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ANALYSIS OF THE FEASIBILITY OF USING THE NVIDIA JETBOT NANO SYSTEM TO CONTROL A WHEELCHAIR FOR PEOPLE WITH DISABILITIES

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Abstract – This work presents the design and analysis of a wheelchair control system using the Nvidia JetBot Nano platform, with the goal of improving the manoeuvrability, independence, and overall quality of life for users with physical disabilities. The system is based on a robotic platform that uses machine learning algorithms for navigation, real-time environment mapping, and obstacle detection. By integrating advanced AI technologies, the system can adapt to its surroundings, making the wheelchair more autonomous and responsive to user needs. The control system uses a gamepad to control the wheelchair movement, allowing users to remotely operate the device from a distance. This feature is especially valuable in situations where users cannot physically interact directly with the wheelchair, providing them with greater freedom and flexibility. Additionally, the system enables wireless control via the GamePad, which can be a significant advantage in various real-world applications. By incorporating AI-based capabilities, such as object recognition and path-following, the system enhances safety and improves navigation, helping users avoid collisions and navigate complex environments. This work demonstrates the potential of integrating AI-driven technologies into assistive devices, offering a promising solution to improve the autonomy and mobility of people with disabilities.

Keywords: Nvidia JetBot, Jetson Nano, Assistive technologies, Smart wheelchair, Assistive robotics, Remote control, Sensor integration, Object tracking, AI, Artificial intelligence.

1. Introduction

The wheelchair is a fundamental mobility device for people with disabilities, typically classified into manual and powered types. Manual wheelchairs rely on the user's own strength, while powered wheelchairs offer motorized assistance to reduce physical effort [6]. The earliest mention of wheeled chairs comes from ancient China, dating back to the 6th century BC [21]. In Europe, the earlies references to wheelchairs come from Spain and France, dating back to the 16th century [12, 21].

Electric wheelchairs first emerged in the early 20th century, although initially they were not specifically designed for people with disabilities. It wasn't until the late 1940s and early 1950s that they became practical for individuals with severe impairments. A major milestone in this development was George J. Kline's 1953 invention of a joystick-controlled friction motor, which influenced wheelchair design for decades [20-21].

Manual wheelchairs remain the most commonly used option for many individuals due to their simple design, ease of use, and relatively low cost [3]. They provide a practical mobility solution without the need for external power sources. On the contrary, powered wheelchairs, though more complex in design, offer significant advantages for individuals with limited upper body strength, enhancing both mobility and independence [3, 6]. Over the years, the design and performance of powered wheelchairs have been shaped by advances in technology, particularly in drive systems.

Powered wheelchairs typically feature four primary drive configurations [2, 8]: rear-wheel drive

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(RWD), mid-wheel drive (MWD), front-wheel drive (FWD), and all-wheel drive (4WD). These configurations vary in terms of stability, manoeuvrability, and speed, each offering unique benefits depending on the user's mobility needs and environment. RWD is the most commonly used system that offers high speed and stability, particularly on smooth surfaces. However, its turning radius is larger compared to other configurations, making it less effective in tight spaces. MWD provides the best manoeuvrability due to its central wheel placement, allowing for tight turns, though it may struggle on uneven terrain. FWD, although slower than RWD, improves traction and control, especially on slopes. For users who require enhanced off-road capability, 4WD is the most versatile, ensuring stability and traction in various terrains, from indoor spaces to outdoor environments such as gardens and rough paths [8].

When it comes to controlling a powered wheelchair, various methods have evolved over time. Initially, wheelchairs used analog linear amplifiers or relay-based systems to regulate speed and direction, providing mobility for some but excluded individuals with complex disabilities. The shift to digital controls, which incorporates digital signal processing and pulse width modulated amplifiers, significantly improved accessibility. These advances enabled precise adjustments, complex feedback algorithms, and rejection of disturbances, making wheelchair operation more responsive and adaptable [2]. Today, manual joysticks remain the most widely used control method due to their intuitive design, allowing users to easily manage direction and speed [3]. Different joystick variations, including hand, chin, and head-controlled versions, cater to users with varying levels of mobility [1]. Beyond traditional input, modern innovations such as voice and eye-tracking controls are becoming increasingly prevalent, particularly for users with limited hand function [11]. For example, Shinde's research on a voice-controlled wheelchair highlights how integrated voice commands and ultrasonic sensors improve accessibility and obstacle detection [16]. Similarly, gaze-tracking technology, as explored by Vasantha et al. [19], further expands the range of personalized control solutions available to users today.

