and optionally an LCD for sentence confirmation. It includes a button to switch languages and special keys for emergency phrases. The prototype is lightweight, battery-powered, and completely offline, making it highly portable and practical for everyday use.

In the final **Test phase**, the device is evaluated for its overall functionality. Testing covers input accuracy using the T9 keypad, reliability of phrase construction, clarity of audio output, responsiveness of emergency buttons, and seamless switching between English and Tamil. Through this iterative and human-centered process, the device is refined to ensure it is intuitive, culturally appropriate, and accessible for mute individuals in real-world situations. The result is a tool that not only facilitates communication but also restores confidence and autonomy to users, allowing them to interact more freely in society without needing assistance or expensive equipment.

1.3 OBJECTIVE

This project aims to develop a portable, user-friendly, and affordable Smart Keypad with a built-in Voice Assistant to support speech-impaired individuals. Utilizing a familiar T9 keypad input system, the device allows users to construct text messages easily and hear them spoken aloud through natural voice output in multiple languages, including English and Tamil. By operating offline and using cost-effective components, the system ensures accessibility in both urban and rural settings. The primary goal is to promote independent communication, enhance social interaction, and improve the self-confidence and quality of life of individuals who are unable to speak.

1.4 CONCLUSION

The Smart Keypad with Voice Assistant offers a practical and inclusive communication tool for speech-impaired individuals. By integrating a T9 keypad interface with voice output in multiple languages, the device empowers users to express themselves clearly and independently. Its portability, low cost, and ease of use make it accessible to a wider community, especially in resource-limited settings. This project not only addresses the lack of affordable assistive technologies but also contributes to enhancing the quality of life for speech-impaired users by promoting autonomy, social interaction, and self-confidence.

CHAPTER 2

LITERATURE REVIEW

2.1 LITERATURE SURVEY

Paper Title: A Novel Approach as an Aid for Blind, Deaf, and Dumb People

Authors: Rajapandian B, Harini V, Raksha D, Sangeetha V

Published Journal/Conference: 2017 IEEE 3rd International Conference on Sensing, Signal Processing and Security (ICSSS)

ISSN: 978-1-5090-4929-5

SUMMARY: Rajapandian B et al. (2017) proposed a communication aid for individuals who are blind, deaf, and mute using wearable technology and Arduino-based circuits. Their study highlights the limitations of existing assistive tools and introduces a novel system that converts gestures into audio, text, or Braille output, enabling effective communication across disabilities. The proposed system consists of flex sensors integrated into a wearable glove, an Arduino microcontroller for processing input, and voice playback kits for auditory feedback. The authors compare their approach to prior technologies, such as Gary Grimes' Digital Data Entry Glove (1983), and explore the effectiveness of using real-time text-to-speech conversion for message Transmission. Through experimental validation, the study demonstrates improved communication accuracy, ensuring accessibility for users with different impairments. The authors discuss potential future enhancements, including internet-based communication features, Bluetooth connectivity, and micro-level optimizations for increased portability. While their device overcomes one-way communication barriers, further refinements could enhance usability and efficiency.

Paper Title: Low Cost and Easy to use Electronic Communication System for Speech Impaired People with Wired and Wireless Operability

Authors: Pradip Mule, A. N. Cheeran, Tejaswini Palav, Shailaja Sasi

Published Journal/Conference: 2nd IEEE International Conference on Engineering and Technology (ICETECH), 2016

Location: Coimbatore, TN, India

ISSN: 978-1-4673-9916-6

SUMMARY: Pradip Mule et al. (2016) proposed a cost-effective and user-friendly Electronic Communication System (ECS) to assist speech-impaired individuals in expressing themselves. Traditional communication methods, such as sign language, are not universally understood and may be ineffective in emergencies. The proposed system uses a numeric keypad and Bluetooth module (HC06) to enable users to select and play pre-recorded voice messages stored in an SD card via the WTV020SD voice module. ECS offers audio and text output for improved accessibility, ensuring quick and reliable communication. Unlike gesture-based image recognition, ECS eliminates recognition errors and enhances usability. Testing and evaluation with speech-impaired individuals revealed that ECS is reliable, easy to use, and highly accessible compared to alternative solutions. Future improvements may include speech-to-text integration, multilingual support, and portability enhancements.

Paper Title: Hand Gesture-Based Communication System for Mute Individuals Using Kinect Sensor

Authors: Iram Haider, et al.

Published Journal/Conference: International Journal of Advanced Research in Computer Science, 2020

SUMMARY: Iram Haider et al. (2020) proposed a hand gesture recognition-based communication system designed to assist mute individuals in conveying messages effectively. Traditional communication methods, such as sign language, can pose difficulties when interacting with individuals unfamiliar with them. The proposed system utilizes a Kinect sensor to capture and analyze hand gestures. The image processing pipeline involves gesture segmentation, hand detection, and real-time posture recognition. Once identified, gestures are converted into audio messages, enabling direct and effective communication. Compared to other gesture-based assistive devices, this system enhances accuracy and usability by leveraging depth sensors and artificial intelligence algorithms. Experimental validation demonstrated high recognition rates and efficiency in converting gestures into meaningful voice messages. Future improvements could focus on enhancing gesture classification, integrating multilingual support, and improving accessibility. The study concludes that Kinect-based gesture recognition can significantly improve social interaction and communication for speech-impaired individuals.

Paper Title: IOT-Based Speaking System for Mute People Using Hand Gesture

Authors: Prof. Heena B Kachhela, Ms. Sakshi S Pathade, Prof. Sneha R Bhange, Ms. Palak O Bhoyar, Mr. Kartik S Pardhi, Ms. Samiksha S Dekate

Published Journal: Vidyabharati International Interdisciplinary Research Journal

Volume & Issue: 18(1), March 2024 - May 2024

ISSN: 2319-497

SUMMARY: Prof. Heena B Kachhela et al. (2024) proposed an IoT-based speaking system that enables mute individuals to communicate through hand gestures. Traditional communication barriers exist between mute individuals and those unfamiliar with sign language, making interactions challenging. The proposed system utilizes a glove embedded with flex sensors to detect hand movements. The collected data is processed through a microcontroller, which converts gestures into pre-recorded speech outputs. The system includes stored messages such as "need help" or "where is the washroom," providing a practical and efficient communication solution. Additionally, it incorporates text-to-speech conversion for long-distance interaction via GSM technology. Experimental analysis demonstrated the system's reliability and usability, improving accessibility for speech-impaired individuals. Future enhancements could involve expanding vocabulary, integrating AI-based gesture recognition, and wireless communication for increased portability. The study concludes that wearable technology significantly bridges the communication gap between mute individuals and the general population.

2.2 SUMMARY OF LITERATURE SURVEY

These papers aim to assist disabled individuals, especially those with speech, hearing, and vision impairments, by offering innovative communication systems. Technologies like Arduino boards, flex sensors, Kinect, and Bluetooth enable gesture recognition, text-to-speech, and Braille output for seamless interaction. Each system provides real-time solutions for effective communication, ensuring accessibility in various scenarios like emergencies and everyday life. The papers highlight future advancements, such as wireless operability, multi-language support, and enhanced portability for broader use. Published between 2016 and 2020, these works represent a global effort by researchers to empower differently-abled individuals.

