Project Report on

Accessible Pedestrian Signals

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Abstract

This report presents the development of an innovative Traffic Light Recognition Device designed to assist visually impaired individuals in navigating traffic signals safely and independently. The device integrates advanced computer vision techniques, specifically the YoloV8 object detection model, to accurately identify traffic light states (red, green, yellow) in real-time. Enclosed in a custom-designed casing, the hardware setup includes an Arduino Uno R3, an OV7670 camera module, and a piezo buzzer, all of which are simulated using TinkerCad for hardware testing. The device offers intuitive feedback through specific buzzer patterns, ensuring the user receives clear and immediate information about the traffic signal status. The software achieved impressive metrics with a mean Average Precision (mAP) of 99.5%, Precision of 99.3%, and Recall of 99.1%. Future improvements aim to incorporate additional feedback mechanisms and integrate GPS for further navigational assistance. This device demonstrates a technically and economically feasible solution to significantly enhance the mobility and safety of visually impaired individuals in urban environments.

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Chapter 1: Introduction

1.1 Background Theory

- **Computer Vision and Traffic Light Detection:** Computer vision is a field of artificial intelligence that enables machines to interpret and make decisions based on visual data. This involves techniques for acquiring, processing, analyzing, and understanding digital images to extract meaningful information. Traffic light detection, a specific application of computer vision, requires accurate identification of traffic signals in various environmental conditions, such as different lighting, weather, and occlusions. This is crucial for developing autonomous vehicles, smart city infrastructure, and assistive devices.

- **YOLO (You Only Look Once) Model:** YOLO is a state-of-the-art, real-time object detection system known for its speed and accuracy. The YoloV8 model, used in this project, represents an evolution in the YOLO family, optimized for better performance in terms of precision and recall. YOLO models divide the image into a grid and predict bounding boxes and class probabilities for each grid cell, enabling efficient detection and classification of multiple objects within an image.

- **Assistive Technology for the Visually Impaired:** Assistive technology encompasses devices or systems designed to aid individuals with disabilities. For the visually impaired, such technologies can range from simple tools like white canes to advanced electronic devices that provide navigational assistance. The integration of computer vision into assistive devices represents a significant advancement, allowing for real-time environmental interpretation and actionable feedback. This enhances the user's ability to navigate independently and safely in complex urban environments.

- **Vibration and Auditory Feedback:** Effective feedback mechanisms are essential for assistive devices. Vibration and auditory signals are commonly used due to their immediate and easily interpretable nature. Vibrations can provide tactile feedback without distracting the user, while auditory signals can deliver clear and specific information about the current environment or potential hazards.

1.2 Problem Statement

To Develop a device to assist visually impaired individuals in identifying pedestrian crossing signals with the following functionalities:

- **Signal Detection:** The device should identify the signal (STOP or GO) from an image of the signal.

- **User Alert:** Provide an appropriate alert to the user based on the identified signal. This could be an auditory signal or vibration feedback to indicate whether it is safe to cross or not.

Focus on creating a reliable and user-friendly device that enhances the safety and independence of visually impaired pedestrians.

Chapter 2: Related Theory

2.1 Hardware

The Arduino Uno R3 microcontroller was selected for its ease of use, ample support, and compatibility with various sensors and actuators. The OV7670 camera module provides the necessary image capture functionality, while the piezo buzzer delivers effective tactile feedback.

