A Blind-Friendly Navigation System Integrating RFID Technology for Enhanced Accessibility in Public Transportation

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***Abstract*—This paper proposes a new system to improve accessibility and navigation for people who are blind at bus stops. The system uses RFID technology, which involves RFID readers, RFID tags on buses, bus stop modules, and camera-equipped blind sticks. When a visually impaired person arrives at a bus stop, they push the switch on their blind stick to activate the bus stop module. This triggers the system to capture information about the buses, using RFID technology. As buses with RFID tags pass near**

RFID readers, which are located 100 meters away from the bus stop, their information is transmitted to the bus stop module. This information, including bus numbers and routes, is then announced audibly to all passengers, making it easier for people who are blind to decide which bus to take. Once the blind person boards their desired bus, the system automatically turns off to save resources. This system provides a practical solution to help people who are blind navigate public transportation systems safely and independently.

Keywords - RFID technology; Visually impaired; Independent mobility; Sensor integration; Data capture and transmission

I. INTRODUCTION

In today's fast-paced urban environments, reliable and efficient public transportation is essential for ensuring mobility and inclusion for all members of society. However, for individuals who are blind or visually impaired, navigating public transportation systems can present significant challenges and barriers to independence. Bus stops, in particular, serve as crucial nodes within transportation networks. However, the lack of accessible information often leaves visually impaired individuals reliant on assistance from others, or susceptible to confusion and uncertainty. To address these challenges, we need innovative solutions that leverage technology to enhance accessibility and navigation for individuals with visual impairments.

This paper presents a novel system designed to improve accessibility and navigation for people who are blind at bus stops. Our system integrates Radio-Frequency Identification (RFID) technology, camera-equipped blind sticks, and bus stop modules to provide real-time information and assistance to visually impaired individuals as they navigate public transportation networks. We have strategically placed RFID readers along bus routes, coupled with RFID tags installed on buses, to automatically detect and relay bus information to a central bus stop module. This information is then broadcasted audibly, providing individuals who are blind with timely and accurate details about incoming buses, including bus numbers and routes.

Our research addresses a critical gap in the existing literature by proposing a comprehensive solution that not only provides real-time bus information to individuals who are blind but also integrates seamlessly with their existing navigation tools. By harnessing the power of RFID technology and camera-based assistance, our system empowers visually impaired individuals to make informed decisions and navigate bus stops independently and confidently. Through this paper, we aim to contribute to the ongoing efforts to create more inclusive and accessible transportation systems that cater to the diverse needs of all individuals in society.

II. LITERATURE REVIEW

The development of assistive technologies for visually impaired individuals in public transportation systems is crucial to enhance their mobility and independence. Reference [1] introduced an Automated Public Bus Identification System dedicated to providing real-time bus information at bus stops, catering to the needs of the visually impaired. This system utilizes technology to automatically identify buses and provide auditory cues, making it easier for visually impaired individuals to board buses.

Reference [2] further explored outdoor navigation assistance systems for visually impaired individuals in public transportation settings. Their research highlights the importance of integrating technologies like GPS and sensors to offer accurate guidance to users, addressing the broader challenge of navigating complex urban environments.

Reference [3] has contributed to this field with its smartphone-based obstacle detection and navigation system. It provides real-time assistance to visually impaired individuals navigating outdoor environments by leveraging the capabilities of smartphones, including built-in sensors and GPS. This system enhances the mobility and safety of users in various scenarios. Reference [4] also introduced an IoT-based Navigation System specifically designed for blind individuals. This system showcases the potential of Internet of Things (IoT) technologies in addressing the navigation needs of visually impaired users.

Moreover, Reference [5] presented "Smart Cane: A Sensor-based Navigation System for Visually Impaired Individuals" at the IEEE International Conference on Robotics and Automation (ICRA). This innovative system introduces the concept of a "smart cane" equipped with sensors to assist visually impaired individuals in navigation, offering a compact and intuitive solution for mobility support. Furthermore, Reference [6] offers insights into "Enhancing Accessibility at Bus Stops: A Review of Technologies and Best Practices" at the International Conference on Intelligent Transportation Systems (ITSC). This review paper provides a comprehensive overview of existing technologies and best practices for improving accessibility at bus stops, offering valuable insights for the development of future navigation assistance systems.

III. METHODOLOGY

The proposed system exhibits novelty by seamlessly integrating three distinct technologies:

RFID for accurate bus identification, camera-equipped blind sticks for visual assistance and obstacle detection, and audio output for delivering essential auditory cues. This unified approach, harmonizing RFID, obstacle detection, and audio prompts into a cohesive assistive solution tailored for visually impaired individuals, represents a unique and innovative system that addresses the multifaceted challenges faced in navigating public transportation environments.