In addition to these approaches, several studies have explored alternative control mechanisms. For instance, Guha et al. [5] proposed a wheelchair driven by an Arduino Mega2560 combined with ultrasonic sensors to interpret user gestures and finger movements. This system demonstrates the potential to combine mechanical design with user-controlled inputs to improve mobility. Similarly, Mahadev et al. [9] demonstrated Bluetooth-controlled wheelchairs that allow users to manage movement wirelessly. The incorporation of Arduino Uno and Bluetooth models illustrates an innovative approach to user interface design.

Despite significant technological progress, there are still limitations in current wheelchair solutions, both in terms of drive systems and control mechanisms. There remains a need for the development of more versatile drive systems that can navigate various terrain conditions, as well as more advanced control systems that grant greater independence, particularly for people with severe motor impairments. Furthermore, the integration of emerging technologies such as artificial intelligence (AI) and sensor data analysis may offer new opportunities to improve wheelchair autonomy [4, 15]

The aim of this work is to design and analyse a wheelchair control system using the Nvidia JetBot Nano platform, which aims to improve the manoeuvrability and independence of users. By leveraging advanced computing capabilities and sensor technologies, the project seeks to address the limitations of current wheelchair systems, offering a more flexible and autonomous mobility solution for individuals with disabilities.

In line with these goals, the implementation of JetBot Nano in a wheelchair harnesses the evolving landscape of assistive technologies. Driven by powerful computing resources and integrated with various sensor technologies, JetBot Nano presents a breakthrough in creating smart wheelchairs that improve user autonomy and safety. This development offers a promising solution to some of the current limitations in wheelchair systems, contributing to more independent and flexible mobility options for users.

2. Materials and Methods

The project involved the implementation of an Nvidia JetBot Nano system to control the movement of a cart. The system is based on a single-platform Nvidia Jetson Nano computer, equipped with a Maxwell GPU with 128 CUDA cores. Control is achieved through machine learning algorithms, using a camera to detect obstacles and recognize the environment.

2.1. System Architecture of JetBot Nano

The project used the Nvidia JetBot Nano system (see Figure 1), which is based on the single-board Nvidia Jetson Nano. This platform is specifically designed for mobile robotics and is equipped with a Maxwell GPU that contains 128 CUDA cores. The system is used to control the movement of a wheelchair, using machine learning algorithms for navigation and obstacle detection.

Figure 1: Waveshare JetBot two-wheeled robot

The JetBot framework integrates several key components, such as the APW7313 voltage regulator for stable 5V output, the ADS1115 analog-to-digital converter for battery monitoring, and the TB6612FNG dual H-bridge for motor control. The system also includes a Raspberry Pi v2 camera for capturing environmental data and an OLED display to show the status of the system. The algorithms implemented on the JetBot system allow it to detect obstacles and make decisions, such as changing direction when a potential collision is detected. The platform was selected because of its flexibility and processing power, which makes it suitable for real-time AI applications in mobile robotics.

2.2. Hardware and Software Setup

The Nvidia Jetson Nano serves as the primary computational unit of the control system. The system is powered by a 20Ah lithium-ion battery, which ensures a long operating range. The system uses a Raspberry Pi v2 camera to capture real-time images and video for obstacle detection and tracking.

The system uses several hardware components to interface with the motors, including the BTS7960 motor driver to control the DC motors of the wheelchair, which are powered by a 24V DC battery. A Pulse Width Modulation (PWM) signal generator module (PCA9685) was added to expand the number of PWM channels available from the Jetson Nano. This allows for more precise control over the motors and other actuators.

In terms of software, the control system was built using Python, and machine learning algorithms were implemented with the PyTorch library. The system uses neural network models such as AlexNet for collision detection and ResNet-18 for path-following. The models are trained and run on the Jetson Nano's GPU to ensure real-time performance.