CHAPTER 3

DOMAIN AREA

This project brings together key elements of assistive technology, embedded systems, and human-computer interaction to provide a practical communication solution for speech-impaired individuals. At its core, the device aims to overcome the communication barriers faced by those who cannot speak, using a T9 keypad and natural voice output in multiple languages. Here's a more detailed explanation of how the project works:

3.1 Assistive Technology for Speech-Impaired Individuals

The device functions as an augmentative and alternative communication (AAC) tool, a category of technology designed to support or replace spoken language. For speech-impaired individuals, communicating effectively is often challenging, especially in environments where more advanced or internet-based devices may not be available. The device allows the user to type words or phrases using the T9 keypad, a widely recognized input method from older mobile phones, which has a set of keys representing multiple letters. The simplicity of this input method makes it easy to use, even for people with limited technical experience.

Once the user types a word or message, the device converts the input into natural-sounding speech. The use of speech synthesis allows the user to communicate more naturally, as they would by speaking, making it easier for them to express thoughts, needs, and emotions. Since the system supports multiple languages, individuals from different linguistic backgrounds can benefit, ensuring that language is not a barrier to communication.

3.2 Embedded Systems

The project is rooted in embedded systems, which integrate specialized components to perform a dedicated function. The device uses a microcontroller, which is the brain of the system. This microcontroller takes input from the T9 keypad and processes it to generate the corresponding text. Once the text is generated, the microcontroller triggers an audio playback module connected to speakers, producing the voice output.

The audio playback module stores pre-recorded voice clips for different words or phrases. This setup reduces the need for high processing power while still ensuring that the speech output is clear and natural. The device also features a compact design, meaning that the entire system can be housed in a small, portable unit. This portability makes it suitable for everyday use, ensuring that individuals can take the device with them to school, work, or social events.

3.3 Human-Computer Interaction (HCI)

In the realm of human-computer interaction, the focus is on creating a device that is intuitive and easy for users to interact with, especially for individuals with little to no prior experience with technology. The T9 keypad is a tactile, familiar input method, making it user-friendly for people who are not tech-savvy. This reduces the learning curve and allows users to begin communicating immediately with minimal training.

The interface is designed to be as straightforward as possible, ensuring that users can type and hear their messages without confusion. Additionally, the device is multilingual, which enhances its accessibility for users from various cultural and linguistic backgrounds. This multilingual support not only broadens the reach of the device but also allows individuals to express themselves in their native language, further empowering them to participate in social interactions.

3.4 Technical Challenges and Solutions

While the project offers numerous benefits, it also presents several technical challenges. One of the key concerns is ensuring that the speech output is clear, intelligible, and natural-sounding. Producing high-quality speech synthesis with limited processing power requires careful optimization of both hardware and software.

Another challenge is error handling. Users may occasionally press the wrong key or make mistakes when typing, so the system must include features for detecting and correcting errors. For instance, the device could offer suggestions or allow users to backtrack and fix their input before triggering the speech output. Battery life is another crucial aspect. Since the device is intended to be portable, it needs to run efficiently on a battery for extended periods. Power consumption must be minimized without sacrificing the device's functionality, and energy-efficient components must be used to extend the battery life.

3.5 Impact on Quality of Life

By improving communication, the device significantly enhances the quality of life for speech-impaired individuals. It empowers them to express themselves more easily, helping to overcome the challenges of social interactions, and fosters independence by enabling users to communicate without relying on others. Whether in a family setting, at work, or in public spaces, this device facilitates interactions that would otherwise be difficult or impossible. Moreover, the device can improve opportunities for education and employment. In educational settings, students with speech impairments can participate more actively in discussions, ask questions, and collaborate with peers. In the workplace, the ability to communicate effectively can reduce barriers to employment and career advancement.

3.6 Conclusion

This project offers a practical, user-centered solution for speech-impaired individuals, blending assistive technology, embedded systems, and human-computer interaction into a device that is both simple and effective. By ensuring that the system is affordable, intuitive, and multilingual, the device addresses a critical need for accessible communication tools. Ultimately, the project promotes independence, social inclusion, and improved quality of life for individuals facing communication challenges.

CHAPTER 4

EMPATHIZE STAGE

During the Empathize Stage, the team conducted detailed research and engaged directly with speech-impaired individuals, caregivers, and professionals to understand their communication challenges. In-depth interviews revealed emotional difficulties such as frustration, isolation, and reliance on others, especially in social, educational, and professional settings. Surveys provided quantitative insights into the limitations of existing AAC tools, while real-life observations identified the need for portable, easy-to-use devices with intuitive interfaces, especially in noisy or varied environments.

User personas were developed to represent children, adults, elderly individuals, and caregivers, helping the team address specific needs. Emotional impacts like the loss of independence and dignity highlighted the importance of creating a non-stigmatizing, empowering solution. Understanding user comfort with technology led to the selection of a T9 keypad for its familiarity and simplicity.

Key insights included: **Pain Points**—complexity and cost of existing devices; **Core Needs**—simple interface, multilingual support, portability, error correction, and natural voice output; **Social Goals**—independence and reduced isolation. The resulting problem statement defined the need for an affordable, user-friendly communication device that supports natural expression.

This stage provided a solid foundation for a user-centered solution that not only addresses practical needs but also emotional and social challenges, ensuring greater acceptance and impact.

CHAPTER 5

DEFINE STAGE

5.1 Analysis of Consumer Needs

The analysis of consumer needs for the assistive communication device reveals key requirements from three primary stakeholder groups: speech-impaired individuals, caregivers, and healthcare professionals. For speech-impaired individuals, the core need is a reliable and easy-to-use communication tool that allows them to express themselves independently, especially in environments where advanced technology or internet access may not be available. This requires a simple, intuitive interface, such as a T9 keypad, paired with a natural-sounding voice output that ensures clear communication. The device must support multiple languages to cater to diverse linguistic backgrounds. Additionally, it must be portable and affordable, offering an accessible solution without compromising on functionality.

For caregivers, the primary need is to provide their patients with a tool that minimizes their involvement in the communication process, allowing the speech-impaired individual to interact with others independently. The device should be robust and dependable, with clear error correction features that ensure effective communication without constant oversight. It should also be lightweight and easily transportable, fitting into the caregiver's daily routine seamlessly.

From a healthcare professional's perspective, the device must promote patient autonomy, offering reliable, consistent performance. It should be flexible enough to accommodate different levels of speech impairment and be adaptable for use in various settings (home, hospitals, schools, etc.). The device must also be designed with the patient's emotional well-being in mind, providing a sense of independence and reducing feelings of frustration or social isolation.

By addressing these needs, the system can empower speech-impaired individuals, enhance caregiver efficiency, and improve the overall quality of life for all stakeholders. The technical and operational parameters of the project must reflect these consumer needs, ensuring that the final solution provides practical, emotional, and social benefits.

5.2 Brainstorming the Problem Statement

During the brainstorming phase for the assistive communication device, several critical pain points in current communication tools for speech-impaired individuals were identified. The core problem lies in the lack of an easy-to-use, affordable, and portable device that facilitates reliable communication for speech-impaired individuals without the need for complex technology or excessive reliance on others. Existing devices are often bulky, costly, and difficult to use, leading to increased frustration and dependence on caregivers or family members for communication.

Key technical challenges emerged during brainstorming:

Simple and Intuitive Interface: Ensuring the device interface (e.g., T9 keypad) is intuitive enough for users with limited or no prior experience with technology. Natural Voice Output: Achieving clear, natural-sounding speech output that can be understood by others without the need for further explanation or interpretation.

Multilingual Support: Developing a system that can support multiple languages to accommodate diverse user populations while ensuring that speech synthesis is accurate and intelligible across different linguistic contexts.