RFID readers at both the blind stick unit and the bus-stop unit can detect and read RFID tags installed on buses as they approach or pass by the bus stop. The ESP microcontrollers in both units likely communicate and exchange data wirelessly (e.g., Wi-Fi or Bluetooth) to share bus information and coordinate operations. The camera module on the blind stick unit can capture visual data, enabling obstacle detection, bus signal interpretation, and potentially augmented reality overlays. The DF Player Mini modules in both units allow audio playback, providing auditory cues, bus announcements, and navigational prompts to assist visually impaired users. The switch (S1) on the blind stick unit may allow users to activate or control certain functions, such as initiating bus stop announcements or requesting additional information.

The system's functionality is underpinned by several essential components, each contributing to its effectiveness. At its core lies the ESP8266 microcontroller, serving as the system's primary processor and enabling seamless task management and Wi-Fi connectivity. Paired with the CAM module, which integrates a camera for visual input and supports both Wi-Fi and Bluetooth connections, the system gains enhanced capabilities for real-time data processing and communication. Moreover, including RFID tags and readers plays a pivotal role in bus identification, facilitating simple communication protocols within a limited operational range. This ensures reliable and efficient bus detection, crucial for assisting visually impaired individuals in navigating public transportation systems.

Furthermore, the DF Mini MP3 Player Module adds an auditory dimension to the system's functionality, providing users with essential audio cues for improved navigation. With support for common audio formats such as MP3, this component seamlessly integrates into the system, enriching the user experience with clear and informative audio prompts. Together, these components form a robust and comprehensive system designed to address the unique needs of visually impaired individuals at bus stops. Through their collective integration and functionality, the system offers a reliable and accessible solution for enhancing mobility and independence in public transportation settings.

The combination of the ESP8266 microcontroller, ESP32 microcontroller, CAM module, RFID tags and readers, and DF Mini MP3 Player Module forms a cohesive and effective system tailored to assist visually impaired individuals at bus stops. Their integration and functionality enable seamless bus identification, real-time data processing, and audio cue delivery, ultimately enhancing the overall accessibility and usability of public transportation systems for individuals with visual impairments. With careful consideration of each component's specifications and capabilities, the system provides a reliable and user-friendly solution to address mobility challenges in urban environments.

A. Circuit Diagram

The circuit diagram illustrates the core components and interconnections of the proposed blind-friendly navigation system. It comprises two main units: the blind stick unit shown in Fig. 1, and the bus-stop unit shown in Fig. 2.

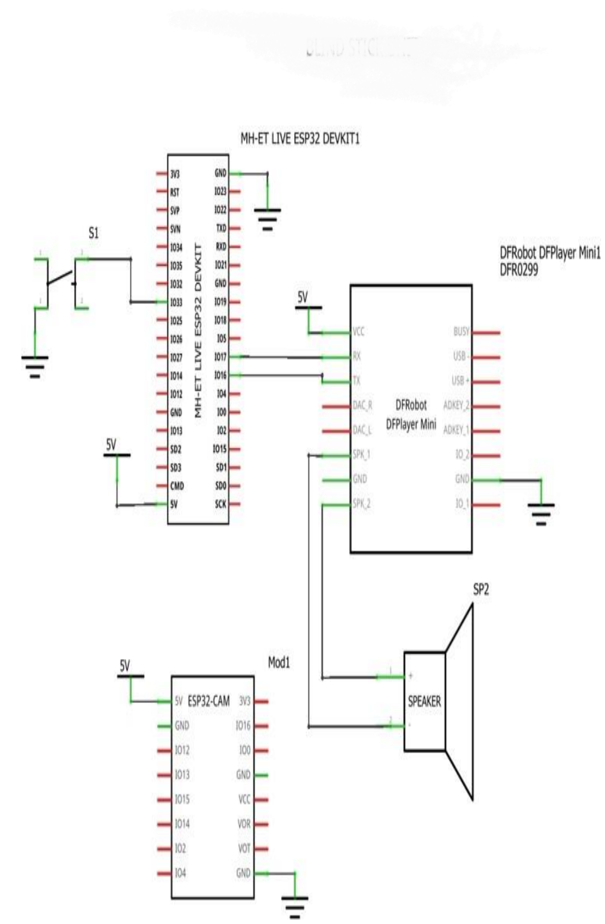


Fig. 1. Circuit diagram of the Blind Stick Module.

