

Arduino Uno Based NFC-Enabled Smart Labels for Instant Text-to-Speech Access in Public Spaces

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Abstract. In the modern world, technology plays an essential role in improving accessibility for people with disabilities. This paper deals with Text-to-Voice Converter System for the Visually Impaired Near Field Communication (NFC) Technology based on Arduino Uno. This helps blind people to identify objects using audio output. This paper addresses the lack of accessible information that supports visually impaired individuals in various settings, including public spaces, hospitals, bus stations, government offices, and educational institutions. To fill this gap, we proposed an Arduino Uno-based Enabled Smart Label System that offers instant text-to-speech (TTS) access. An NFC label encoded with essential information about different products or objects for which we need to be tagged. Once the user taps an NFC card or tag on the NFC reader module PN532, NFC is used to detect NFC tags via the I2C interface. The reader is interfaced with a microcontroller, typically Arduino Uno, and the system identifies the previously stored text. The DF Player Mini, which is a mini-MP3 module, is used to play MP3 files stored on a microSD card, and a Micro (4/8GB) SD Card is used to store audio files (mp3), and it converts them into speech using a dedicated TTS module. A buzzer system and LED are used to enhance user feedback and confirm successful reading. This system operates at low power, supports multi-language audio output, and is mainly suitable for use in crowded or high-noise environments. The proposed method also provides low-cost, fast, and reliable assistive technology that promotes independence and accessibility for visually impaired individuals. The results in this paper demonstrate high response accuracy, and interaction with the user is simple and scalable for various public applications.

Keywords: Arduino Uno, DF Player Mini, Micro (4/8GB) SD Card, PN532 NFC Reader, NFC Tags, Buzzer

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1 INTRODUCTION

In recent years, Near Field Communication (NFC) has emerged as powerful and convenient wireless technology for enabling seamless data exchange between electronic devices [10], [12-14]. Its short-range, secure, and low-power communication capabilities make it ideal for innovative assistance applications, particularly in environments where quick access to information is essential. One such innovative application is text-to-audio conversion using NFC technology, which enables users to obtain instant spoken information by simply tapping an NFC tag [1-3]. An Arduino Uno-based text-to-audio conversion system leverages the simplicity of microcontroller programming and the assistive solutions to create an assistive solution for visually impaired individuals, elderly users, or public information systems. When an NFC tag is scanned, the stored text data is retrieved and processed, then converted into speech through an integrated audio playback module or text-to-speech engine [4]. This provides an intuitive, contactless, and user-friendly way to access information, eliminating the need for visual reading [11], [15]. Such systems are increasingly being adopted in bright public spaces, including museums, libraries, hospitals, parking areas, and product labeling. The combination of Arduino, NFC, and audio output enables low-cost, portable, and customizable solutions that enhance accessibility and improve user experience. By reducing dependency on manual reading and providing instant voice feedback, this technology plays a crucial role in promoting inclusivity and ease of interaction in modern, innovative environments [5-9], [16].

2 IMPLEMENTATION OF NFC-ENABLED SMART LABELS FOR INSTANT TEXT-TO-SPEECH ACCESS

2.1 BLOCK DIAGRAM

Fig. 1 illustrates the block diagram of NFC-Enabled Smart Labels for Instant Text-to-Speech implemented using Arduino Uno. It consists of NFC Tag, NFC reader, buzzer, DF Player Mini, micro-SD card and connecting wires [16]. All the above components are connected to Arduino Uno with help of breadboard and connecting wires which are shown in Fig.2.

