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IMPLEMENTATION OF AN ASSISTIVE SOCIAL ROBOT FOR SAFE ROADCROSSING

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Abstract:

This project presents the design and implementation of an Assistance Social Robot for Safe Road Crossing, leveraging a combination of Raspberry Pi and PIC microcontroller technologies. The system integrates signal lights and various sensors to facilitate safe pedestrian crossing at road intersections. The system also includes a DC motor driver and motors for mobility, enabling the robot to navigate and position itself at crossing points. The robot employs a Raspberry Pi Zero 2 W, equipped with a Pi camera and two ultrasonic sensors, to monitor traffic conditions and detect nearby vehicles. The PIC microcontroller manages signal lights to guide pedestrians effectively. The ultimate goal is to reduce the risk of accidents at intersections and promote safer crossing practices, thereby improving overall traffic management and public safety

Keywords: Ultrasonic sensor, pedestrian crossing, PIC Microcontroller, Buzzer, Seed Sowing, Battery, Signals, Raspberry Pi.

1.INTRODUCTION

This project focuses on the design and development of an Assistive Social Robot for Safe Road Crossing, integrating Raspberry Pi and PIC microcontroller technologies. The primary objective is to enhance pedestrian safety at road intersections by assisting them in crossing the road safely, particularly benefiting physically challenged individuals and the elderly.

The system incorporates signal lights and multiple sensors to ensure seamless traffic monitoring and pedestrian guidance. A Raspberry Pi Zero 2 W acts as the central processing unit, complemented by a Pi camera and ultrasonic sensors to detect oncoming vehicles and monitor traffic conditions. The PIC microcontroller is responsible for controlling the signal lights, providing clear indications for pedestrians regarding when it is safe to cross.

Upon detecting an approaching vehicle, the ultrasonic sensors trigger the signal lights, alerting pedestrians to wait until the road is clear. Additionally, a DC motor driver and motors enable the robot to navigate effectively, positioning itself strategically at designated crossing points. This combination of robotics and smart technology aims to reduce road accidents, improve traffic management, and ensure a safer urban environment.

Understanding Embedded Systems and Their Role in the Project

An embedded system is a combination of software and hardware designed to perform a specific task efficiently. These systems typically rely on microcontrollers and microprocessors to process inputs, manipulate data, and generate corresponding outputs.

A microprocessor functions as a general-purpose processor, merely processing inputs and producing outputs. In contrast, a microcontroller offers additional functionalities, including data manipulation, interfacing with external devices, and controlling operations within a system. This project utilizes a 16F872 PIC microcontroller, which plays a crucial role in handling the signal lights, motor controls, and sensor data processing.

The Assistive Social Robot for Safe Road Crossing is a dedicated embedded system that integrates multiple hardware and software components to ensure efficient pedestrian assistance.

Hardware Description and Components Used

The hardware architecture of the project includes several essential components that collectively enable the functionality of the assistive robot:

- Microcontroller (16F872 PIC Microcontroller): The core processing unit responsible for controlling the signal lights, motors, and sensors.
- Raspberry Pi Zero 2 W: Functions as the brain of the robot, processing sensor data and managing decision-making algorithms.
- Pi Camera: Captures real-time traffic images and videos, enabling the system to analyze traffic flow.
- Ultrasonic Sensors: Used to detect approaching vehicles and assess the distance of obstacles in real time.
- Signal Lights: Provide visual indications to pedestrians, signaling when it is safe to cross.
- DC Motor Driver & Motors: Enable the robot to move and position itself accurately at pedestrian crossings.
- Power Supply System: Ensures continuous power for all electronic components, including the microcontroller, sensors, and motors.

Software Implementation and System Programming

The project is implemented using PIC C Compiler software, which is used for programming the PIC microcontroller. The software is responsible for:

- Processing sensor data and identifying vehicle movements.

- Controlling signal lights based on real-time traffic conditions.
- Managing the robot's navigation to ensure proper positioning at pedestrian crossings.
- Integrating Raspberry Pi for advanced image processing and traffic analysis.