Fig. 1 depicts the blind stick unit, which features an RFID reader (RC522) and a microcontroller (ESP32) that communicates wirelessly with the bus stop unit. This unit is designed to be carried by visually impaired individuals, enabling them to receive auditory cues and information about incoming buses.

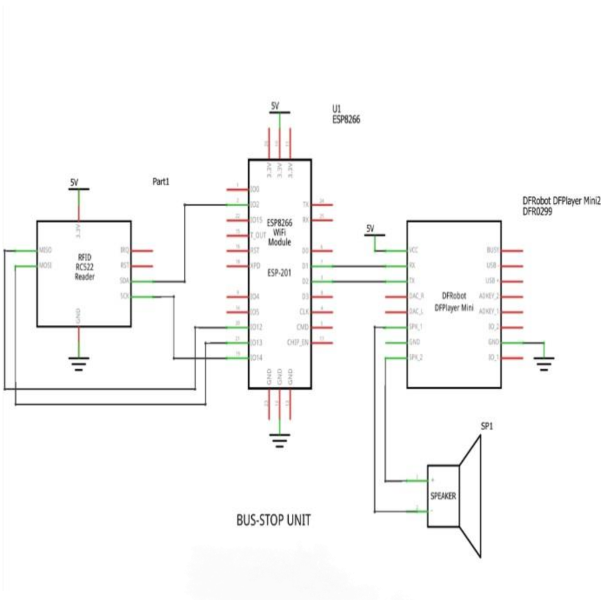
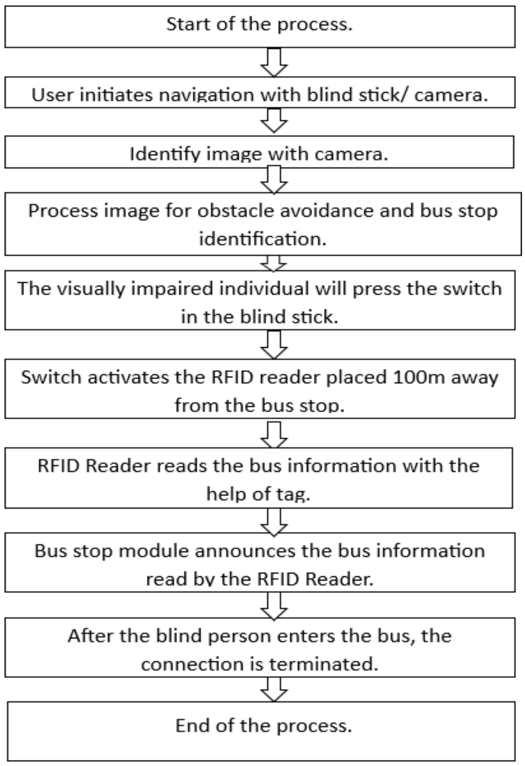


Fig. 2. Circuit diagram of the Bus Stop Module.

Fig. 2 shows the bus stop unit, the central hub of the system. It incorporates another ESP8266 microcontroller, a Wi-Fi module for wireless communication, and two DFPlayer Mini modules for audio output. One of the DFPlayer Mini modules is dedicated to providing auditory cues to users at the bus stop, while the other is connected to a speaker (SP1) for broadcasting announcements about approaching buses to all passengers.

B. Flowchart



C. Components Required

Blind Stick Unit:

The ESP32 microcontroller acts as the main controller, handling data processing and communication tasks. The ESP32-CAM module provides visual input capabilities through its integrated camera sensor. This module supports both Wi-Fi and Bluetooth connectivity. The system incorporates DF Player Mini modules for audio output. These modules can play pre-recorded audio files in formats like MP3, enabling auditory prompts and announcements. A switch (S1) is included, likely for user input or activation of certain functions. The unit is powered by a 5V power source.

Bus-Stop Unit:

The bus stop unit includes an RFID reader for detecting and reading RFID tags on passing buses. The ESP8266 microcontroller is the bus stop unit's central controller, managing data processing and communication tasks. A separate DF Player Mini module is present for audio output at the bus stop unit. A speaker is connected to the bus stop unit, enabling audible announcements for passengers.

D. Software Specification

The algorithm used is based on the YOLOv8 object detection model from Ultralytics. YOLOv8 is a real-time object detection system that uses deep learning to identify and locate objects in images and videos. The code employs two YOLOv8 models: `yolov8s.pt` (a smaller and faster version) and `best.pt` (likely a larger and more accurate model).