2.3. Training Process and Datasets Used

The AI models for the system were trained using the collected environmental data. The training process for each model is as follows:

- **Collision Detection:** The AlexNet neural network was trained using images captured in both safe and hazardous environments. These images were collected by the Raspberry Pi v2 camera and used to train the network to recognize obstacles and make decisions, such as changing direction to avoid a collision. The model was trained using the PyTorch library and processed on the Jetson Nano's GPU.
- **Object Detection and Tracking:** The system used the COCO dataset, which contains 80 object categories, to train the object detection model. This model allows the wheelchair to track moving objects and adjust its movement accordingly.
- **Path Following:** For path-following, the ResNet-18 model was trained using images with manually placed waypoints. These waypoints were captured using a gamepad and provided to the neural network, which predicts the coordinates necessary for the wheelchair to follow a designated path. The model was also trained and executed on the Jetson Nano's GPU.

3. System Design

The design of the wheelchair control system was based on the implementation of the Nvidia JetBot Nano platform, with the aim of replacing the existing control system with a more advanced and autonomous solution. The design process involved the integration of various components, including the Nvidia Jetson Nano, motor drivers, power supply, and additional custom elements to meet the specific needs of the wheelchair.

3.1. Conceptual Design

The primary goal of this project was to implement the Nvidia JetBot system as the core control unit for the wheelchair, taking over the functionality of the existing control system. The system was designed to provide wireless control through a web browser interface, connected to the JetBot Nano via Wi-Fi. The concept included the modification of the existing JetBot software to accommodate the integration of high-current motor drivers, an appropriate power source, and a user interface suitable for wheelchair control.

Key considerations during the conceptual phase included ensuring compatibility with existing wheelchair hardware and the ability to handle high-current motor control for the wheelchair drive system. The system also needed to be flexible, allowing users to control the wheelchair through a web interface that could be operated from a computer or mobile device.

3.2. Functional Prototype

A functional prototype of the control system was mounted on the Airwheel H3S wheelchair (see

Figure 2), which features a rear-wheel drive system powered by 24V DC motors with 200W power output. The wheelchair, originally controlled via a remote controller, was modified to integrate the Nvidia JetBot Nano system, with motor controllers and other essential components.

Figure 2: Wheelchair Airwheel H3S

The Airwheel H3S wheelchair is equipped with a 20 Ah lithium-ion battery, offering a range of up to 35 km. The prototype included the integration of motor controllers (BTS7960) capable of handling high current for the wheelchair's motors, with a PWM signal control for precise speed regulation. Additionally, a relay module was used to control the electromagnetic brakes of the motors.

Nvidia JetBot Nano module was powered by a 12.6V lithium-ion own, onboard battery, providing sufficient energy for extended usage.

3.3. Hardware Architecture

The hardware architecture of the system was based on the Nvidia Jetson Nano, a single-board computer featuring a quad-core ARM Cortex-A57 processor and a Maxwell GPU with 128 CUDA cores. The Jetson Nano supports AI and machine learning applications, making it a suitable platform to control the wheelchair. It includes multiple connectivity options, such as Ethernet, HDMI, USB, and GPIO pins, which enable communication with external components. Specifically, the system incorporates the following:

- **BTS7960 motor drivers:** These high-current motor drivers were used to control wheelchair motors, enabling precise speed control via PWM signals and handling up to 43A of current.
- **PWM generator module (PCA9685):** To address the limited number of PWM pins on the Jetson Nano, this module expands the number of PWM channels, enabling control over motors and other components.

Figure 3 illustrates the wiring diagram of connections of the control system.

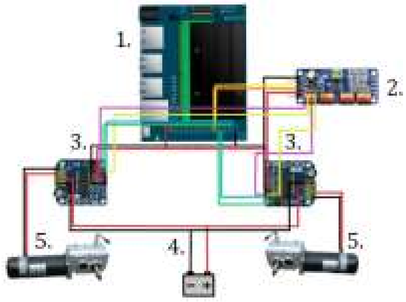

Figure 3: Simplified diagram of connections of the control system: 1. Jetbot Nano module, 2. PWM generator module (PCA9685), 3. BTS7960 motor drivers, 4. Battery, 5. Wheelchair motors.

The schematic shows how the Jetson Nano interfaces with the BTS7960 motor driver via PWM signals. This setup ensures stable and reliable motor control while maintaining compatibility with the existing electrical system of the wheelchair.