Portability and Affordability: Creating a lightweight, portable device that is cost-effective, ensuring accessibility for a wide range of individuals, regardless of their financial background.

Error Correction: Allowing for easy correction of mistakes during communication, ensuring the system is forgiving and flexible without compromising on usability.

Discussions with caregivers and healthcare professionals highlighted additional constraints:

Emotional Impact: The device must support emotional well-being, reducing feelings of social isolation and fostering a sense of independence in users.

Ease of Integration: The device should be easy to integrate into daily life and routines, with minimal training required for both users and caregivers.

Long-Term Reliability: Ensuring the device can function consistently over time without frequent malfunctions or maintenance.

Multimodal Input Verification: Combining T9 keypad input with simple gesture recognition or button customization for users with different types of motor abilities. Multilingual Text-to-Speech Engine: Implementing a robust multilingual text-to-speech system that can generate high-quality, natural speech in multiple languages. Portable, Rechargeable Design: Designing a lightweight, rechargeable device that allows users to carry it with them easily throughout the day. Customizable Feedback: Offering adjustable speech output volumes, pitch, and speed, allowing the user to personalize the device according to their preferences. Emergency Mode: Adding a feature for quick communication during emergencies, enabling users to convey urgent messages with minimal input.

Through these brainstorming sessions, the project's technical and operational challenges were clearly identified, and potential solutions were discussed

CHAPTER 6

IDEATION

6.1 ANALYSIS OF PROBLEM STATEMENT

The ideation stage of the assistive communication device focuses on formulating feasible and impactful solutions to the challenges defined during the problem analysis phase. The goal is to conceptualize a user-centered communication tool that is low-cost, intuitive, and reliable, enabling speech-impaired individuals to interact naturally using a simple interface and voice output. Based on technical insights and stakeholder needs, various ideas were generated using available embedded components: Arduino microcontroller, MP3-TF-16P audio module, speaker, LCD display, T9 keypad, and SD card.

Core Solution Idea:

The system will allow users to input predefined phrases or words using a T9 keypad—a familiar layout resembling old mobile phones—making it accessible for users with minimal technical exposure. The selected input will be displayed on an LCD screen for feedback and then translated into natural-sounding speech using pre-recorded audio files stored on an SD card and played through the MP3-TF-16P module connected to a speaker.

6.2 Ideation Stage

A. Functional Goals & Component Mapping

Input Method – T9 Keypad Enables character input through multi-tap or predictive typing. Simplifies navigation for users with limited dexterity. Buttons are large and tactile, providing physical feedback.

Processing – Arduino Microcontroller, Serves as the central processing unit. Maps keypad inputs to corresponding audio file names. Manages display updates and triggers the audio playback module.

Feedback Interface – LCD Display, Displays typed words/phrases for confirmation. Offers intuitive real-time feedback to guide user interaction. Helps users verify input before outputting speech.

Voice Output – MP3-TF-16P + Speaker Uses pre-recorded audio files for natural speech output. Triggered via serial commands from the Arduino. Ensures high-quality, clear voice playback for effective communication.

Audio Storage – SD Card Stores all pre-recorded voice files in multiple languages. Organized into folders for different categories (e.g., greetings, emergency, basic needs). Can be easily updated to include new phrases or additional languages.

B. Key Features Brainstormed

Multilingual support: Audio files are stored in different folders categorized by language. Users can switch language modes using specific key combinations or a mode button.

Error Correction: A "backspace" function allows users to correct characters before final selection. A "clear" key resets the input buffer.

Emergency Mode: Dedicated emergency keys (e.g., “Help”, “Call family”) directly trigger predefined phrases to expedite urgent communication.

Phrase Shortcuts: Commonly used phrases can be assigned to long-press key combinations for faster interaction.

Low Power Consumption: Optimized circuit design ensures long battery life. The LCD uses low backlight, and components are chosen for efficiency.

Offline Operation: Since all audio is preloaded on an SD card and processed locally, the device requires no internet connection—ideal for rural or resource-limited settings.

C. Challenges Anticipated During Ideation

Memory Management: Preloading large numbers of high-quality audio files in multiple languages requires efficient SD card management and optimal file naming for fast lookup.

Latency Minimization: Ensuring that audio playback triggers immediately after user confirmation to keep the experience fluid.

Voice Quality Standardization: Pre-recorded phrases need consistent volume, tone, and clarity to ensure natural interaction across different situations.

D. Conclusion of Ideation Stage

This ideation process explores a well-integrated, component-based solution that meets the critical needs of speech-impaired users. The combination of familiar hardware (T9 keypad, LCD display) with effective voice playback (MP3-TF-16P, speaker, SD card) under a robust microcontroller (Arduino) delivers a device that is both technically viable and socially impactful. The next step will involve prototyping and iterative testing with real users to refine the device's usability, accessibility, and performance.

6.3 MIND MAP

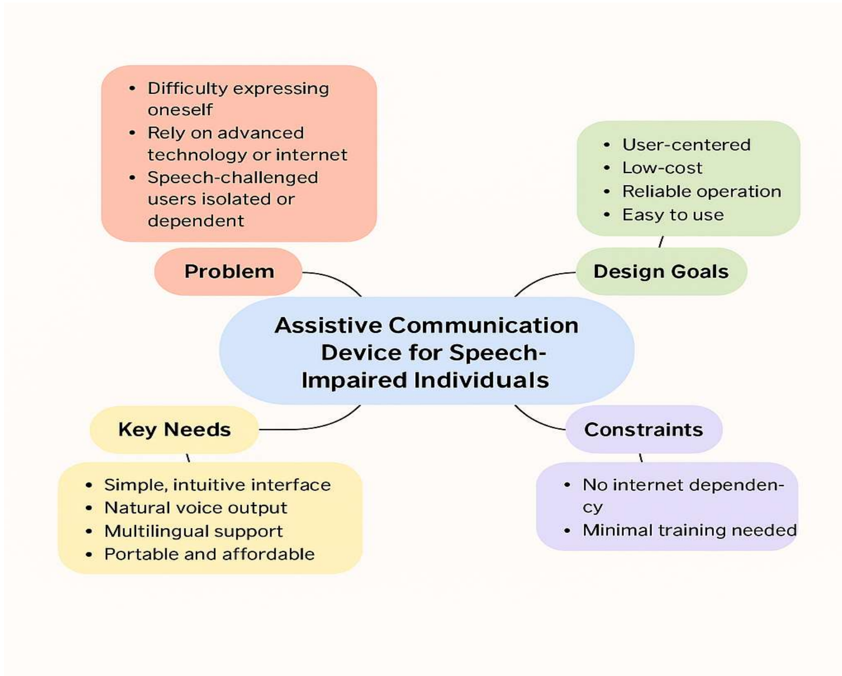


Fig 6.1 Mind map of the problem statement

CHAPTER 7

BLOCK DIAGRAM AND COMPONENTS DESCRIPTION

7.1 INTRODUCTION

In the Smart Keypad with Voice Assistant project, several hardware components work together to assist speech-impaired individuals in communicating effectively. At the core of the system is the Arduino Microcontroller, which serves as the central processing unit. It reads user inputs from the keypad, processes commands, and controls other connected components. The Keypad is used by the user to input text using a T9-style method. Once the desired message is typed, it is displayed on the LCD Display, providing visual confirmation and allowing the user to review or edit the message before voice output. The MP3-TF-16P DFPlayer Mini Module plays a crucial role in voice generation. It reads pre-recorded audio files stored on an SD Card and sends them to the Speaker. The Arduino sends commands to the MP3 module to play the appropriate audio file corresponding to the entered text. The Speaker then outputs the sound, enabling the user to "speak" the message aloud. This combination of components creates a simple, portable, and cost-effective solution that bridges communication barriers for speech-impaired users. The inclusion of multi-language support, including Tamil and English, further enhances the device's accessibility and inclusivity.