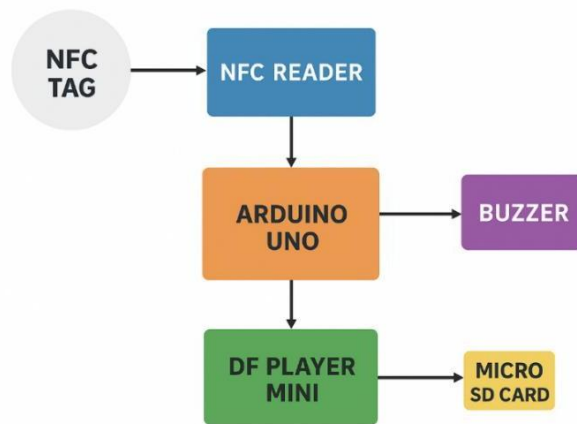


Fig. 1. Block Diagram

2.2 SYSTEM CONNECTION

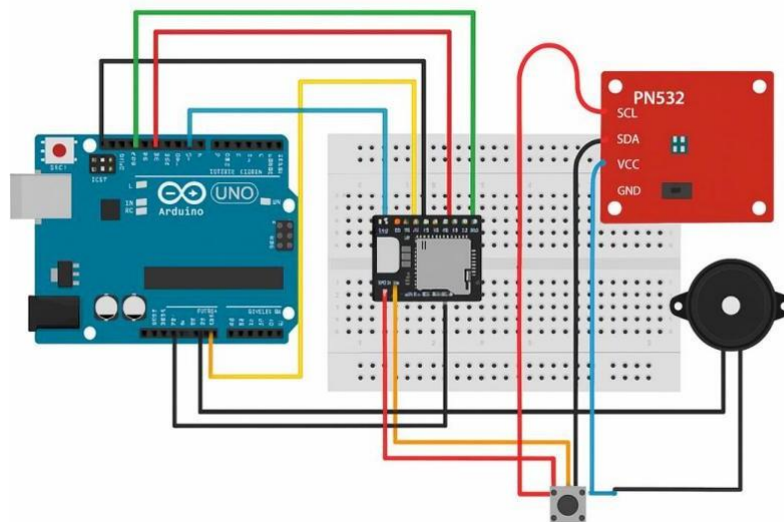


Fig. 2. System Connections of the design

3 HARDWARE COMPONENT DESCRIPTION FOR PROPOSED DESIGN

3.1 ARDUINO UNO

Fig. 3 represents the Arduino Uno. The Arduino Uno is a microcontroller board, and it has the ATmega328P microcontroller on it. Arduino Uno generally has 14 digital general-purpose input/output pins of which 6 are used as PWM outputs, 6 are analog inputs, it has a 16 MHz ceramic resonator and one USB connection, a power jack, and a reset button restart the program. It is like minicomputer which contains everything to support the microcontroller, simply we connect it to a computer with a USB cable or power or battery to get started. Jack and Jack cable is used to transmit the code from IDE to Arduino Uno. It has flash memory of 32KB and SRAM is of 2KB. Also, includes

ICSP header and power LED. Arduino Uno is user friendly along with both hardware and software are Open source. Which use for multiple real time applications [10-14].



Fig. 3. Arduino Uno

3.2 DfPlayer Mini

Fig. 4 is represents DfPlayer Mini MP3 Player is small and low cost which is used for Arduino with a simplified output directly to the speaker. This has a standalone module with attached battery, speaker and push buttons are used with combination of micro-controllers such as Arduino, ESP32, Raspberry Pi and any microcontrollers.

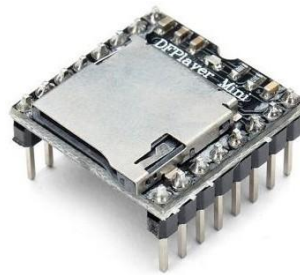


Fig. 4. DfPlayer Mini

3.3 PN532 NFC Reader

Fig. 5 represents the PN532 is transmission module which is highly integrated for con-tactless communication which operates at 13.56 MHz which also includes microcontroller functionality based on an 80C51 core. PN532has the feature like with 1 Kbytes of RAM and it has a 40 Kbytes of ROM. The PN532 will be combined with both modulation and demodulation concept which is completely integrated for contactless communication methods and protocols at 13.56 MHz, it is easy-to-use firmware for the different supported modes which require host controller interfaces. It is virtual card and supports NFC with Android phone. It is compatible with Arduino.