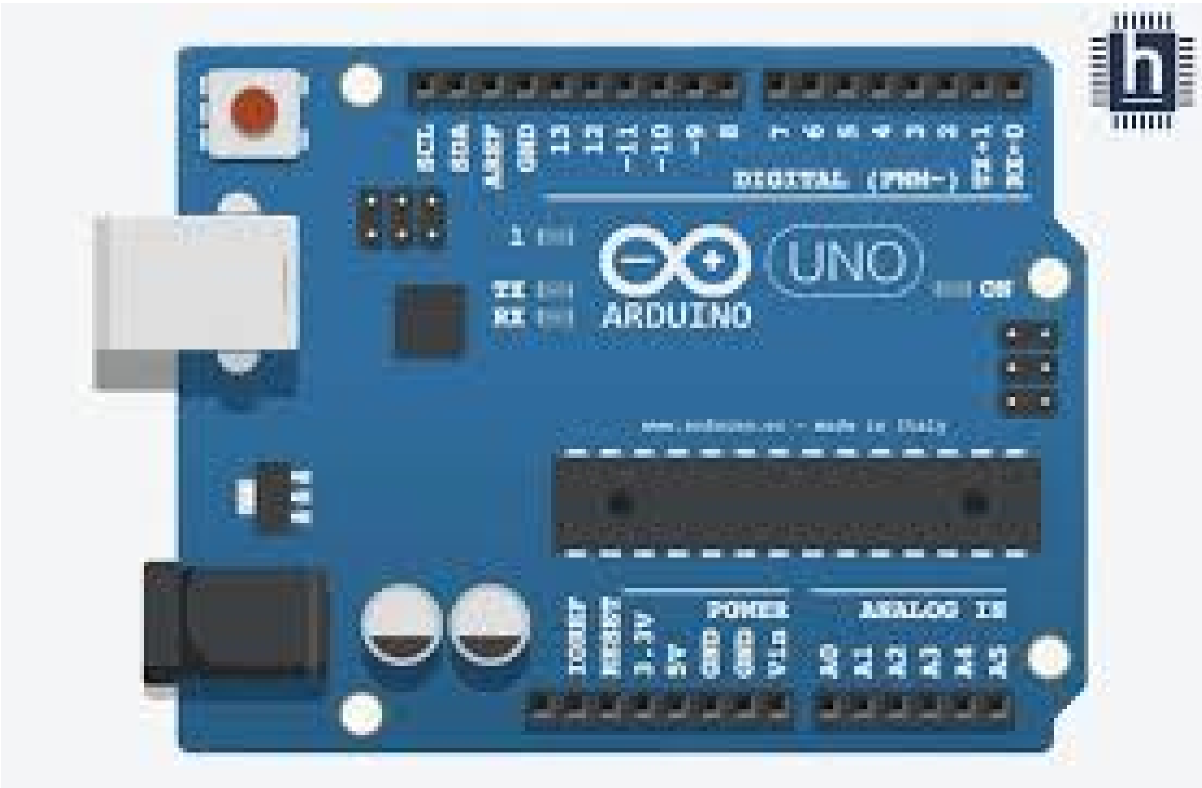

Figure 2.1: Arduino UNO

2.2 Mechanical

The enclosure was designed using Fusion 3D to ensure robustness, ease of use, and accessibility. The design considerations included user ergonomics, durability, and effective integration of all hardware components.

2.3 Software

YoloV8, a state-of-the-art object detection model, was chosen for its high accuracy and real-time performance capabilities. It excels in identifying objects within complex environments, making it ideal for traffic light recognition.

Chapter 3: Feasibility Study

3.1 Technical Feasibility

- **Hardware:** Readily available and well-supported components (Arduino Uno R3, OV7670 camera, piezo buzzer).
- **Software:** Leveraging pre-trained models (YoloV8) reduces development time and increases reliability.
- **Integration:** Seamless integration of hardware and software ensures real-time performance and user-friendly operation.

3.2 Economic Feasibility

- **Cost-Effective Components:** Using affordable and readily available components minimizes the overall cost.
- **Scalability:** The design is scalable, allowing for mass production and wider accessibility.

Chapter 4: Methodology

4.1 Approach to Solving the Problem

4.1.1 Enclosure Design (Fusion 3D):

The device enclosure, designed in Fusion 3D, measures 127.6 x 94.4 x 35 mm, and is tailored to house an Arduino Uno R3, a buzzer, a battery, and an OV7670 camera module. Key features include:

- A switch for camera control.
- A revolving lid for circuit protection.
- A dedicated battery compartment for easy replacement.
- Strategically placed slits to ensure effective vibration feedback.
- A vertically positioned camera module for straightforward image capture.

4.1.2 Software (YoloV8):

- Using YoloV8, the software was trained on a dataset of 2,526 images with three classes (red, green, and yellow).
- Suitable Preprocessing steps were employed to ensure model's performance under various lighting conditions (bright sunlight, shadows, nighttime).
- Link to Dataset (self annotated)

4.1.3 Hardware Simulation (TinkerCad):

The hardware components include a piezo buzzer and Arduino Uno R3, with the following response patterns:

- Green Light (GO): Continuous buzz for 3 seconds.
- Red Light (STOP): Three short buzzes at 0.5-second intervals.
- Yellow Light (WAIT): Five quick buzzes at 0.3-second intervals.
- Invalid or No Signal: Seven short buzzes to alert the user to be cautious.