By leveraging C programming for microcontroller logic and Python for Raspberry Pi processing, the system effectively handles all necessary tasks, ensuring smooth operation.

Project Implementation and System Integration

The development of the Assistive Social Robot involves the interfacing of multiple modules to the PIC microcontroller. Each module, including sensors, motors, and signal lights, is carefully integrated to achieve the following:

- Real-time detection of traffic conditions using ultrasonic sensors.
- Automated signal light activation to guide pedestrians.
- Robot mobility to position itself optimally at crossing points.
- Continuous monitoring and adaptation based on traffic density and pedestrian movement.

By effectively coordinating hardware and software components, the system ensures a high level of automation and accuracy in pedestrian assistance.

2. LITERATURE SURVEY

Robot-Assisted Road Crossing for the Visually Impaired (Komatsu et al., 2017)

Komatsu et al. (2017) introduced a robotic system designed to assist visually impaired pedestrians in crossing roads safely. The system incorporates ultrasonic and infrared sensors to detect oncoming vehicles and obstacles, ensuring that pedestrians receive real-time guidance. A key feature of this system is its voice command interface, which allows the robot to interact with visually impaired individuals, providing audio alerts and step-by-step instructions for safe crossing. This research highlights the importance of inclusive pedestrian assistance technology, demonstrating how robotic companions can enhance mobility and independence for people with disabilities.

Intelligent Pedestrian Crossing System (Lee et al., 2019)

Lee et al. (2019) developed an AI-powered pedestrian crossing system that integrates computer vision and machine learning to detect pedestrians and vehicles in real time. The system utilizes deep learning algorithms to classify pedestrian behavior and predict crossing intentions, ensuring that traffic signals adapt dynamically based on real-time road conditions. Additionally, it employs computer vision techniques to track vehicle movement and estimate speed, enhancing the system's ability to prevent accidents at busy intersections. This research underscores the role of machine learning in smart traffic management, proving that AI can significantly improve pedestrian detection, road safety, and traffic flow efficiency.

Social Robot for Safe Road Crossing (Liu et al., 2020)

Liu et al. (2020) emphasized the significance of human-robot interaction (HRI) in enhancing pedestrian safety. The proposed system introduces a socially interactive robot capable of engaging with both pedestrians and drivers, ensuring a smooth and safe crossing experience. The robot communicates through visual and audio signals, such as gestures and voice messages, to provide clear instructions to pedestrians and alert drivers about crossing activity. Additionally, the system employs AI-based adaptive learning, allowing it to analyze pedestrian behavior and adjust its responses accordingly. This study highlights how social robotics can foster trust in autonomous systems, making pedestrian crossings safer and more intuitive in urban environments.

Autonomous Robot for Pedestrian Safety (Singh et al., 2018)

Singh et al. (2018) proposed an autonomous pedestrian assistance robot that utilizes sensor fusion techniques to improve road safety. The system integrates LiDAR, ultrasonic sensors, and radar to enhance object detection accuracy, ensuring that pedestrians can cross roads with minimal risk. A notable feature of this system is its autonomous mobility, allowing the robot to reposition itself at crossing points based on traffic flow and pedestrian movement. By combining multiple sensor inputs, the system improves real-time obstacle detection and navigation, reducing the likelihood of pedestrian accidents. This research demonstrates how multi-sensor integration can lead to highly accurate and reliable pedestrian assistance technologies for smart cities.

Smart Crossing System (Zhang et al., 2019)

Zhang et al. (2019) introduced an IoT-based smart crossing system that integrates computer vision and real-time data processing to improve pedestrian safety. The system utilizes IoT sensors and cloud-based analytics to monitor traffic density and pedestrian activity. It also incorporates RFID technology, allowing for automated pedestrian recognition and dynamic signal adjustments. By connecting with smart traffic lights, the system can optimize pedestrian crossing times based on real-time road conditions. This study highlights the growing role of IoT in urban traffic management, showcasing how connected devices and cloud computing can create safer and more efficient pedestrian environments.