3.4. User Interface and Integration

For user interaction, the system was designed to operate via a Web browser interface, enabling users to control the wheelchair remotely. The interface includes buttons and sliders to control various functions, such as forward and backward movement, speed adjustment, and stopping. The system can also be controlled by a joystick mounted on the wheelchair.

All electronic components were securely placed in a protective case and mounted at the rear of the wheelchair to ensure smooth integration with its existing structure (see Figure 4). This placement prevents any interference with essential functions such as movement, folding, and unfolding. Careful arrangement of the hardware components was necessary to avoid obstructing the user's comfort and mobility.

Figure 4: Location of the control system elements mounted on the Airwheel H3S wheelchair

Mounting the control system and camera on the front of the wheelchair could have caused an inconvenience to the user, potentially limiting visibility and ease of use. To prevent this, the entire system was installed at the rear of the wheelchair, ensuring both stability during movement and an unobstructed user experience (see Figure 5).

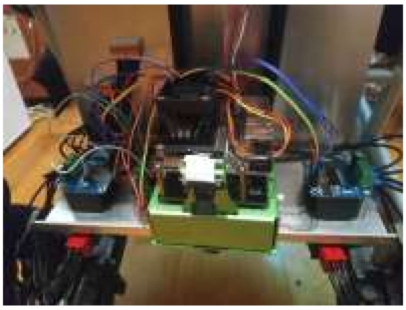

Figure 5: A functional prototype of the control system

4. Results and Discussion

Integration of the Nvidia JetBot system into the wheelchair control system was successfully achieved with modifications to the system code and hardware. The primary function of the Motor() class, which is responsible for controlling the direction and speed of wheelchair motors, was adapted to accommodate the new hardware setup. The system controls the motors via pulse width modulation, which was implemented using the PCA9685 PWM generator to handle the motor drivers, as the Jetson Nano provides limited PWM outputs.

The power source for the system was derived from the wheelchair's 25.2V lithium-ion battery, which powered the motors, while other components, such as the motor drivers and relay coil module, were powered by the Jetson mini-computer's battery. Components were connected according to a specified schematic, and quick connectors were used to facilitate assembly and ease of connection (see Figure 5).

Despite the successful integration, there were some limitations. One major challenge was the dependence on a stable Wi-Fi connection. If the system lost the Internet connection, remote control functionality would not be available, rendering the system inoperable. This limitation highlights the need for a reliable backup system in case of network failure. Additionally, the image processing functions of the JetBot system, which rely on neural networks for object detection, collision avoidance, and path following, may not be fully effective in environments with highly variable conditions. This is because these functions require the continuous gathering and learning of environmental data, which might not be feasible if the wheelchair moves between different environments. Although these functions could be useful in controlled settings, such as within a single room or similar rooms, their performance might be compromised in dynamic environments.

Another challenge identified during the evaluation was the need for continuous data collection for machine learning tasks, such as object detection and collision avoidance. This data gathering is crucial to ensure that the system can adapt to different surroundings. However, it could be a burden on users if separate data need to be collected for each new environment through which the wheelchair is pushed.

On a more positive note, the system's ability to control the wheelchair remotely via a gamepad, which is not physically attached to the vehicle, offers significant advantages over traditional joystick controls. This feature allows users to operate the wheelchair from a distance, which could be particularly useful in scenarios where the user needs to navigate the wheelchair through confined spaces, such as exiting a garage or approaching a car.

In comparison with existing solutions, the proposed wheelchair control system, based on the Nvidia JetBot Nano platform, stands out by leveraging advanced AI technologies, including real-time environment mapping and obstacle detection for enhanced navigation and safety. Our solution offers a more autonomous approach by implementing machine learning algorithms, in contrast to the works of Noman et al. [10] and Guha et al. [5], which focus on gesture-based control using microcontrollers and sensors. Moreover, our system offers greater flexibility by utilizing a GamePad controller, unlike the approach proposed by Mahadev et al. [9], where control is managed via a mobile application and a Bluetooth module. Our control system enables both remote operation and precise maneuvering of the wheelchair. Thus, our approach integrates cutting-edge AI technologies to improve navigation, safety, and user autonomy.

