# Frankfurt University of Applied Sciences

in the study program

**Inclusive Design - Intelligente Systeme (M.Sc.)**

Module

**2310 – Robotics**

Theme

**Smart Navigation for the Visually Impaired: A Low-Cost Approach Using a 2WD Smart Car**


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## 1. Introduction

Navigating autonomously while avoiding obstacles is a fundamental challenge in robotics, requiring precise sensor-based technology and efficient decision-making systems[1]. This project initially set out to develop an autonomous parking system using a 2WD smart car robot. However, given the project's time limitations and the complexity of execution, the focus shifted to a different yet related application: assistive navigation for visually impaired individuals. The new objective is to use the 2WD smart car as the base for a smart cane that can help visually impaired individuals navigate their environment. This system detects obstacles, provides real-time feedback, and offers navigation suggestions. The initial implementation outputs suggestions via the Arduino Serial Monitor, with potential future expansions including Bluetooth feedback to a smartphone or haptic vibration signals.

## 2. Background

People with visual impairments encounter numerous mobility challenges that can impact their safety and independence. Navigating unfamiliar environments is particularly difficult, increasing the risk of accidents and reducing confidence in daily movement. Limited perception of obstacles and changes in terrain further complicates mobility, making it harder to move freely and securely. While traditional aids like white canes provide some level of assistance, they offer only minimal feedback and require extensive training to use effectively[2].

Although various smart cane technologies are available, their high cost prevents widespread adoption. An example is *WeWalk*, a commercially available smart cane equipped with advanced technology[3]. However, its price makes it inaccessible to many individuals who could benefit from it. Economic constraints often hinder visually impaired individuals from accessing these innovative mobility solutions, even though they have the potential to enhance their quality of life[4].

[1] (Summer, Mooney, Ahmad, Huber, & Clark, 2020)
[2] (Summer, Mooney, Ahmad, Huber, & Clark, 2020)
[3] (WeWalk, 2025)
[4] (Summer, Mooney, Ahmad, Huber, & Clark, 2020)

To bridge this gap, there is a need for low-cost, yet effective, mobility solutions. This project seeks to address this issue by developing an affordable smart cane alternative that leverages obstacle detection and navigational assistance. Using a repurposed 2WD smart car, the system aims to enhance mobility and independence for visually impaired users, offering a practical and accessible solution where high-end smart canes remain out of reach.

## 3. Smart Canes

A smart cane is an assistive device designed to help visually impaired individuals navigate their surroundings with greater safety and confidence. Unlike traditional white canes, which rely solely on physical contact to detect obstacles, smart canes use advanced sensor technology to identify hazards in real time and alert the user accordingly. These alerts can be conveyed through haptic vibrations, auditory signals, or smartphone notifications, enhancing situational awareness and mobility[5].

Key features of smart canes often include:

- Ultrasonic sensors for real-time obstacle detection.
- GPS integration for location tracking and guided navigation.
- Bluetooth connectivity to sync with smartphones or wearable devices.
- Haptic feedback mechanisms for discreet alerts and improved user experience.

While smart canes offer significant benefits, they also present challenges such as high cost, added weight, and social stigma. Some users may be hesitant to adopt these devices due to concerns about being visibly identified as visually impaired. Addressing these issues is essential for making smart canes a viable, widely adopted mobility aid[6].

[5] (Summer, Mooney, Ahmad, Huber, & Clark, 2020)
[6] (Summer, Mooney, Ahmad, Huber, & Clark, 2020)

## 4. Project Implementation

The robot used in this project is based on a 2WD smart car kit controlled by an Arduino microcontroller. The kit includes all necessary components for assembling an intelligent vehicle, allowing it to be programmed for autonomous navigation and obstacle avoidance using the Arduino IDE.

The hardware components include a chassis, motors, motor drivers, wheels, an ultrasonic distance sensor for detecting obstacles, and additional expansion options such as Bluetooth communication or line-tracking capability. The assembly process is designed to be flexible, allowing modifications and enhancements as needed. A list of the components can be seen in Image 1.


*Image 1 - List of components*

The assembly process involves mounting the motors, attaching the chassis, and connecting the motor driver, sensors, and control board. The wiring diagram can be viewed in Image 2.