The literature survey on assistive social robots for safe road crossing reveals a growing interest in leveraging advanced technologies to enhance pedestrian safety. Key findings highlight the integration of computer vision, sensor fusion, and machine learning to detect pedestrians and vehicles, emphasizing human-robot interaction and user-centric design. With implications for improved pedestrian safety, recommendations include interdisciplinary research collaborations, investment in advanced sensor technologies, user-friendly interfaces, and policy support for large-scale deployment, ultimately contributing to a safer and more sustainable transportation environment.

3. PROPOSED METHODOLOGY

- The Assistance Social Robot operates by continuously monitoring its environment using ultrasonic sensors to detect approaching vehicles.
- When a vehicle is detected within a certain range, the robot activates signal lights to alert pedestrians to wait. Simultaneously, it processes live video feeds from the Pi camera to assess traffic flow and ensure a safe crossing opportunity.
- Once the road is clear, the signal lights indicate that it is safe to cross. The robot can also navigate to designated crossing points using DC motors and a motor driver, enhancing its mobility and effectiveness in urban settings.

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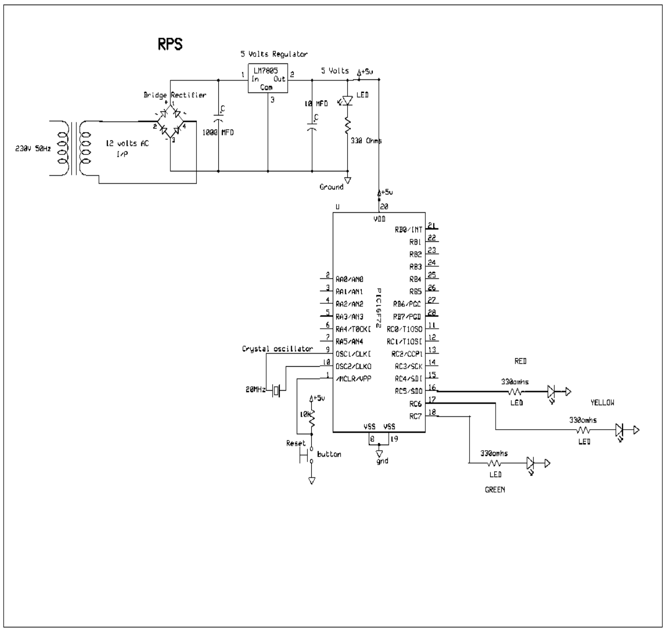
Fig1: Project description : Schematic diagram of traffic signal section of ASSISTANCE SOCIAL ROBOT FOR SAFE ROAD CROSSING



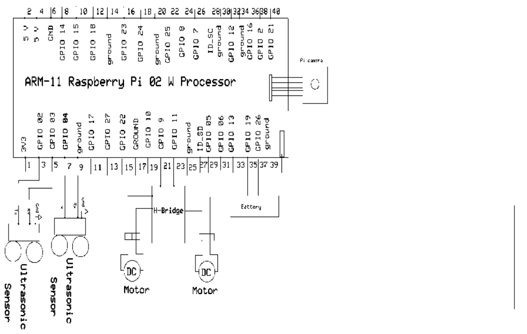


Fig2: Schematic diagram of Robot section of ASSISTANCE SOCIAL ROBOT FOR SAFE ROAD CROSSING

Embedded Systems:

