Paper ID #44766

Helping Pedestrians with Special Needs to Cross the Roads using a Robot

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Abstract

The increasing pedestrian accident rate, especially among disabled individuals and children, demands innovative solutions. Many pedestrians in the US have lost their lives in motor vehicle-related crashes, occurring at a rate of one fatality every 75 minutes, as reported in 2022. Despite this, road safety rules have seen minimal changes, presenting a considerable danger to pedestrians. Individuals with disabilities face heightened risks due to impaired mobility or sensory functions, and there is limited data on road traffic injuries for this group. Children, particularly at school crossings, are vulnerable, potentially struggling to analyze situations and panicking without adult or school staff assistance safely crossing the street.

This research addresses the risks associated with road crossings by developing and testing a Python-based program on the NAO robot simulator. Focused on identifying key elements contributing to pedestrian accidents involving vulnerable individuals, the research aims to deploy the simulated design using a physical robot for testing and evaluation. The NAO robot's step-by-step actions, guided by its camera and sensors, seek to assist pedestrians in safe road crossings. Future advancements include integrating advanced machine learning algorithms for enhanced accuracy in pedestrian recognition and crossing actions.

This interdisciplinary initiative aims to enhance urban mobility by promoting safety and inclusivity. While this research has demonstrated the potential of robot assistance in pedestrian crossings at a small lab scale, further advancement to full-scale implementation in real-world environments is recommended once resources become available. Additionally, it is suggested to utilize an IoT handheld or body-mounted device with the capability to interact with traffic signals, facilitating safe street crossings for pedestrians facing challenges.

1. Introduction

In today's fast-paced urban environments, pedestrian safety, especially at signalized intersections, remains a significant concern. For individuals with special needs, such as children, the elderly, and those with physical or cognitive impairments, crossing these intersections can be particularly challenging and hazardous. This research addresses this critical issue by exploring the integration of advanced robotics technology, specifically the NAO robot, as a solution to assist individuals with special needs.

Signalized intersections are essential for urban transportation networks that regulate traffic flow and ensure pedestrian safety. However, for children, older adults, and people with special needs, crossing these intersections can be fraught with difficulties. Challenges may include understanding traffic signals, perceiving vehicle movements, and responding promptly to changing traffic conditions. This vulnerable demographic often faces a higher risk of accidents, making it imperative to develop innovative solutions to enhance their safety and independence.

Existing assistive technologies for pedestrian safety primarily focus on audible signals and tactile cues, which are essential but may not provide sufficient support for individuals with diverse special needs. Therefore, there is a pressing need to explore more comprehensive solutions that can bridge the gap in accessibility for this population.

Artificial Intelligence (AI) in Pedestrian Crossing refers to integrating AI technologies to enhance safety and efficiency at crosswalks and intersections for pedestrians. This involves using intelligent systems, algorithms, and sensors to manage and optimize pedestrian traffic, improve signaling, and reduce the risk of accidents. AI applications in pedestrian crossing can include the development of assistive technologies to aid individuals with special needs or those facing challenges while crossing roads. These technological advancements aim to create safer and more accessible urban environments for pedestrians, addressing concerns related to traffic management and pedestrian safety.

The primary objective of this research is to design, develop, and evaluate the effectiveness of an assistive system that employs the NAO robot to aid children and people with special needs in safely crossing signalized intersections. To achieve this overarching goal, the study will address the following specific objectives:

1. Robot System Development: Develop a user-friendly and adaptable system that integrates the NAO robot's capabilities with real-time traffic signal information to assist users with special needs crossing intersections.

2. Safety and Efficiency Assessment: Conduct comprehensive testing and evaluation of the developed system to assess its safety, efficiency, and effectiveness in assisting users with special needs crossing signalized intersections.

2. Literature review

In 2020, crashes involving motor vehicles resulted in the deaths of over 7,000 pedestrians on the roads in the US: a fatality every 75 minutes.[1] The street traffic is getting worse every day, but the driving rules remain the same. As a result, crossing the road becomes a dangerous task, threatening pedestrians with death or injuries. Some pedestrians have disabilities with limited mobility or ability to hear or see. Therefore, vehicles on the roads are a considerable threat to pedestrians in general and people with disabilities in particular since their mobility or senses are impaired, and they are not able to filter sounds, noise, and other environmental factors to help them make the appropriate decision to cross the road safely. Research has shown that disabled pedestrians are at a higher risk of being injured in road traffic incidents, and data is limited in this regard.[2] Pedestrian crossing poses the same danger also to children and kids, especially at the school crossing. Children sometimes cannot analyze the situation and panic when no adults or school staff can help them cross the street safely.