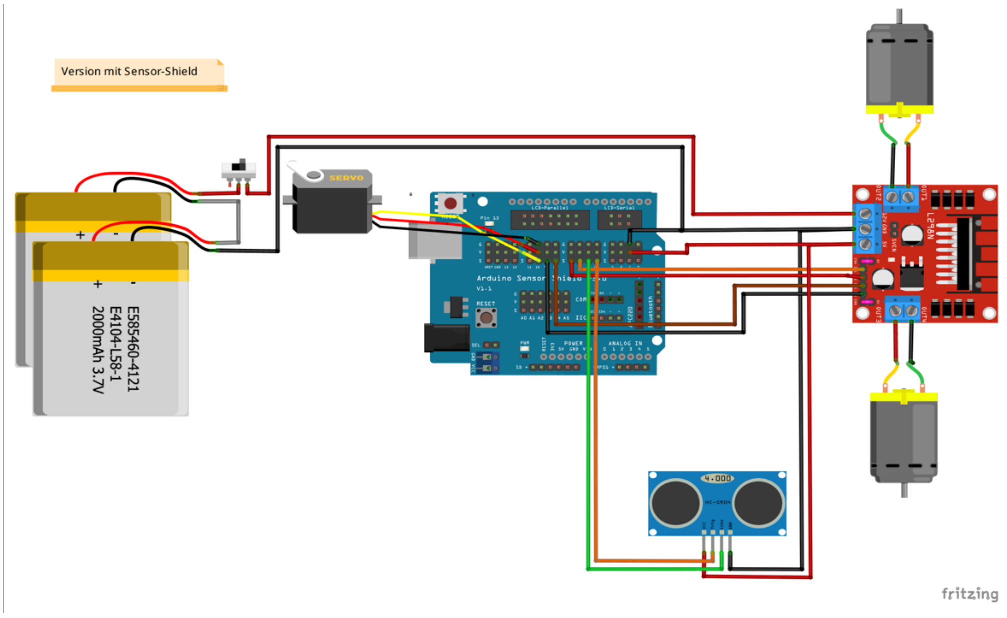


*Image 2 - Wiring diagram*

## 5. Obstacle Avoidance

In the context of the 2WD smart car robot, one of the primary goals was to implement obstacle avoidance to enable safe and efficient navigation. Obstacle avoidance is a fundamental capability in robotics that allows a robot to move through an environment while preventing collisions with obstacles. It is essential for ensuring smooth and autonomous movement, particularly in dynamic or unstructured settings.

There are two main types of obstacle avoidance: static and dynamic. Static obstacle avoidance involves planning a path around known obstacles using pre-mapped environments. Algorithms such as Dijkstra's Algorithm and the A* Algorithm are commonly used for this purpose. A global map is utilized to determine the optimal route before movement begins. In contrast, dynamic obstacle avoidance deals with unexpected obstacles that appear in real time. The robot detects these obstacles using sensors and adjusts its trajectory accordingly. A local map is used to make on-the-fly decisions about movement[7].

Several common algorithms are used for obstacle avoidance. The Bug Algorithm, specifically Bug 2, directs the robot to move straight toward its goal until it encounters

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an obstacle. When this happens, the robot follows the boundary of the obstacle, usually in a counterclockwise direction, until it finds a point where it can resume its original path. Although this method is simple, it can be inefficient in complex environments.[8] Another approach is the use of occupancy grid maps, which divide the environment into a grid where each cell is assigned a weight based on whether it is a free space or an obstacle. This helps the robot make informed decisions about movement based on sensor input[9].

Obstacle avoidance is a critical component of autonomous navigation, enabling robots to operate safely in real-world environments. Many autonomous systems integrate obstacle avoidance with Simultaneous Localization and Mapping (SLAM) to continuously update their understanding of the environment. Path-planning algorithms such as A* and Dijkstra's Algorithm help determine the most efficient route while avoiding obstacles[10]. As a result, obstacle avoidance plays a key role in ensuring that autonomous robotic systems, including the 2WD smart car, can function effectively in complex and dynamic environments.

### 5.1 Implementation of Obstacle Avoidance in the Smart Car

The obstacle avoidance functionality was developed using the Arduino platform, where the programming logic was written and tested within the Arduino IDE. The finalized code was uploaded to the Arduino microcontroller on the robot via USB, enabling real-time debugging and iterative improvements to optimize navigation accuracy and response time.

Since the project was implemented on an Arduino-based system, complex path-planning algorithms such as A* or Dijkstra's Algorithm were not feasible due to hardware limitations. Instead, a reactive sensor-based approach was used, where the robot continuously scans its environment and makes real-time decisions to avoid obstacles.

### 5.2 Smart Car Operation

[8] (Kurtipek, 2025)
[9] (Nauth, 2023)
[10] (Nauth, 2023)

The obstacle avoidance system follows a structured process to ensure navigation:

- Measuring distances – The ultrasonic sensor continuously scans the environment, detecting objects within a defined range.
- Decision-making process – If an obstacle is detected within a critical distance, the Arduino executes a predefined avoidance maneuver based on real-time sensor input.
- Adjusting movement – The robot either stops, turns left or right, or reverses to find a new path, ensuring uninterrupted motion.

This behavior is similar to Bug 2 algorithms, where the robot moves toward its goal but, when encountering an obstacle, evaluates alternative routes and adjusts its trajectory accordingly. However, the system does not implement full path-tracking or global planning, as it makes decisions based purely on local sensor data.

Due to the length of the code, it will not be included in this report. However, the complete implementation will be provided in the submission for reference.

## 6. Results

The final prototype of the project was successfully built, and images of the assembled robot will be included in this report. Additionally, videos demonstrating its functionality will be provided in the submission.

During the assembly and testing process, some electrical issues with the motors were encountered, likely due to voltage-related wiring mistakes. As a result, the robot does not navigate optimally—it moves in circles instead of following a straight path. Despite this, the obstacle detection system is functional, and the robot is able to recognize obstacles and react accordingly. However, after running for some time, the robot stops working, indicating potential power or wiring issues that require further investigation.

While the current implementation achieves partial obstacle avoidance, it does not fully meet the intended navigation performance. Nevertheless, the prototype demonstrates the feasibility of using an Arduino-based system for autonomous movement and real-time obstacle detection.

## 7. Conclusion

The initial goal of this project was to develop a smart cane for visually impaired individuals, using the 2WD robot as a base. To fully realize this vision, additional components such as a GPS module, Bluetooth module, and a buzzer would need to be integrated. These enhancements could improve navigation, provide real-time feedback through voice or haptic signals, and make the system more practical for daily use.

However, one important consideration is the social stigma associated with assistive devices. Some visually impaired individuals may not want to be visibly identified as such, meaning the design and appearance of the device would need to be carefully refined to balance functionality with discreet usability[11].

Due to time constraints and the project's scope, the full realization of the smart cane concept was not possible in this iteration. Nevertheless, this prototype serves as a foundation for future improvements, demonstrating a potential low-cost, assistive navigation device that could benefit visually impaired individuals. Future work could focus on refining movement accuracy, improving power management, and enhancing usability to better align with the vision of this project.

[11] (Summer, Mooney, Ahmad, Huber, & Clark, 2020)

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