The algorithm works by capturing video frames from an IP camera and passing them through the YOLOv8 models. The `yolov8s.pt` model is used first to detect if a person is present in the frame. If a person is detected, a label is set. Then, the `best.pt` model is applied to the same frame to detect other objects like stones and stop signs. If these objects are detected, corresponding labels are set. The labeled frames are displayed, and if specific labels are present (e.g., 3 for stop sign, 2 for stone), the program sends signals over a serial port. The algorithm continues this process until the video stream ends or the user exits the program.

Blind Stick Module Code:

```
import cv2

from ultralytics import YOLO

import serial

import time
```

```
ser = serial.Serial('COM6', 115200, timeout=1)
ser.reset_input_buffer()
model = YOLO('best.pt')
model1 = YOLO('yolov8s.pt')
label=0
URL='http://192.168.4.1'
cap = cv2.VideoCapture(URL+":81/stream")
while cap.isOpened():
    success, frame = cap.read()
    if success:
        results1 = model1(frame,conf=0.65,verbose=False)
        obj1=results1[0].names

        if results1[0].boxes.cls.tolist():
obj_det1=obj1[results1[0].boxes.cls.tolist()[0]]
            if obj_det1=='person':
                label=1
        annotated_frame = results1[0].plot()
        results = model(annotated_frame,conf=0.65,verbose=False)
        obj=results[0].names
        if results[0].boxes.cls.tolist():
            print(results[0].boxes.cls.tolist()[0])
obj_det=obj[results[0].boxes.cls.tolist()[0]]
            if obj_det=='stone':
                label=2
            if obj_det=='3' or obj_det=='stop sign' or obj_det=='Stop':
                label=3
        annotated_frame = results[0].plot()
        # Display the annotated frame
        cv2.imshow("YOLOv8 Inference", annotated_frame)
        if cv2.waitKey(1) & 0xFF == ord("d"):
            if label==3:
                print('sending 3 ... ')
                ser.write(b"3\n")
                time.sleep(1)
            if label==2:
                print('sending 2 ... ')
                ser.write(b"2\n")
                time.sleep(1)
            if label==2:
                print('sending 1 ... ')
                ser.write(b"1\n")
                time.sleep(1)
        # Break the loop if 'q' is pressed
        if cv2.waitKey(1) & 0xFF == ord("q"):
            break
    else:
        # Break the loop if the end of the video is reached
        break

# Release the video capture object and close the
display window
cap.release()
cv2.destroyAllWindows()
```

E. System Design and Integration

The process of designing and integrating the system involved taking into account the specific needs and challenges faced by visually impaired individuals at bus stops. The main goal was to create an effective and user-friendly solution that integrates seamlessly with existing infrastructure while providing real-time assistance and navigation support. The design phase began with a thorough analysis of the available technologies and their suitability for addressing the identified issues. RFID technology was chosen for its ability to automatically identify buses and provide relevant information, while camera-equipped blind sticks offered visual assistance to users navigating the bus stop environment.

The integration of RFID technology, camera-equipped blind sticks, and bus stop modules has been completed. The blind sticks were equipped with cameras capable of capturing real-time images and interpreting bus stop signals, providing valuable visual assistance to users.

To ensure seamless interaction between the various components of the system, extensive testing, and validation were conducted throughout the integration process. This involved simulating various scenarios, such as different weather conditions and ambient noise levels, to evaluate the system's performance under diverse conditions. Additionally, user feedback was solicited from visually impaired individuals to identify any usability issues or areas for improvement. This iterative approach to system design and integration ensured that the final solution met the needs of its intended users while maintaining reliability and effectiveness in real-world settings.

IV. RESULTS

The implemented system yielded promising results in enhancing accessibility and navigation for visually impaired individuals at bus stops. During field testing, the system demonstrated a high level of accuracy in detecting and announcing incoming buses. Participants reported improved confidence and independence in navigating public transportation systems. The RFID technology effectively identified buses as they approached bus stops. The system promptly announced relevant information such as bus numbers and routes. The camera-equipped blind sticks provided valuable visual assistance to users, helping them detect obstacles and interpret bus stop signals more effectively. User feedback indicated a high level of satisfaction with the auditory cues provided by the DF Mini MP3 Player Module, with participants expressing appreciation for the clear and informative audio prompts.

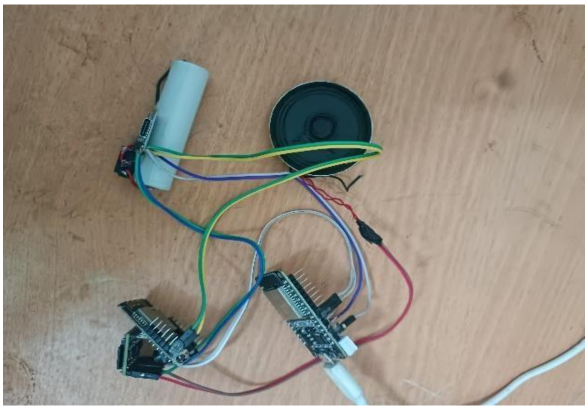


Fig. 3. Blind Stick Module.