Winfield et al.[3] explores ethical governance for robotics and AI systems. They propose a roadmap linking ethics, standards, regulation, research, innovation, and public engagement. Ethical governance is crucial to establishing public trust in robotics and AI. Siau et al.[4] studied trust in artificial intelligence, machine learning, and robotics. They first reviewed the concept of trust in AI and highlighted how it differs from other technologies. They then compared interpersonal trust with trust in technology and suggested essential factors to establish initial trust and develop continuous trust in artificial intelligence.

3. System Design

3.1 System Components

To simulate a pedestrian crossing, we designed a system replicating a real-world scenario, as shown in Figure 1. The system comprises the following components.

- Pedestrian crosswalk: For controlled testing, we implement a scaled-down traffic light and crosswalk arrangement. This miniature setup accurately replicates real-world traffic signals and pedestrian crossings, facilitating precise assessment of the robot's responses. The pedestrian crossing design was four feet long and five feet wide. The dimensions were chosen due to the robot's limitation in recognizing the traffic signal.

- Miniature pedestrian traffic light: a small model of traffic light at 28" height that simulates the pedestrian signal.

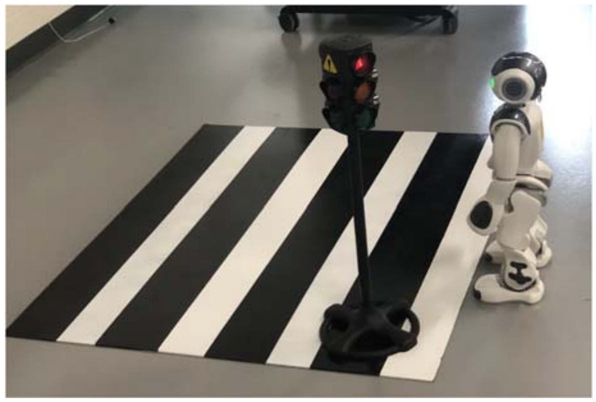

Figure 1: System Design to Simulate Pedestrian Crossing.

- NAO Robot: The primary component of our system is the NAO robot, chosen for its humanoid form and sensory capabilities. The robot has cameras, microphones, and sensors to perceive the environment and communicate with users.

- Choregraphe Software: To develop and test the code governing the NAO robot's interactions, we employ Choregraphe software, offering a visual programming environment to streamline behavior design and testing.

- Pedestrian Subject: In this controlled experiment, a 5-year-old child holds the robot's hand, and the robot actively guides the child to cross the intersection safely. This authentic child-robot interaction provides invaluable insights into the effectiveness of the robot's assistance.

3.2 System Design and Experiment Steps

The following steps were used to develop the system that integrates the NAO robot's capabilities with real-time traffic signal information to assist users with special needs crossing intersections.

1. Sensor Integration: Configure the NAO robot's sensory apparatus, comprising cameras and microphones, to capture real-time environmental data, including input from the miniature traffic light and the presence of the actual child pedestrian.

2. Choregraphe Programming: Employ Choregraphe to develop and validate the code that enables the NAO robot to interact with the actual child pedestrian and respond to cues from the miniature traffic light.

3. Traffic Signal Data Integration: While the traffic light in our miniature setup is manually operated, our system can be programmed to recognize and react to different signal phases grounded in visual cues.

4. User Interaction Design: Ensuring that the robot's behaviors are engaging and comprehensible for a young child is a paramount consideration.

5. Traffic Signal Interpretation: Implement algorithms within Choregraphe to empower the NAO robot to interpret traffic signals, ascertain when it is safe to cross and guide the pedestrian accordingly.

6. Safety Features: Integrate safety mechanisms to prevent potential hazards during interactions between the NAO robot and the pedestrian, prioritizing the pedestrian's safety throughout the crossing process.

7. User Testing and Iteration: Conduct controlled experiments with the actual child pedestrian to systematically assess the system's performance. Obtain feedback from the child and iteratively enhance the system based on their responses and interactions.

8. Real-World Testing: Progress to real-world testing scenarios at actual signalized intersections, ensuring that the NAO robot can adapt its acquired behaviors effectively while interacting with pedestrians.

9. Data Collection and Analysis: Collate data on system performance, user experiences, and safety outcomes during both controlled and real-world testing phases. Thoroughly analyze this data to assess the system's effectiveness and discern areas necessitating further refinement.

10. Documentation: Elaborately document the system design, coding algorithms, testing results, and any relevant safety certifications, fostering transparency and serving as a valuable reference for potential future development or implementation.