7.2 BLOCK DIAGRAM AND EXPLANATION

This Arduino-based audio playback system operates by integrating several components: a keypad for input, an Arduin o Uno as the central controller,

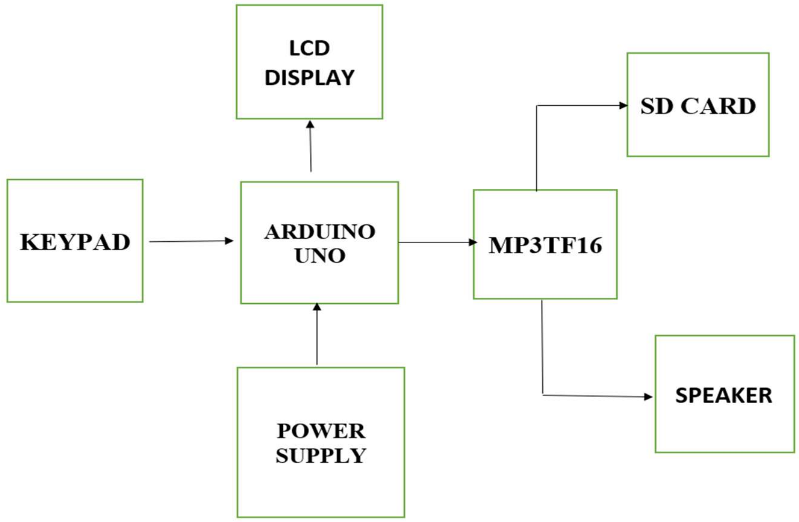


Fig 7.1 Block diagram of the proposed system

This Arduino-based audio playback system operates by integrating several components: a keypad for input, an Arduino Uno as the central controller, an MP3TF16 module (like the DFPlayer Mini) for audio playback, an LCD display for visual output, and a speaker for sound output. The system begins with the power supply energizing the Arduino Uno, which in turn powers connected modules. The user interacts with the system by pressing a key on the keypad. Each key corresponds to a specific audio file stored on an SD card connected to the MP3TF16 module. Once a key is pressed, the Arduino reads the input, processes it, and sends a corresponding command to the MP3TF16 module via serial communication. Simultaneously, the Arduino updates the LCD display to show which track is being played (e.g., "Playing Track 3"). The MP3TF16 module reads the designated MP3 file from the SD card and routes the audio output to the speaker, allowing the user to hear the selected file.

This system is useful for applications like audio-based quizzes, assistive learning tools, or talking information kiosks, and it efficiently combines user input, control logic, and multimedia output in a compact embedded solution.

7.3 COMPONENT DESCRIPTION

7.3.1 Arduino Uno R3:

The Arduino Uno R3 is an open - source microcontroller board based on the ATmega328 chip. This Board has 14 digital input/output pins, 6 analog input pins, on-board 16 MHz ceramic resonator, Port for USB connection, on-board DC power jack, An ICSP header and a microcontroller reset button. Out of the 14 digital input/output pins 6 pins are capable of providing PWM output. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm Centre-positive plug into the board's power jack. Also leads from a battery can be inserted in the Gnd. and Vin pin headers of the Power connector. The board can operate on an external supply of 6 to 20 volts. The recommended supply range is 5v to 12v for Arduino Uno. The DC Current per I/O Pin is 20 mA. The DC Current for 3.3V Pin is 50 mA. The Flash Memory is 32 KB of which 0.5 KB used by boot loader. The SRAM is 2 KB. The EEPROM is 1 KB. The Clock Speed is 16 MHz.

Fig.2.2 shows the hardware diagram of ARDUINO UNO R3. The Arduino can be programmed using the arduino open - source software. Once the program is developed, the program can be dumped on the board by connecting it either with a laptop or computer. Once the program is dumped, we can remove its connection from laptop or computer and can be powered using external supplies.

Once a program is dumped to the board, the program remains in the board until a new programmed is dumped.

The programs can be changed or updated and can be dumped multiple times. The function of the controller is to receive the speed of rotation of rotor shaft from the speed sensor and check whether the speed is within the desired range and if it exceeds the range increase the gear and if it is below the range the gear is decrease until the speed comes back to optimum value. The gear can be changed by connecting the shifter to geared DC motor and this motor is interfaced with the controller.