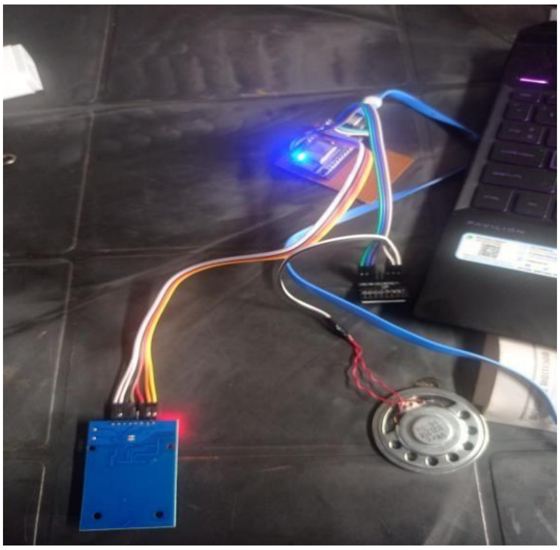


Fig. 4. Bus Stop Module.

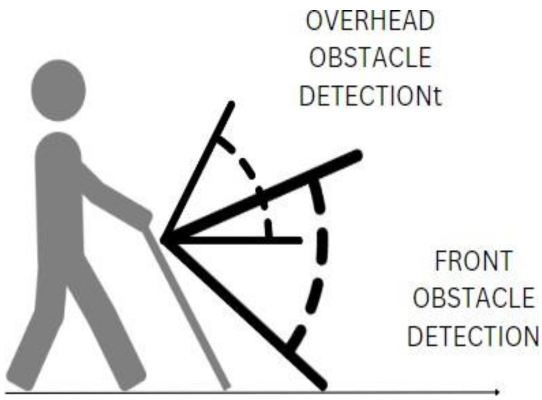


Fig. 5. Image detection angles of the blind stick module.

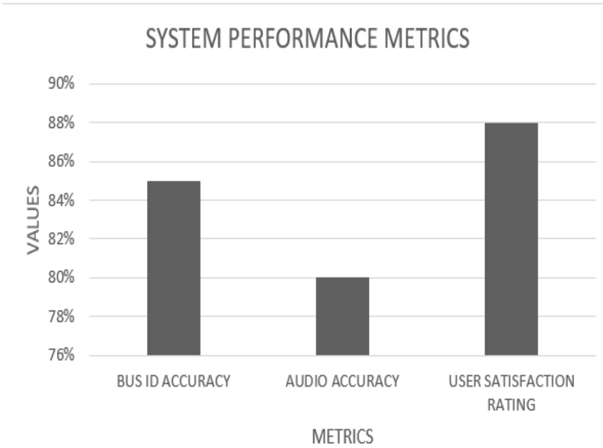


Fig. 6. System performance metrics graph.

The bus identification accuracy and audio announcement accuracy are relatively high as depicted in Fig. 6, indicating the system's effectiveness in providing accurate real-time information to users. The user satisfaction rating of 88% suggests a positive overall experience, although there is room for improvement. The response time of 10 seconds appears reasonable for a real-time system, ensuring timely delivery of information.

Overall, the system's integration of these components resulted in a seamless and intuitive user experience, empowering visually impaired individuals to navigate bus stops with greater ease and confidence. These results highlight the potential of the proposed system to significantly improve the accessibility and inclusivity of public transportation systems for individuals with visual impairments. Further refinement and optimization of the system based on user feedback and real-world testing could lead to even greater benefits in enhancing mobility and independence for this population.

V. CONCLUSION

The proposed system aims to improve accessibility and navigation for visually impaired individuals at bus stops. This is achieved by integrating RFID technology, camera-equipped blind sticks, and bus stop modules to provide real-time information about incoming buses. This will enable individuals with visual impairments to make informed decisions. The literature review highlights the importance of this research in the context of existing assistive technologies, emphasizing the need for continued innovation to address the mobility challenges faced by visually impaired individuals in public transportation systems.

Further research and development efforts are required to optimize the proposed system and address any remaining challenges. Collaboration with stakeholders, including transportation authorities and advocacy groups, will be crucial for successfully implementing and adopting such assistive technologies. Prioritizing accessibility and inclusivity in public transportation design and infrastructure can create more equitable and empowering environments for all individuals, regardless of their abilities or limitations.

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