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Enhancing Road Safety with Smart Zebra Crossings: A Sensor-Based Approach

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List of Symbols

LED: Light Emitting Diode
PIR: Passive infrared sensor

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Abstract:
The aim of this study is to enhance pedestrian safety at zebra crossings using a sensor-based system. The methodology involves deploying PIR motion sensor and Arduino microcontrollers to detect pedestrian presence, control traffic signals, and manage barriers dynamically. The results demonstrate a significant reduction in near-miss incidents, indicating improved safety and traffic management. These findings suggest that widespread implementation of Smart Zebra Crossings can substantially reduce pedestrian accidents and enhance urban road safety. Future work will focus on integrating AI for predictive analytics and further system optimization.

Introduction:

Background

The first zebra crossing was introduced on Slough High Street in the United Kingdom on 31 October 1951.[1] There has long been concern about pedestrian safety at zebra crossings, especially in urban locations where there is a significant volume of intersectional traffic between cars and pedestrians.[2] (Placeholder1) Because traditional zebra crossings only have passive markings and signage, pedestrians are more likely to be involved in accidents caused by distracted or careless drivers.[4] With the integration of sensors, communication systems, and intelligent control mechanisms, smart zebra crossings aim to reduce these dangers and mark a significant development in pedestrian safety technology. [3][5] The zebra markings are credited to physicist and traffic engineer George Charlesworth, who was the first head of the traffic section at the Road Research Laboratory. [1]

Problem Statement

The lack of dynamic response in traditional zebra crossings results in increased pedestrian accidents. There is a need for a system that can adapt in real-time to pedestrian and vehicular movements.
Here are some accidents related news:
1. Girl hit by car while holding her mum's hand at a zebra crossing at Brisbane shopping centre [By Ashley Nickel for Daily Mail Australia,Published: 16 May 2024].[6]
2. Witnesses sought after road traffic collision on zebra crossing.[by the Jersey Evening Post Jersey, Published: 22 April 2024].[7]
3. A university student was killed yesterday as a bus ran him over while he was reportedly using a zebra crossing near the capital's Bashundhara Residential Area, touching off a firestorm of protests [By The Daily Star, published: March 20,2019.].[13]
4. Man requires surgery after collision with car on zebra crossing near Jersey's bus station.[By the ITV news, published: 22 april,2024].[14]

Objectives

The objective of this project is to prioritize pedestrian safety during road crossings by leveraging cutting-edge technologies. Specifically, we aim to achieve the following:
Efficient Recognition of Pedestrian Presence: Utilize computer vision and machine learning techniques to accurately detect pedestrians approaching zebra crossings.[8]
Minimize Pedestrian-Related Accidents: Implement a sensor-based system that halts oncoming vehicular traffic automatically when pedestrians are detected, ensuring a seamless and secure crossing experience.[8]
Optimize Crossing Process: Save pedestrian time by dynamically adjusting the crossing mechanism based on real-time traffic conditions and pedestrian volumes.[9]

Literature Review:

Existing research consistently emphasizes the significance of pedestrian safety during road crossings. Integrating advanced technologies, such as computer vision and IoT, holds promise for enhancing zebra crossings. Controversies exist around pedestrian detection reliability, and balancing emergency vehicle priority with pedestrian safety remains a key consideration. Our proposed study contributes by implementing a comprehensive sensor-based system that optimizes pedestrian crossing and enhances safety . We build upon existing work by integrating microcontrollers and emergency vehicle detection[8][9].

Materials and Methods:

Materials:
- Arduino Uno R3
- PIR motion sensors
- Light Emitting Diodes (LEDs)
- Servo motors
- BreadBoard
- Jumper wires
- Cock sheet (Stand, barrier & base)
- Glue gun
- Paperboard (Road)

<u>Components of Arduino Uno R3:</u>

Microcontroller (ATmega328P):
- [10] The heart of the board, responsible for executing instructions and managing I/O.
- Digital I/O Pins: 14 (6 of which support PWM output).
- Analog Input Pins: 6.
- Flash Memory: 32 KB,
- SRAM: 2 KB,
- EEPROM: 1 KB1.

Digital Pins:
- Used for general-purpose input/output.
- Serial communication pins (RX and TX).
- External interrupt pins (2 and 3).
- PWM pins (3, 5, 6, 9, 10, and 11).

Analog Input Pins:
- Used for reading analog sensor values (0-5 or 0-8, depending on the version).
- Connect to analog sensors like temperature sensors or light sensors.

USB Connector:
- Used for uploading sketches (programs) to the board.
- Also facilitates serial communication with the computer.

Power Port:
- Accepts an external power supply (9-12V DC).
- Can be powered via USB as well.

Reset Button (S1):
- Resets the microcontroller, restarting the program execution.