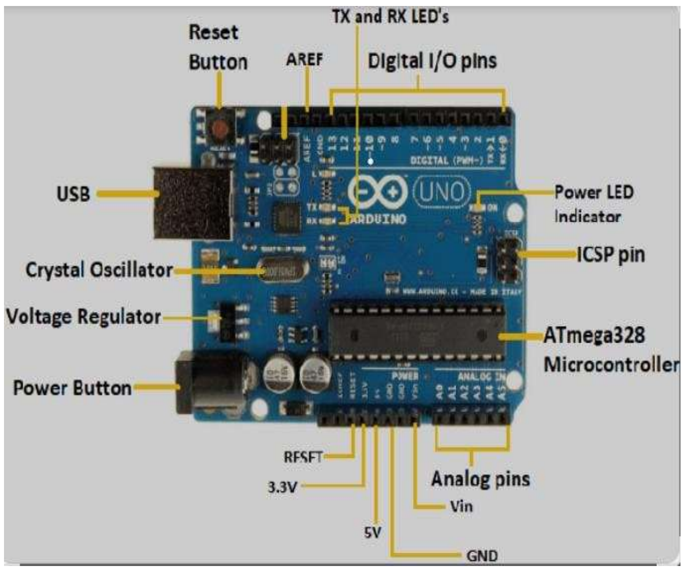


Fig.7.2 ARDUINO UNO R3

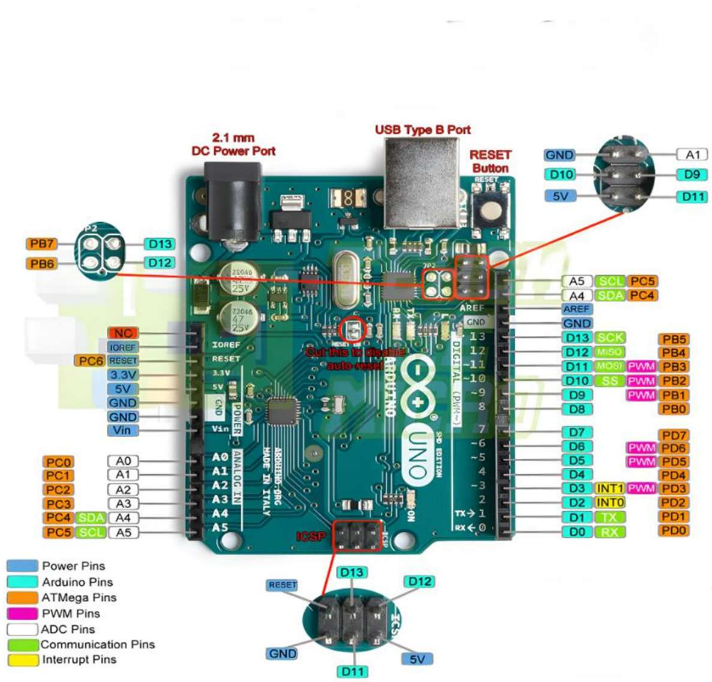


Fig 7.3 in details of Arduino UNO R3

7.3.2 MP3TF16 [DFMINI AMPLIFIER MODULE]

The DFPlayer Mini MP3 module, often referred to as MP3TF16, is a compact and affordable audio playback module widely used in embedded systems for playing MP3, WAV, and WMA files. It integrates a microSD/TF card reader, an MP3 decoder chip, and a built-in 3-watt mono audio amplifier, allowing it to directly drive a speaker without needing an external amplifier. The module supports microSD cards up to 32GB, formatted in FAT16 or FAT32, where audio files can be stored with names like "001.mp3", "002.mp3", and so on for easy file selection. It can be controlled in three ways: using a microcontroller through serial UART communication (commonly with an Arduino), through simple push-button inputs using its AD Key mode, or via IO mode for standalone use. For serial control, the DFPlayer Mini communicates at a default baud rate of 9600 bps, and a voltage divider is often required when connecting to a 5V

microcontroller to protect its 3.3V-tolerant RX pin. The module has dedicated pins for power (VCC and GND), serial communication (TX and RX), and audio output (SPK_1 and SPK_2 for speaker, DAC_L and DAC_R for line-out to.

Fig 7.4 MP3TF16 DFMINI Amplifier Module

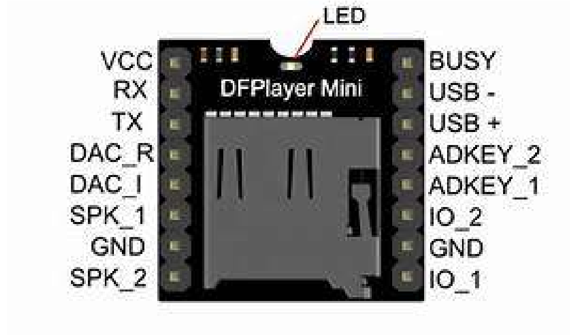


Fig 7.5 MP3TF16 PIN OUT

7.3.3 4x4 KEYPAD

The 4x4 membrane keypad is a widely used input device in embedded systems due to its simplicity, reliability, and compact design. It consists of 16 tactile switches arranged in a matrix format with 4 rows and 4 columns, allowing efficient use of microcontroller I/O pins. Instead of needing 16 separate connections (one for each key), it requires only 8 digital I/O pins—a significant advantage when working with microcontrollers that have limited GPIO availability. Each button on the keypad is positioned at the intersection of a row and a column. When a key is pressed, it connects the corresponding row and column, completing an electrical circuit. The microcontroller detects this by sending a signal through the rows and scanning the columns (or vice versa) using a method known as matrix scanning. The keypad is typically interfaced using libraries such as Keypad.h in Arduino, which handles debounce and scanning automatically.

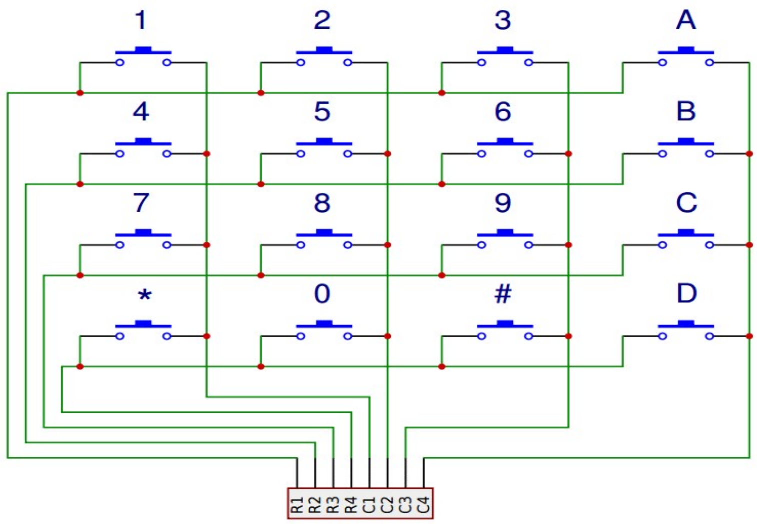


Fig 7.6 Circuit Diagram of 4x4 keypad

Physically, the 4x4 keypad is often constructed from a flexible membrane material, making it thin, lightweight, and easy to mount on flat surfaces. The buttons may be labeled with numbers (0–9), letters (A–D), and symbols (*, #), allowing it to serve as a numeric pad or custom interface for user-defined functions. The keypad operates at standard logic voltage levels (usually 3.3V or 5V), making it directly compatible with popular microcontrollers like Arduino, ESP32, and STM32. It's commonly used in security systems (like PIN entry for door locks), menu-driven systems (such as in vending machines or measurement instruments), and any project that requires user interaction through discrete button presses.

Fig 7.7 4x4 KEYPAD

Some variants of 4x4 keypads also come with adhesive backing for easy panel mounting or headers for breadboard-friendly prototyping. Overall, the 4x4 keypad offers a practical and low-cost way to gather multi-key input from users in a variety of electronics and automation projects.

7.3.4 SPEAKER

The speaker works by converting electrical audio signals into sound waves through the interaction of electromagnetism and mechanical motion. When an analog audio signal is sent to the speaker, it passes through a component called the voice coil, which is a wire coil placed in a magnetic field created by a permanent magnet. As the electrical current in the coil changes with the audio signal, it generates a varying magnetic field. This causes the coil to move back and forth due to attraction and repulsion with the permanent magnet. The voice coil is attached to a diaphragm (cone), so this movement causes the diaphragm to vibrate. These vibrations push and pull the surrounding air, producing sound waves that we hear as audio. The frequency of the vibrations determines the pitch of the sound, and the strength of the signal (amplitude) determines the volume.

Fig 7.8 Speaker

7.3.5 SD CARD

The SD card operates as a compact, solid-state storage device that reads and writes digital data using NAND flash memory. When integrated into an embedded system, its operation begins with initialization through the SPI (Serial Peripheral Interface) or SDIO protocol. Once initialized, the SD card responds to data requests from the host (such as a microcontroller or audio module) using a command-response structure.

Fig 7.9 Sd Card

Data on the SD card is organized into sectors (typically 512 bytes each). When the host sends a read command specifying a sector address, the SD card's internal controller locates the corresponding sector in its memory and sends the data back. For write operations, the host sends data along with a write command, and the SD card stores it in the specified location. The card includes an internal memory controller that handles wear leveling, error detection, and correction to ensure reliable long-term use.

In audio-based applications like your project, the SD card stores .mp3 files. When the user selects a phrase via the keypad, the microcontroller sends a command to the MP3 module, which then instructs the SD card to retrieve and send the corresponding audio file data. The MP3 module decodes this data and plays the sound through a speaker. The SD card supports hot-swapping, allows multiple file systems (like FAT16/FAT32), and ensures fast, non-volatile data access with low power consumption—making it ideal for embedded and portable applications.