Table 1. Pin configuration of PN532
Reader

S. No		Input	Output
1		SDA	Arduino SDA (Rx)
2		GND	Arduino Ground
3		VCC	Arduino 3.3V
4		SCL	Arduino SCL(Tx)

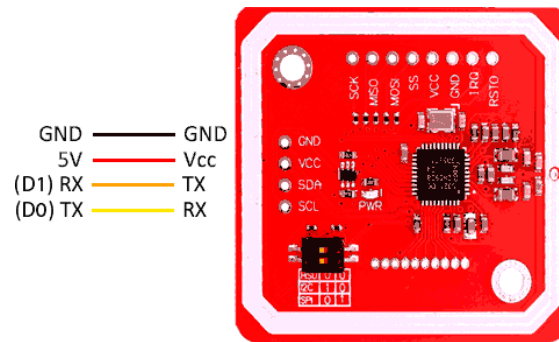


Fig. 5. PN532 NFC Reader

3.4 Micro (4/8GB) SD Card

Fig. 6 represents the Micro SD cards are nothing but memory cards that act as electronic storage for your devices by storing digital media such as photos, audios and videos. In many applications like camera, camcorder, drone or mobile device, we can use these micro-SD cards as memory cards. Most used are SD and microSD variants in smartphones and digital cameras. This can fit into everything. However, different devices require a different type of memory card.



Fig. 6. Micro SD card

3.5 NFC Tags

Fig. 7 represents NFC Tag. Because of the quick exchange of a few bits of digitized information and comes in handy in many applications NFC tags are being used. One of the more commonly used applications is in smartphones that can make mobile payments. Due to NFC tags some phones can simply be tapped at a reader to make the payments. Generally, there really are no limits to using NFC Tag. These NFC devices are passive devices which can draw power from the device that reads them through magnetic induction. Once the reader approaches close enough to NFC Tag it energizes the tag and start transferring the data.



Fig. 7. NFC Tag

3.6 HARDWARE SUPPORTING COMPONENT

A push button is an electrical component used to control the flow of electricity to a device by either completing (closing) or interrupting (opening) an electric circuit with help of joystick is shown in Fig. 8(a). Fig. 8(b) represents Breadboard. A breadboard is a solderless device with vertical and horizontal shorts, which is used to build and test any temporary electronic circuitry and prototypes on it because it is reusable. It consists of a plastic board with a matrix of holes that contains internal

spring clips to hold components and connecting wires. These internal connections allow for easy assembly and disassembly of circuits without soldering, making them ideal for learning, experiment-ing, and prototyping. A buzzer is used here to send the audio signals that creates sounds (beeps, alarms, music) from electrical signals, commonly used in alarms, timers, and user feedback systems, working via mechanical, electromechanical, or piezoelectric principles is to Converts electrical signals (DC voltage with varying frequencies) into audible sounds. being popular for their simplicity and low cost, requiring only DC voltage to produce tones is shown Fig. 8(c). The volume of the sound depends upon the value of the resistor as the resistor value increases then volume will be reduced vice versa. Jumper wires are essential, flexible cables used for temporary, solderless electrical connections in electronics, especially for prototyping with breadboards, Arduino, or Raspberry Pi, connecting components like sensors, modules, and microcontrollers is shown in Fig. 9. There are different types of jumper wires like male to male, male to female and female to female. Based on the type of connection we choose the jumper wires to connect any two different components. snap terminals, and suitability for devices needing steady, portable power, though alkaline versions can be prone to overheating if short-circuited.