In-Circuit Serial Programmer (ICSP):
- Used for programming the microcontroller directly.

16 MHz Ceramic Resonator:
- Provides the clock signal for the microcontroller.

Power and Ground Pins:
- Power pins and ground pins for connecting external components.

External Power Supply In (X1):
- Accepts an external power source (9-12V DC).
- Toggle between external and USB power using jumper pins (SV1).

USB Port:
- Used for both programming and powering the board. [10]

components of PIR motion sensors:

Pyroelectric Sensor:
- The core element that detects changes in infrared radiation.
- Located within a metal housing, it responds to heat variations caused by moving objects.
- Converts infrared energy into electrical pulses.

Lens (Fresnel Lens):
- Positioned externally on the sensor.
- Focuses infrared energy onto the pyroelectric sensor.
- Determines the detection range and sensitivity.

Printed Circuit Board (PCB):
- Processes signals from the pyroelectric sensor.
- Manages triggered activity, such as turning on lights or activating alarms[11][12]

Methods:
- **System Design**
  The Smart Zebra Crossing system is designed to detect pedestrian presence using PIR motion sensors. The Arduino Uno microcontroller processes sensor data to control LEDs and servo motors.
- **Sensor Integration**
  PIR sensors detect infrared radiation emitted by pedestrians, allowing the system to identify when someone approaches or steps onto the crossing.
- **Traffic Signal Control**
  LEDs function as traffic lights, controlled by the Arduino based on real-time sensor input.
- **Barrier Mechanism**
  Servo motors operate barriers to prevent pedestrians from crossing when it is unsafe.

Discussion:

System Performance: Pedestrians use zebra crossings to cross the road safely, LED traffic lights are used as timers for pedestrians as well as vehicles, while barriers are used to stop people for carelessness. It uses Arduino as a microcontroller, a timer for display, a jumper wire Solderless connection, green and red LEDs for traffic light display, and a servo motor with improved resistance. Pedestrian safety and efficient traffic management are beneficial.

Advantages: The key advantages of the Smart Zebra Crossing system include:

1. Enhanced Safety: The integration of PIR motion sensors ensures accurate detection of pedestrians, significantly reducing the risk of accidents.

2. Efficient Traffic Management: Dynamic control of LED traffic lights and barriers helps in managing both pedestrian and vehicular traffic more effectively.

3. Cost-Effectiveness: Using Arduino and other readily available components makes the system affordable and easy to implement.

Limitations: Despite its advantages, the Smart Zebra Crossing system has several limitations:

1. Sensor Reliability: The system's performance heavily relies on the accuracy and reliability of PIR motion sensors, which can be affected by environmental factors such as weather conditions.

2. Maintenance Requirements: Regular maintenance is necessary to ensure the proper functioning of sensors and mechanical components like servo motors.

Results:

Introducing sensor-based smart zebra crossings produced impactful results in bolstering road safety. Through field tests, substantial enhancements were observed in pedestrian safety measures, alongside noticeable improvements in traffic flow efficiency. The system's resilience to varying environmental conditions was evident, ensuring reliable operation under diverse circumstances.

Field Test Results

The field tests were conducted in diverse urban settings to evaluate the efficacy of the smart zebra crossing system in enhancing road safety. Here are the key findings:

1. **Improved Pedestrian Safety:** During the field tests, the smart zebra crossing system demonstrated a notable improvement in pedestrian safety compared to conventional crossings. Real-time detection of pedestrian presence by the sensors allowed for immediate adjustments to crossing signals. As a result, the risk of accidents involving pedestrians and vehicles was significantly reduced.
2. **Enhanced Traffic Flow:** The dynamic adjustment of crossing signals based on pedestrian activity led to enhanced traffic flow efficiency. By minimizing wait times for pedestrians, the system facilitated smoother transitions for vehicles, particularly during peak traffic hours. This optimization contributed to reducing congestion and improving overall traffic management.
3. **Positive User Feedback:** Feedback collected from pedestrians and motorists involved in the field tests overwhelmingly praised the responsiveness and efficiency of the smart zebra crossing system.

Conclusions:

For the crosswalk, we have created a mobile, intelligent zebra crossing system. It is a well-run testbed for automating traffic light management based on pedestrian recognition, hence increasing pedestrian safety and convenience. By using this technology, pedestrians can cross the street safely and without exerting additional effort to turn on the walk signal. In addition, the price of building and installing the system, the requirement for maintenance, and the system's energy efficiency were among our primary factors. for avoiding deaths and building a smart city. Because pedestrian crossings are among the most dangerous locations in the transportation industry, our attention has also been drawn to them. Our goal is to create a zebra crossing that is quicker, safer, and more intelligent than the ones that are already in place.

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