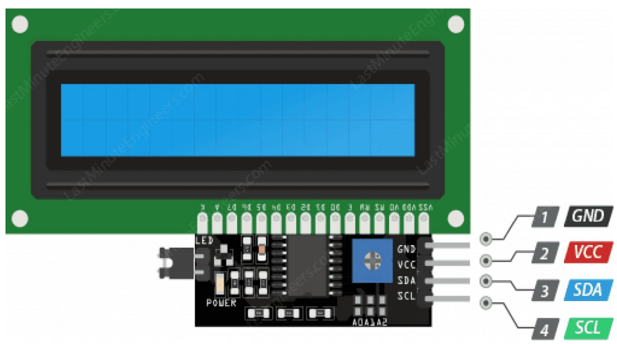
The SD card (Secure Digital card) works as a non-volatile memory storage device that retains data even when power is off. In an embedded system like your assistive communication device, the SD card stores pre-recorded voice files (usually in .mp3 format), which are accessed by the microcontroller through the MP3 module. When the system is powered on and a user selects a phrase using the keypad, the Arduino sends a command to the MP3-TF-16P module to retrieve a specific audio file stored on the SD card. The SD card has a built-in flash memory controller that interprets this command and locates the corresponding file in its memory sectors. Once found, it transmits the digital data from the file to the MP3 module, which then decodes it into an analog signal and sends it to the speaker for playback.

The SD card communicates with the microcontroller via the SPI (Serial Peripheral Interface) protocol, which uses four signal lines: MISO (Master In Slave Out), MOSI (Master Out Slave In), SCK (Clock), and CS (Chip Select). This allows fast and reliable data transfer. Because it's removable and rewritable, the SD card makes it easy to update or expand the device's vocabulary and language support without changing the hardware.

7.3.6 LCD DISPLAY

An LCD (Liquid Crystal Display) works through the interaction of light with liquid crystals, which are special materials that can change their molecular structure when subjected to an electric field. These displays are composed of multiple layers: a backlight, two polarizing filters, a liquid crystal layer, and electrodes that control the alignment of the liquid crystals.

The backlight, typically made of LEDs, serves as the light source. The first polarizing filter, positioned behind the liquid crystal layer, ensures that light is polarized as it passes through. The liquid crystal layer, which is sandwiched between two glass substrates, contains millions of liquid crystal molecules that can rotate or align in different ways when an electric current is applied. The second polarizing filter, placed at the front of the display, controls whether light can pass through the liquid crystals to reach the viewer's eye.



7.10 LCD Display

In an off state, when no voltage is applied, the liquid crystals are aligned in such a way that the polarized light from the backlight is blocked by the second polarizer, resulting in a dark pixel. However, when a voltage is applied to the electrodes, it causes the liquid crystals to reorient, allowing light to pass through the second polarizer, thereby making the pixel appear bright. This change in light transmission is the basic principle that makes the display visible.

In color LCDs, each pixel is made up of three sub-pixels: red, green, and blue. By adjusting the liquid crystal alignment in each sub-pixel, the intensity of light passing through each color filter is controlled. By combining varying intensities of red, green, and blue light, the full spectrum of colors can be produced, allowing the display to show a wide range of colors and images.

CHAPTER 8

PROTOTYPE STAGE

The prototype stage of a project using components like an Arduino microcontroller, speaker, MP3-TF-16 DF mini amplifier, LCD display, keypad, and SD card typically involves assembling the components, writing the necessary code, and testing the functionality of each part to ensure they work together. Here's an overview of how these components would come together in a prototype:

Arduino Microcontroller: The Arduino serves as the central controller for the system. It will handle the logic and communication between the other components. The Arduino will read input from the keypad, send data to the LCD display, control the MP3-TF-16 DF mini amplifier, and manage the playback of audio files stored on the SD card.

Speaker: The speaker outputs sound that is driven by the MP3-TF-16 DF mini amplifier. The speaker will be used to produce the audio files, such as music or voice prompts, based on input from the keypad or instructions programmed into the Arduino.

MP3-TF-16 DF Mini Amplifier: The MP3-TF-16 DF mini amplifier is a key component for audio output. This module interfaces with the Arduino and the SD card to read and decode audio files (like MP3s). It amplifies the audio signals and sends them to the speaker for sound output. The Arduino will send commands to this module to start, pause, or stop audio playback.

LCD Display: The LCD display is used for visual feedback to the user. For example, it can show instructions, status messages, or information about the current audio file being played. The Arduino controls the LCD by sending data to it, such as the names of MP3 files, status of the system (e.g., “Playing,” “Paused”), or any other relevant information based on the input.

Keypad: The keypad is an input device that allows the user to interact with the system. It can be used to trigger actions like starting or stopping audio playback, navigating through different tracks, adjusting volume, or controlling playback functions. The Arduino reads the keypresses and processes the inputs accordingly to perform the correct actions.

SD Card: The SD card stores the audio files (e.g., MP3s or WAV files) that the system will play. It connects to the Arduino and the MP3-TF-16 DF mini amplifier, allowing the Arduino to read files from the card and send data to the amplifier for playback. The SD card is essential for storing and accessing the media content for the audio output.

8.1 Prototype Process:

Wiring and Assembly: Connect the Arduino to the MP3-TF-16 DF mini amplifier: The Arduino communicates with the MP3 module to play the audio files stored on the SD card. Use the appropriate pins (e.g., TX/RX for serial communication).

Connect the speaker to the amplifier: The amplifier outputs the sound, and the speaker converts it to audible sound.

Connect the LCD to the Arduino: Typically, the LCD is connected via the I2C or parallel interface, depending on the model.

Connect the keypad: The keypad connects to the Arduino to allow for user input, usually using digital pins.

Insert the SD card: The SD card is placed in the MP3 module or connected directly to the Arduino using an SD card module.

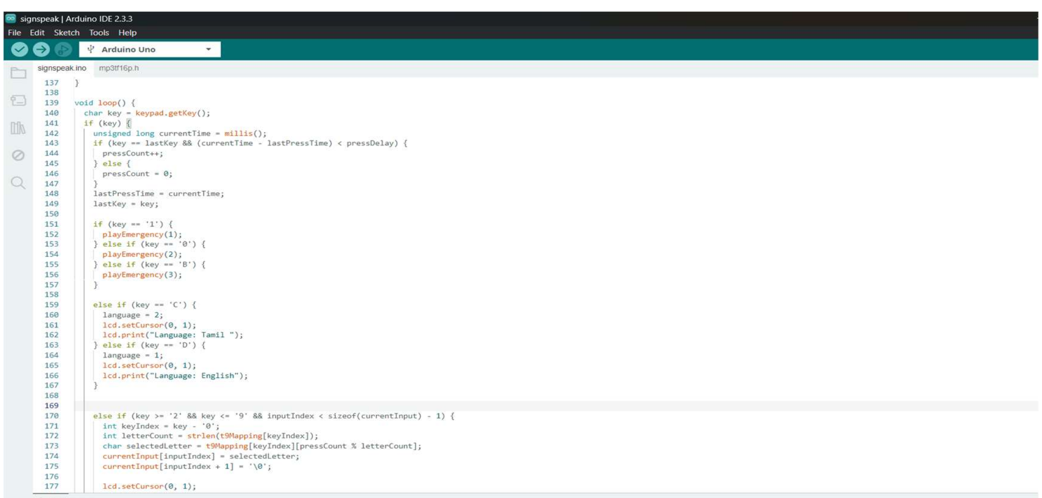
8.2 Software Development

Initialize the components: Write code to initialize the keypad, LCD, MP3 module, and SD card. The Arduino needs to communicate with the SD card to load and read MP3 files and send them to the MP3 module for playback.

Keypad Input Handling: Program the keypad to detect button presses. Each button will trigger a different function, such as changing tracks or controlling the volume.