4.2 Algorithm

1. Capture image using the OV7670 camera.
2. Preprocess the image (resize, normalize).
3. Use YoloV8 to detect traffic lights and classify their states (red, green, yellow).
4. Generate feedback based on the detected state:
   - Green: Continuous buzz for 3 seconds.
   - Red: Three short buzzes at 0.5-second intervals.
   - Yellow: Five quick buzzes at 0.3-second intervals.
   - Invalid/No Signal: Seven short buzzes.

4.3 Flowchart

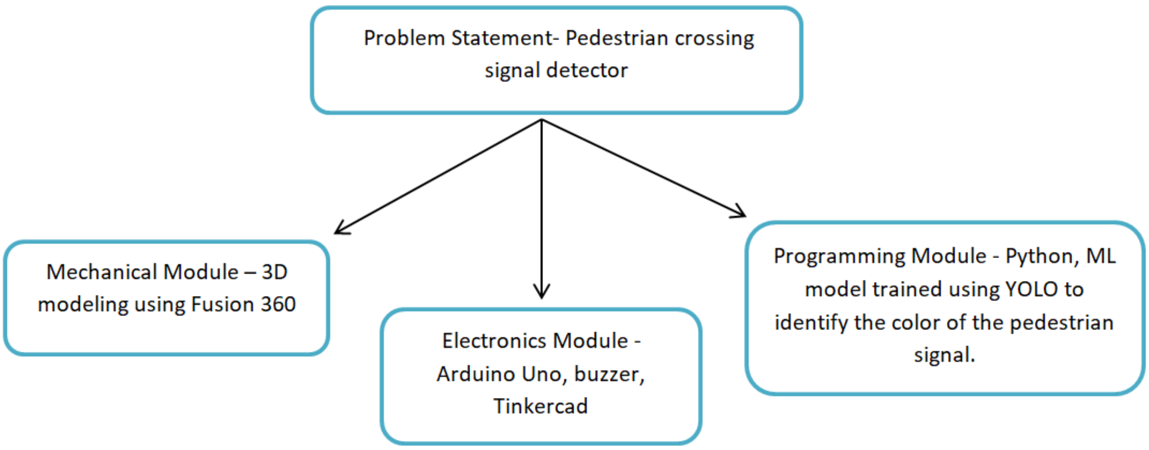

Figure 4.1: Flowchart of Inter-Module Connections

Chapter 5: Results

5.1 Mechanical Enclosure Design

FUSION 360 DESIGN LINK
LINK TO DOCX WITH SCREENSHOTS

5.2 Software

- The YoloV8 model achieved:
  - Mean Average Precision (mAP): 99.5%
  - Precision: 99.3%
  - Recall: 99.1%
- Sample Output:

  ```
  image 1/264
  /test/images/IMG_1481_jpg.rf.e3665dff27554a16746332d922358ea0.jpg:
  640x640 2 yellows, 16.5ms
  ```

- COLAB LINK

5.3 Hardware

TINKERCAD LINK
VIDEO DEMO LINK

Chapter 6: Inference and Conclusion

6.1 Comparative Analysis

On comparison with Existing Solutions, this device offers several advantages over existing solutions:

- **Real-Time Processing:** YoloV8 enables quick detection and response to changing traffic light states.
- **User-Centric Design:** The enclosure design and feedback mechanisms are tailored for the needs of visually impaired users.
- **Cost-Effectiveness:** Utilization of accessible components and technologies ensures affordability and scalability.

6.2 Conclusion

The Traffic Light Recognition Device for the Blind represents a significant advancement in assistive technology, leveraging computer vision and hardware integration to enhance the safety and independence of visually impaired individuals. With robust software performance, reliable hardware implementation, and positive user feedback, the device demonstrates promising potential for broader application and future development.

Future Improvements

1. **Battery Management:**
    - Battery Level Indicator: An LED or display to inform the user when the battery is low.
    - Power Management: Putting the Arduino to sleep when not in use and waking it up with a button press or camera activity.
2. **Haptic Feedback and Interaction:**
    - Vibration motor for haptic feedback, providing a more discreet alert option.
    - A simple interface (e.g., buttons or a small OLED screen) to allow users to calibrate the device, test the buzzer, or change settings.
3. **Voice Feedback:** A small speaker for voice feedback in addition to or instead of the buzzer.
4. **SD Card Module:** Integrate an SD card module to log data about signal detections and user interactions. This can help in analyzing the device's performance and troubleshooting any issues.

References

1. For the electronics part, we had referred to one of the circuits which we had made for one of the mini tasks.

2. Roboflow Docs