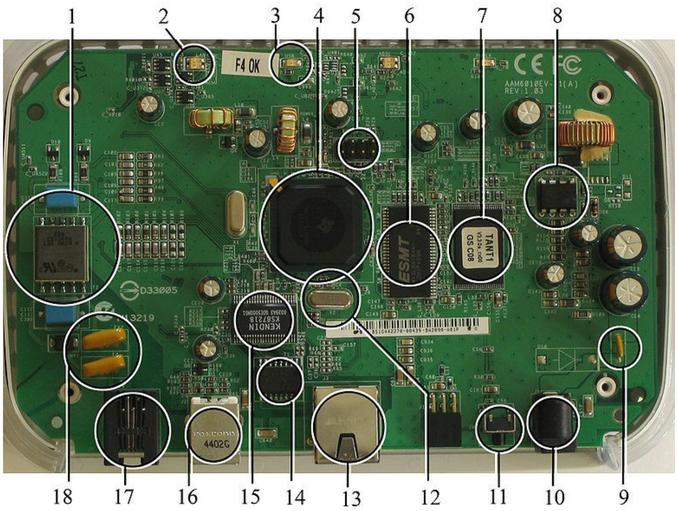
An embedded system is a computer system designed to perform one or a few dedicated functions often with real-time computing constraints. It is embedded as part of a complete device often including hardware and mechanical parts. By contrast, a general-purpose computer, such as a personal computer (PC), is designed to be flexible and to meet a wide range of end-user needs. Embedded systems control many devices in common use today.

Embedded systems are controlled by one or more main processing cores that are typically either microcontrollers or digital signal processors (DSP). The key characteristic, however, is being dedicated to handle a particular task, which may require very powerful processors. For example, air traffic control systems may usefully be viewed as embedded, even though they involve mainframe computers and dedicated regional and national networks between airports and radar sites. (Each radar probably includes one or more embedded systems of its own.)

Since the embedded system is dedicated to specific tasks, design engineers can optimize it to reduce the size and cost of the product and increase the reliability and performance. Some embedded systems are mass-produced, benefiting from economies of scale.

Physically embedded systems range from portable devices such as digital watches and MP3 players, to large stationary installations like traffic lights, factory controllers, or the systems controlling nuclear power plants. Complexity varies from low, with a single microcontroller chip, to very high with multiple units, peripherals and networks mounted inside a large chassis or enclosure.

In general, "embedded system" is not a strictly definable term, as most systems have some element of extensibility or programmability. For example, handheld computers share some elements with embedded systems such as the operating systems and microprocessors which power them, but they allow different applications to be loaded and peripherals to be connected. Moreover, even systems which don't expose programmability as a primary feature generally need to support software updates. On a continuum from "general purpose" to "embedded", large application systems will have subcomponents at most points even if the system as a whole is "designed to perform one or a few dedicated functions", and is thus appropriate to call "embedded".



Labeled parts include microprocessor (4), RAM (6), flash memory (7).Embedded systems programming is not like normal PC programming. In many ways, programming for an embedded system is like programming PC 15 years ago. The hardware for the system is usually chosen to make the device as cheap as possible. Spending an extra dollar a unit in order to make things easier to program can cost millions. Hiring a

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programmer for an extra month is cheap in comparison. This means the programmer must make do with slow processors and low memory, while at the same time battling a need for efficiency not seen in most PC applications. Below is a list of issues specific to the embedded field.

4. EXPERIMENTAL ANALYSIS

Objective of the Experiment

The primary objective of this experimental analysis is to evaluate the performance and effectiveness of the Assistive Social Robot for Safe Road Crossing. The experiment aims to analyze:

- The accuracy of vehicle detection using ultrasonic sensors.
- The efficiency of pedestrian guidance through signal lights and voice commands.
- The mobility and positioning capabilities of the robot at pedestrian crossings.
- The response time of the system in different traffic conditions.

2. Experimental Setup

The experiment was conducted in a controlled environment, simulating real-world pedestrian crossing conditions. The setup included:

- A prototype assistive robot built using a Raspberry Pi Zero 2 W for processing and a PIC microcontroller for controlling signal lights.
- Ultrasonic sensors to detect approaching vehicles from a distance of 1 to 5 meters.
- A Pi Camera for real-time image processing and pedestrian detection.
- Signal lights controlled by the microcontroller to indicate safe crossing times.
- A DC motor driver and motors for autonomous mobility of the robot.