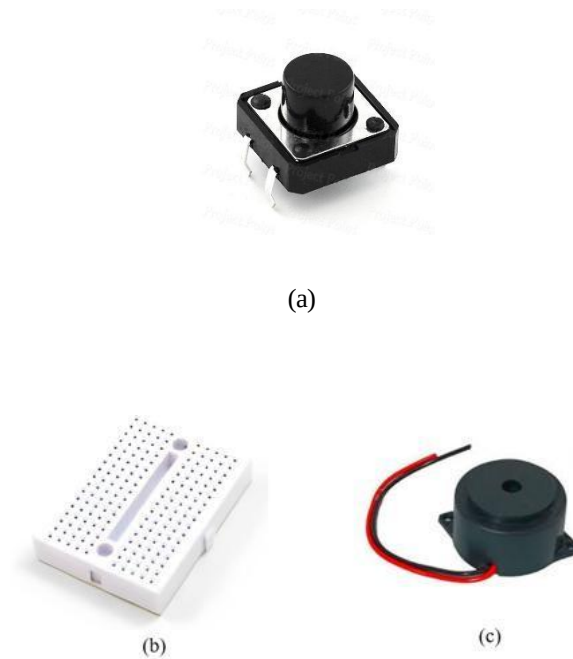


Fig. 8. Hardware supporting components (a) Push Button (b) Breadboard (c) Buzzer



Fig. 9. Jumper Wires

4 FLOW CHART and ALGORITHM

4.1 Algorithm

1. Start
2. Power ON the system
3. Initialize all modules
 - a) Initialize Arduino Uno
 - b) Initialize PN532 NFC Reader (I²C/SPI)
 - c) Initialize DFPlayer Mini
 - d) Initialize Rambus/SD Memory
4. Wait for NFC Tag Detection
Continuous poll PN532 for nearby NFC Tag
5. Is NFC Tag detected? Yes → Go to Step 6 No → Keep scanning
6. Read NFC Tag Data
Read NDEF text / unique ID / encoded index
7. Verify Tag Data
If data is corrupted → Show error tone If valid → Proceed
8. Identify Required Audio/Text
Match Tag ID with stored database (in SD card, Rambus memory, or internal mapping)
9. Retrieve Data
If pre-recorded audio → Fetch audio file
If text file → Fetch text and send to TTS engine
10. Play Audio Output
Use DFPlayer Mini (TTS module)
Output sound through speaker or headphone jack
11. Wait for playback to finish
12. Prompt for next scan
13. System returns to NFC scanning state
14. End

4.2 Flow Chart

Fig. 10 represents the Flow Chart of the proposed model. An ingenious social mobility device that extends beyond the capabilities of an ordinary white stick to improve the safety of visually impaired people is the Smart Advance Blind Stick, that was created using an Arduino Uno. Naturally, it employs a microcontroller (such as an Arduino Uno) to interpret this distance data in real-time and an ultrasonic sensor to identify impediments in the user's route. The advance stick provides haptic feedback through vibrating motors and auditory alerts via a buzzer based on the proximity of an object. It frequently uses different patterns or intensities (Critical, Warning, Proximity) to communicate the severity and distance of the obstacle, enabling the user to navigate their environment more safely and effectively.

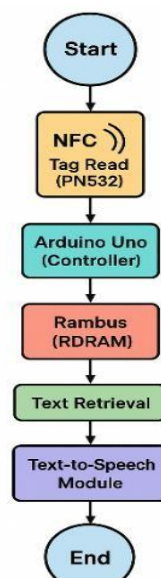


Fig. 10. Flow Chart

5 PROGRAMMING LANGUAGE

C and C++ programs are being used in Arduino programming to interface with system modules. An Integrated Development Environment (IDE) will enhance the Arduino, which includes the Android application, written in Java. It has all been designed with an editor, message area, text module, and toolbar and menu. The central C and C++ code is uploaded to the Arduino microcontroller using a USB cable. The tool's basic functions include cut and paste, as well as search and replace. We can observe that the screen shows output in the IDE. Users can upload code from the toolbox and create a menu. Afterward, they can open the serial monitor and save their sketch to their local drive.