These findings underscore the transformative potential of AI integration in wheelchair systems. The integration of AI algorithms in wheelchair navigation allows for obstacle detection and navigation in variable conditions, which enhances user autonomy. Additionally, the introduction of remote control via a gamepad marks a step toward greater independence for wheelchair users who may not always be able to interact directly with the device. Studies have demonstrated that AI-based technologies can significantly improve mobility for individuals with disabilities, enabling them to participate more fully in daily activities [14].

Similarly, like other studies exploring AI's impact on safety, the use of obstacle detection algorithms in this project significantly contributes to reducing the risk of accidents and injuries associated with wheelchair use. Functions such as real-time collision avoidance play a key role in improving overall safety and user comfort. Research shows that intelligent wheelchair systems can minimize the risk of accidents by automatically reacting to hazards [18]. Additionally, remote control systems can also reduce the risk of injuries related to manual steering, which is particularly beneficial for users who may have limited physical capability to operate a traditional joystick.

This project also aligns with the trend of improving the cost-effectiveness of technological solutions in the mobility sector for people with disabilities. By utilising accessible platforms like the Nvidia JetBot Nano, the system becomes more affordable, potentially increasing the accessibility of advanced technologies for a wider range of users. Such technologies could revolutionize the wheelchair market, offering cheaper alternatives that do not sacrifice performance [13]. Investments in these systems can lead to more diverse wheelchair options, tailored to the unique needs of users, both in terms of functionality and cost.

An important aspect of integrating AI into wheelchair technology is the collection and analysis of environmental data. The AI system in this project, based on image recognition and real-time data analysis, allows for the gathering of information that can be used to further enhance the system. Modern AI solutions enable the collection of large datasets, which help in evaluating the performance of wheelchairs in different environments, optimizing their functionality [7]. AI systems can also detect usage patterns, which is valuable for designers to tailor devices to real-world user needs.

This project contributes to the development of innovations in the field of assistive technologies. The integration of AI into wheelchair control systems is a step toward creating more advanced, flexible solutions that are better suited to individual user needs. As studies show, the development of technology in this area has the potential to trigger a wave of innovation, providing users with greater control over their devices and better support in their daily lives [17].

In conclusion, the implementation of an AI-based system to control a wheelchair, as presented in this article, offers several benefits that can significantly improve the quality of life for people with physical disabilities. Enhancing mobility, improving safety, reducing costs, and fostering innovation are key factors that could contribute to a shift in how technologies assist people with disabilities.

5. Conclusions

This work demonstrates the successful adaptation of the Nvidia JetBot robotic system to control an electric wheelchair, showcasing both the potential of the system and its limitations. Integration of JetBot's basic motion control functions, remote control via a gamepad, and advanced image-processing capabilities represents a promising solution for enhancing the mobility of individuals with physical disabilities.

The developed control system addresses a significant need for remote operation, allowing users to control their wheelchairs from a distance, which can be particularly valuable in situations where the user is not physically able to interact directly with the vehicle. The ability of the system to use a gamepad for remote control, in contrast to a traditional joystick, improves user flexibility and convenience.

However, the dependence on a Wi-Fi connection and the challenges related to the adaptability of image processing functions in dynamic environments highlight key areas for improvement. Reliance on network connectivity emphasizes the need for a backup system to ensure continuous operation. Additionally, the issue of environmental data gathering for neural network-based functions needs to be addressed to improve system robustness and reliability in diverse settings.

Overall, this work demonstrates the viability of integrating AI-based systems into wheelchair control systems. The developed system offers enhanced mobility, improved safety, and greater user flexibility, which could substantially improve the quality of life for people with physical disabilities. As technology advances, the integration of such systems will continue to evolve, creating new opportunities for wheelchair users to experience greater autonomy and independence.

5.1. Directions for Future Research

In terms of future research, the potential for integrating more conventional control methods (e.g., joysticks, touch panels), along with autonomous navigation, could significantly enhance the system's usability. Moreover, adding features such as GPS for localisation, emergency braking, and collision detection would improve both safety and navigation capabilities. Allowing communication with smartphones via Bluetooth and exploring the use of augmented reality (AR) for real-time navigation could further revolutionise wheelchair operation, enhancing user independence and providing intuitive navigation cues in unfamiliar spaces.

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