Audio Playback Control: Write logic to control the playback of audio, such as starting, pausing, or stopping the audio based on keypad input.

LCD Display Updates: Program the LCD to display relevant information, like track names, playback status, or any other messages based on the current system state.



Arduino Code

```
#include <Keypad.h>

#include <SoftwareSerial.h>

#include <DFRobotDFPlayerMini.h>

#include <LiquidCrystal_I2C.h>

#include <avr/pgmspace.h>

#include <ctype.h>

SoftwareSerial mp3Serial(10, 11);  // RX, TX

DFRobotDFPlayerMini mp3;

LiquidCrystal_I2C lcd(0x27, 16, 2);

const byte ROWS = 4;

const byte COLS = 4;

char keys[ROWS][COLS] = {

  {'1', '2', '3', 'A'},{'4', '5', '6', 'B'},{'7', '8', '9', 'C'},{'*', '0', '#', 'D'} };

byte rowPins[ROWS] = {2, 3, 4, 5};

byte colPins[COLS] = {6, 7, 8, 9};

Keypad keypad = Keypad(makeKeymap(keys), rowPins, colPins, ROWS, COLS);

const char* t9Mapping[10] = {

  " ",   // 0

  "1",   // 1

  "ABC_", // 2

  "DEF",  // 3

  "GHI",  // 4
```

```
  "JKL",  // 5
  "MNO",  // 6
  "PQRS", // 7
  "TUV",  // 8
  "WXYZ"  // 9
};
const char s0[] PROGMEM = "HELLO_HOW_ARE_YOU";
const char s1[] PROGMEM = "GOOD_MORNING";
const char s2[] PROGMEM = "GOOD_AFTERNOON";
const char s3[] PROGMEM = "GOOD_EVENING";
const char s4[] PROGMEM = "WHAT_IS_YOUR_NAME";
const char s5[] PROGMEM = "MY_NAME_IS_VIJAY";
const char s6[] PROGMEM = "NICE_TO_MEET_YOU";
const char s7[] PROGMEM = "HOW_OLD_ARE_YOU";
const char s8[] PROGMEM = "WHERE_ARE_YOU_FROM";
const char s9[] PROGMEM = "I_AM_FROM_INDIA";
const char s10[] PROGMEM = "SEE_YOU_LATER";
const char s11[] PROGMEM = "HAVE_A_NICE_DAY";
const char s12[] PROGMEM = "TAKE_CARE";
const char s13[] PROGMEM = "WELCOME_BACK";
const char s14[] PROGMEM = "HOW_WAS_YOUR_DAY";
const char s15[] PROGMEM = "GOOD_NIGHT";
const char s16[] PROGMEM = "ITS_NICE_TO_MEET_YOU";
```

```
const char s17[] PROGMEM = "WHAT_DO_YOU_DO";
const char s18[] PROGMEM = "I_AM_A_STUDENT";
const char s19[] PROGMEM = "CAN_WE_BE_FRIENDS";
const char s20[] PROGMEM = "WHATS_GOING_ON";
const char s21[] PROGMEM = "NOTHING_MUCH";
const char s22[] PROGMEM = "WHATS_NEW";
const char s23[] PROGMEM = "HOWS_IT_GOING";
const char s24[] PROGMEM = "I_AM_FINE_THANK_YOU";
const char* const sentences[] PROGMEM = {
  s0, s1, s2, s3, s4, s5, s6, s7, s8, s9,
  s10, s11, s12, s13, s14, s15, s16, s17, s18, s19,
  s20, s21, s22, s23, s24, s25, s26, s27, s28, s29,
  s30, s31, s32, s33, s34, s35, s36, s37, s38, s39,
  s40, s41, s42, s43, s44, s45, s46, s47, s48, s49,
  s50, s51, s52, s53, s54, s55, s56, s57, s58, s59
};
const int numSentences = sizeof(sentences) / sizeof(sentences[0]);
int language = 1; // 1: English, 2: Tamil
char currentInput[100];
int inputIndex = 0;
char lastKey = '\0';
unsigned long lastPressTime = 0;
int pressCount = 0;
```

```
const int pressDelay = 500;
void setup() {
  Serial.begin(9600);
  lcd.init();
  lcd.backlight();
  lcd.setCursor(0, 0);
  lcd.print("System Ready");
  mp3Serial.begin(9600);
  if (!mp3.begin(mp3Serial)) {
    Serial.println("DFPlayer init failed");
    while (1);
  }
  mp3.volume(30);
  delay(1000);
}
void loop() {
  char key = keypad.getKey();
  if (key) {
    unsigned long currentTime = millis();
    if (key == lastKey && (currentTime - lastPressTime) < pressDelay) {
      pressCount++;
    } else {
      pressCount = 0;
```

```
}
lastPressTime = currentTime;
lastKey = key;
 if (key == '1') {
  playEmergency(1);
} else if (key == '0') {
  playEmergency(2);
} else if (key == 'B') {
  playEmergency(3);
}
  else if (key == 'C') {
  language = 2;
  lcd.setCursor(0, 1);
  lcd.print("Language: Tamil ");
} else if (key == 'D') {
  language = 1;
  lcd.setCursor(0, 1);
  lcd.print("Language: English");
}
  else if (key >= '2' && key <= '9' && inputIndex < sizeof(currentInput) - 1) {
  int keyIndex = key - '0';
  int letterCount = strlen(t9Mapping[keyIndex]);
  char selectedLetter = t9Mapping[keyIndex][pressCount % letterCount];
```

```
    currentInput[inputIndex] = selectedLetter;
    currentInput[inputIndex + 1] = '\0';
    lcd.setCursor(0, 1);
    lcd.print(currentInput);
  }
  else if (key == 'A') {
    if (inputIndex < sizeof(currentInput) - 2) {
      inputIndex++;
      currentInput[inputIndex] = '\0';
    }
  }
  else if (key == '#') {
    playSentence();
    clearInput();
  }
  else if (key == '*') {
    clearInput();
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("System Ready");
  }
 }
}
```

```
void playSentence() {
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Playing...");
  toUpperCase(currentInput);
  bool found = false;
  char buffer[50];
  for (int i = 0; i < numSentences; i++) {
    strcpy_P(buffer, (char*)pgm_read_word(&(sentences[i])));
    if (strcmp(buffer, currentInput) == 0) {
      mp3.playFolder(language, i + 1);
      found = true;
      break;
    }
  }
  lcd.setCursor(0, 0);
  if (found) {
    lcd.print("Done        ");
  } else {
    lcd.print("Not found    ");
  }
}
void toUpperCase(char* str) {
```

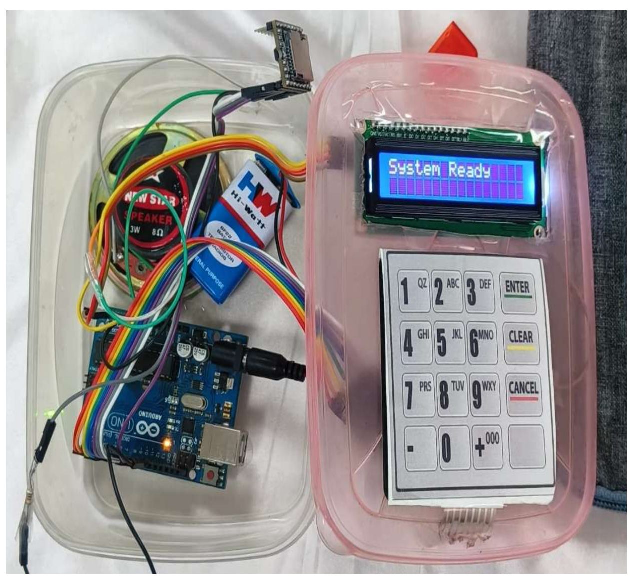
```
  while (*str) {
    *str = toupper(*str);
    str++;
  }
}
void clearInput() {
  memset(currentInput, '\0', sizeof(currentInput));
  inputIndex = 0;
  lastKey = '\0';
}
void playEmergency(int trackNumber) {
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("EMERGENCY ALERT");
  mp3.playFolder(3, trackNumber); // Folder 3 is for emergency clips
  delay(1000); // Optional delay for effect
  lcd.setCursor(0, 1);
  lcd.print("Playing Track ");
  lcd.print(trackNumber);
}
```