6 Results and Discussion

6.1 Experimental Setup

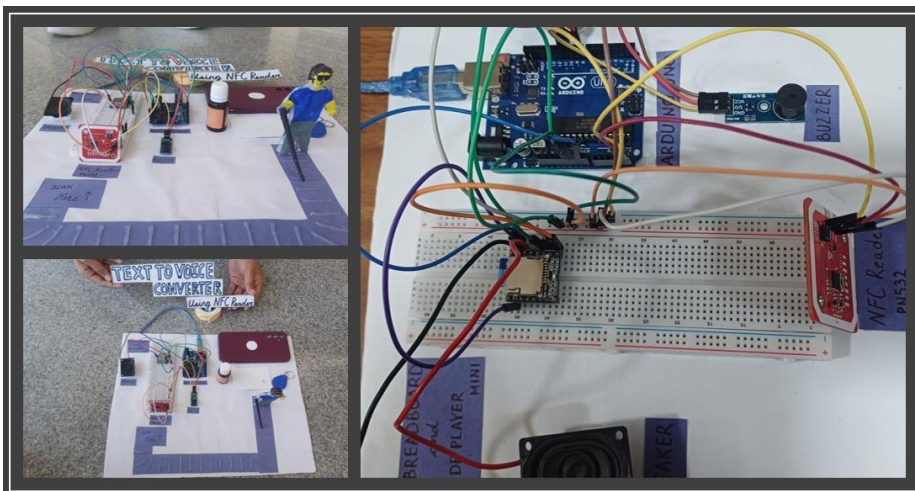
The proposed Arduino Uno Based NFC-Enabled Smart Label system was implemented using an Arduino Uno, PN532 NFC reader, DFP layer Mini audio mod-ule, micro-SD card, speaker, and passive NFC tags. Text information related to public services (room names, warnings, instructions, and announcements) was pre-converted into audio files and stored on the SD card. Each NFC tag was uniquely mapped to a corresponding audio file. When a tag was scanned, the sys-tem instantly played the associated speech output. The system was tested in a simulated public environment such as corridors, classrooms, offices, and information boards to evaluate performance and usability.

6.2 Performance Results NFC Detection Accuracy.

The PN532 NFC reader successfully detected NFC tags within a range of 3–5 cm, ensuring intentional and secure interaction. During testing with multiple tags. Detection accuracy is 98%, false detection is negligible and average tag response time is < 300 ms. This confirms the reliability of NFC technology for short-range, user-initiated in-formation access.

Text-to-Speech Response Time and Power Consumptions.

The total time taken from NFC tag scanning to audio playback was measured as the average response time is 1-1.5 seconds and maximum delay observed is 2 seconds. The delay was mainly due to audio file initialization from the SD card. However, the re-sponse time was acceptable for real-time public information systems. The DFPlayer Mini provided clear and audible speech with low distortion even in moderately noisy environments, the speech output was understandable, making the system suitable for visually impaired users and public announcements. The system was powered using a 5V supply, it consumes low power, low power consumption makes the system suitable for battery-powered or solar-assisted deployments in public locations. Fig. 11 shows the prototype model of the proposed NFC-Enabled Smart Labels for Instant Text-to-Speech Access in Public Spaces



.Fig. 11. Prototype of NFC-Enabled Smart Labels for Instant Text-to-Speech Access

Limitations.

Despite its advantages, the system has some limitations. Limited audio storage depending on SD card size Static prerecorded audio (no dynamic text processing) and Short NFC range requires close interaction.

7 CONCLUSION

In this paper successfully demonstrates that the design and implementation of an Arduino-based NFC-Enabled Smart Labels for Instant Text-to-Speech Access in Public Spaces. This paper ensures fast response, reliable audio output, and seamless interaction. This makes it ideal for smart public infrastructure, such as hospitals, transportation hubs, museums, libraries, and any government facilities. The modular design allows us to easily upgrade, which includes multilingual support, large audio databases, and cloud-based TTS integration. Overall, the results demonstrate a powerful approach to inclusive technology by transforming simple NFC labels into intelligent accessibility tools that promote independence and safe navigation for all users.

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