3.3 Programming

In this study, we utilized Choregraphe 2.1.4 to implement and execute our code on the robot using Python. We designed a scenario with 15 boxes, as illustrated in Figure 2. The following is a summary of the functions assigned to each box:

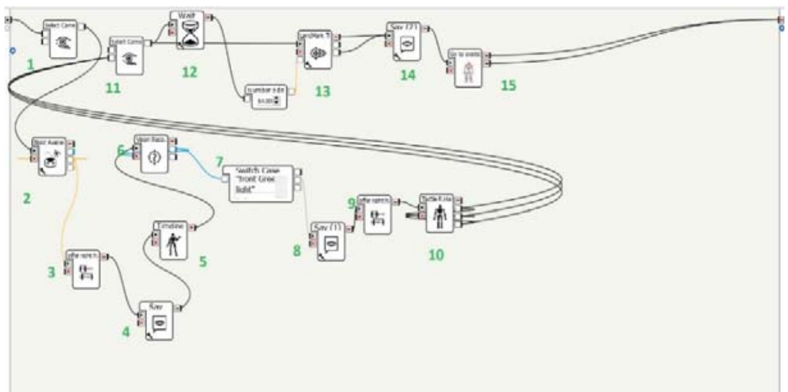

Figure 2: Step-by-step guide for the implementation process.

Box 1: Select the top camera.

Box 2: The robot is waiting for any interactions/signals.

Box 3: If a robot detects a human who needs help, it offers a hand.

Box 4: The Robot says it is waiting for a green color.

Box 5: The robot changes position to see the traffic light.

Box 6: Vision recognition for traffic light color detection.

Box 7: Switch cases for colors.

Box 8: If a green light is detected, the robot informs that it is safe to cross the road.

Box 9: The robot is set to start position.

Box 10: The Robot makes sure that the human holds its hand.

Box 11: Select the bottom camera.

Box 12: Wait box.

Box 13: The Target is 64, which equals our destination mark, and the robot crosses the road.

Box 14: Robot informs that they crossed the road.

Box 15: The robot is set to start position.

The system underwent multiple testing phases to evaluate the robot's responsiveness to traffic signals and interaction with children. However, it was found that the robot's sensors could only reliably detect signals within a maximum distance of 4 feet. This constraint necessitated scaling down the experiment to accommodate this limited range.

Initially, there were challenges as children adapted to the robot's instructions, particularly when they attempted to cross the distance quickly, resulting in the robot falling over. However, with repeated attempts, the children became accustomed to the robot's behavior, leading to the successful completion of the experiment. Moving forward, it is advisable to conduct further experiments using a more advanced robot system and in real-life environments to enhance the validity and applicability of the findings.

4. Conclusions

In this research paper, we have addressed the critical issue of pedestrian safety, especially at signalized intersections, focusing on individuals with special needs, such as children, older adults, and those with physical or cognitive impairments. We introduced the concept of integrating advanced robotics technology, specifically the NAO robot, to assist these vulnerable populations in safely navigating signalized intersections.

Our research methodology focused on designing, developing, and evaluating an assistive system utilizing the NAO robot. We outlined key stages, including a literature review, system development, user-centered design, safety and efficiency testing, and real-world testing. Through this comprehensive approach, our research aimed to contribute to the development of an effective solution for assisting children and people with special needs in crossing signalized intersections, ultimately enhancing their safety and mobility in urban environments.

In conclusion, our research represents a significant step towards enhancing pedestrian safety, particularly for individuals with special needs, by integrating robotics technology. By addressing the recommendations outlined above, we can continue to advance the field and create safer, more inclusive urban environments for all pedestrians. However, considering the limitations of resources, the mobility of the robot in real-life settings, and challenges in communication between the robot and pedestrians, a more targeted approach should be considered to assist vulnerable pedestrians in crossing streets, especially at signalized intersections.

5. Recommendations

Building on the findings and insights from this research, we offer the following recommendations for future work in this field:

1. Further Development and Refinement: Continue to refine and develop the assistive system incorporating the NAO robot. Incorporate advancements in robotics, computer vision, and machine learning to improve the system's capabilities and responsiveness.

2. User-Centered Design: Maintain a strong focus on user-centered design by collaborating closely with individuals from the target population and their caregivers. Gather continuous feedback to ensure that the system remains user-friendly and effective.

3. Real-World Implementation: Transition from controlled testing to real-world implementation by deploying the NAO robot at actual signalized intersections. Evaluate its performance in diverse urban settings and under varying traffic conditions.

4. Data Collection and Analysis: Continue to collect and analyze data on system performance, user experiences, and safety outcomes. Use this data to identify areas for improvement and optimize the system's effectiveness.

This interdisciplinary initiative aims to enhance urban mobility by promoting safety and inclusivity. While this research has demonstrated the potential of robot assistance in pedestrian crossings at a small lab scale, further advancement to full-scale implementation in real-world environments is recommended once resources become available. Additionally, it is suggested to utilize an IoT handheld or body-mounted device with the capability to interact with traffic signals and effectively communicate with pedestrians to facilitate safe street crossings for individuals facing challenges.

Acknowledgment

This research was made possible through funding from the EMU Office of Research Development and Administration's "Undergraduate Research Stimulus Program" 2023 summer grant. This program aims to foster collaborative research endeavors between undergraduate students and faculty members at Eastern Michigan University.

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