Testing and Debugging:

Once all components are wired and the code is written, upload the code to the Arduino and begin testing the prototype. Verify that pressing buttons on the keypad changes the playback as expected (e.g., skip to the next track, play/pause). Check that the LCD updates correctly with relevant information, such as track names or status messages. Test audio playback to ensure the MP3 files are correctly decoded by the MP3 module and output through the speaker.

Refining the Prototype

After testing, refine the prototype by troubleshooting any issues (e.g., incorrect sound output, keypad not responding, LCD glitches). Make any necessary adjustments in the code or wiring to improve performance. If the system works as intended, the prototype can be further refined, adding features like volume control, multiple playlist options, or enhancing the user interface on the LCD.



CHAPTER 9

TEST AND FEEDBACK

The testing and feedback phase of the speech-assistive device project is crucial to ensure it is functional, user-friendly, and suitable for real-world use. It begins with rigorous functional testing of hardware components. Each keypad button is tested for responsiveness, ensuring it correctly signals the Arduino to play the appropriate audio via the MP3 module. The speaker is checked for clarity, volume, and speed, while the LCD is evaluated for accurate message display and system feedback, including error alerts like “SD Card Missing.” Battery life and power efficiency are also assessed to confirm reliable performance over time.

After technical validation, usability testing is conducted with speech-impaired individuals and caregivers. This phase focuses on how easily users can interact with the device. Observations and feedback help determine if buttons are intuitive, the LCD is readable in different lighting, and if the audio output is clear and natural. Real-life scenarios, such as greetings or requests, provide deeper insights into usability.

Feedback leads to design refinements—adjusting button size, improving LCD readability, optimizing audio playback, or simplifying code. User suggestions may also inspire features like multilingual support or headphone connectivity. This iterative, user-centered approach ensures the final product is practical, empowering, and tailored to the needs of its users.

CHAPTER 10

RE DESIGN AND IMPLEMENTATION

The project redesign and construction phase focuses on transforming the initial prototype into a more robust, compact, and user-friendly device. After testing the basic functionality using components like the Arduino microcontroller, MP3-TF-16P module, speaker, LCD display, keypad, and SD card, the system is redesigned for better integration and usability. This includes creating a compact layout by replacing the breadboard with a custom PCB (Printed Circuit Board), ensuring proper connections and reducing the risk of loose wires. Power supply is optimized by using a rechargeable battery system with voltage regulation, making the device portable and independent from constant USB power. A custom enclosure is designed using 3D printing or acrylic sheets, ensuring that all components such as the LCD, keypad, and speaker are properly mounted and accessible, with clear labeling for ease of use.

The keypad interface is improved to allow users, especially speech-impaired individuals, to access frequently used phrases more easily, while the LCD provides clear feedback such as the name of the selected message or playback status. The Arduino code is refined to improve responsiveness, handle errors like SD card issues, and support additional features such as volume control or multi-language output. Once the hardware redesign is complete, components are soldered onto the PCB, mounted into the enclosure, and securely connected. After uploading the final Arduino code, the system undergoes thorough testing to ensure all components work together reliably. The result is a durable, portable, and user-centric device that can be used in real-world scenarios to assist individuals with speech impairments in communicating more effectively.

CHAPTER 11

CONCLUSION

The development of this assistive speech communication device marks a significant achievement at the intersection of embedded systems, human-computer interaction, and inclusive technology. Designed for individuals with speech impairments, the device uses accessible components—Arduino, MP3-TF-16P audio module, LCD, keypad, SD card, and speaker—to provide a low-cost, reliable tool for communication. By pressing a keypad button, users trigger pre-recorded audio messages, with real-time feedback shown on the LCD, allowing essential interactions like greetings or requests.

The project followed a user-centered design approach, with every phase—conceptualization, prototyping, testing, and refinement—guided by real-world feedback. Inclusive input from speech-impaired users, caregivers, and therapists helped improve usability, such as larger tactile buttons and clearer visual prompts. These insights shaped a device that not only functions effectively but also empowers users with greater independence and dignity.

Technically, the Arduino efficiently handles input and audio output, demonstrating how modular, open-source systems can solve real-world challenges. Future versions may include features like Bluetooth, voice input, or multilingual support. This project showcases how empathetic, thoughtful design using basic components can lead to impactful solutions. It reflects the broader mission of inclusive innovation—ensuring technology benefits all members of society, especially those with different abilities.

CHAPTER 12

FUTURE WORK

The future scope of this speech assistive device project is promising, with significant potential for technological advancements and increased accessibility. A key area of development involves integrating AI-based natural language processing and voice recognition, enabling users with limited speech abilities to trigger commands vocally. Adding Bluetooth or Wi-Fi connectivity could allow synchronization with smartphones and cloud platforms, enabling real-time updates, personalized voice settings, and storage of new messages through a dedicated mobile app managed by caregivers or family members.

Multilingual support is another crucial enhancement, allowing users to select from languages such as English, Tamil, or Hindi, making the device more inclusive. Hardware improvements could include replacing physical keypads with touchscreens, using compact custom PCBs to improve portability, and adding features like volume control, headphone support, and battery indicators. The ability to record custom phrases using a family member's voice could provide emotional comfort.

To further enhance accessibility, future versions may incorporate gesture control or eye-tracking for users with severe physical disabilities. Collaborating with hospitals, rehab centers, and special education institutions for testing and feedback can help refine the device. Ultimately, this project can evolve into a scalable, AI-powered, multilingual solution that significantly improves communication for speech-impaired individuals.

CHAPTER 13

LEARNING OUTCOME OF DESIGN THINKING

The development of this speech-assistive device provided valuable learning experiences through the application of Design Thinking, extending beyond technical knowledge. One of the most impactful lessons was learning to empathize with users—individuals with speech impairments—by understanding their communication struggles, emotional challenges, and need for independence. This human-centered approach allowed the team to design a solution that was both functional and personally meaningful.

User-centered design and iterative development emerged as critical learning outcomes. Initial prototypes were refined through constant feedback from users, caregivers, and professionals. This process emphasized the importance of flexibility, patience, and adapting the design to better address real-world pain points. Observations and user interaction helped the team define the problem more accurately and develop practical, impactful solutions.

Collaborative ideation was another key takeaway. Brainstorming features like pre-recorded messages, LCD feedback, and multi-language support highlighted the importance of teamwork and creative problem-solving. The prototyping phase taught the value of building quickly, testing often, and learning from failure.

Ultimately, the project reinforced the concept of inclusive innovation—designing for all, including marginalized communities. It instilled a mindset focused on empathy, creativity, rapid iteration, and social responsibility—core skills essential for creating meaningful, user-driven technology in today's world.

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