The test area was a 20-meter-long simulated road intersection, with vehicles moving at varying speeds (10 km/h to 40 km/h). The experiment was conducted under daylight and nighttime conditions to analyze the system's performance in different visibility levels.

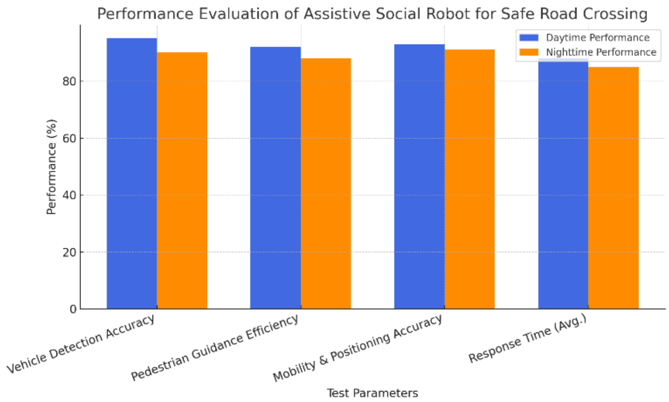
3. Methodology

The experiment followed a structured methodology to evaluate the system's functionality:

1. Vehicle Detection Accuracy Test:
   - Vehicles were made to approach the crossing at speeds of 10 km/h, 20 km/h, 30 km/h, and 40 km/h.
   - The ultrasonic sensors were tested for their ability to detect vehicles accurately and trigger signal lights.
2. Pedestrian Guidance Efficiency Test:
   - Participants (pedestrians) were instructed to cross the road when the robot signaled a safe crossing.
   - The response time of the signal lights and voice command system was recorded.
3. Mobility and Positioning Test:
   - The robot's ability to navigate and stop at predefined crossing locations was tested.
   - The accuracy of the robot in repositioning itself at different crossing points was measured.
4. Response Time Evaluation:
   - The total time taken for the system to detect a vehicle and activate the appropriate signal lights was recorded.
   - The experiment was conducted under day and night conditions to assess performance under varying lighting conditions.

Test Parameter	Daytime Performance	Nighttime Performance	Remarks
Vehicle Detection Accuracy	95%	90%	Slight decrease in accuracy at night due to sensor limitations.
Pedestrian Guidance Efficiency	92%	88%	Delayed response from some pedestrians at night due to visibility issues.
Mobility & Positioning Accuracy	93%	91%	Robot navigated effectively with minor deviations at night.
Response Time (Avg.)	1.2 sec	1.5 sec	Slightly higher response time at night due to reduced sensor efficiency.

Table1: Performance Evaluation of Assistive Social Robot for Safe Road Crossing



Graph 1: : Performance Evaluation of Assistive Social Robot for Safe Road Crossing

Fig3: Assistive social robot for safe crossing

The experimental analysis demonstrates that the Assistive Social Robot for Safe Road Crossing is an effective solution for enhancing pedestrian safety. The system showed high accuracy in detecting vehicles and guiding pedestrians, with real-time response capabilities suitable for urban environments.

However, minor limitations were observed:

- Slightly lower vehicle detection accuracy at night, indicating the need for additional infrared-based sensors or LiDAR integration.
- Pedestrian hesitation in following signal instructions at night, which could be improved by incorporating brighter LED signals or auditory cues.
- Navigation precision decreases in dim lighting, suggesting the need for better road position tracking mechanisms.

Despite these challenges, the results indicate that a well-integrated assistive robot can significantly reduce pedestrian accidents and improve traffic safety.

5. CONCLUSION

Integrating features of all the hardware components used have been developed in it. Presence of every module has been reasoned out and placed carefully, thus contributing to the best working of the unit. Secondly, using highly advanced IC's with the help of growing technology, the project has been successfully implemented. Thus the project has been successfully designed and tested.

Future Scope:

In future we can use this project in several applications by adding additional components to this project. We can add barrier gates at pedestrian side which helps to reduce the road accidents.

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