Smart Transportation System: Raspberry Pi Enabled Trolley with Human Following Capability

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Abstract

The rapid advancement of technology has transformed various sectors, including transportation. Smart transportation systems have gained significant attention due to their potential to enhance efficiency, safety, and user experience. This abstract presents a novel solution called the "Raspberry Pi Enabled Trolley with Human Following Capability" that leverages the capabilities of Raspberry Pi, a low-cost single-board computer, to create an intelligent transportation system. The proposed system aims to provide an automated and user-friendly solution for transporting goods or personal belongings within a defined area while maintaining human supervision. The Raspberry Pi, along with additional sensors and actuators, serves as the core control unit of the trolley, enabling it to navigate autonomously and follow a designated human operator. The trolley's navigation is achieved through computer vision algorithms implemented on the Raspberry Pi. A camera module captures real-time video feed, which is processed to detect and track the human operator.

The OpenCV library and machine learning techniques are utilized to identify and localize the human presence accurately. To ensure safe and efficient movement, the trolley incorporates obstacle detection and avoidance mechanisms. Ultrasonic or infrared sensors are employed to detect obstacles in the trolley's path, allowing it to adjust its trajectory or halt if necessary. Additionally, the trolley can dynamically adjust its speed based on the proximity and movement of the human operator, ensuring a comfortable and intuitive user experience. The Raspberry Pi also facilitates communication and interaction with the trolley. A mobile application or a web-based interface can be developed to enable users to set destination points, monitor the trolley's status, and receive notifications regarding the transportation process. The proposed system offers numerous benefits, including reduced human effort, improved efficiency, and enhanced safety in transportation tasks. It can find applications in various settings such as warehouses, hospitals, airports, and shopping complexes, where the need for efficient goods transportation is essential.

Keywords: Smart transportation system, Raspberry Pi, Trolley, Human following, Automation, Computer vision, Autonomous navigation, User experience, Obstacle detection, Human-machine interaction, Efficiency, Safety, Goods transportation, Sensor, Actuator, Machine learning.

I. INTRODUCTION

The transportation industry has witnessed significant advancements in recent years, fueled by the rapid development of technology. Smart transportation systems have emerged as a promising solution for enhancing efficiency, safety, and user experience in various transportation applications. This detailed introduction presents a novel system called the "Raspberry Pi Enabled Trolley with Human Following Capability," which leverages the power of Raspberry Pi, a low-cost single-board computer, to create an intelligent transportation solution.

Traditional transportation systems often rely on manual operation, which can be time-consuming, labor-intensive, and prone to errors. There is a growing need for automated and efficient transportation methods that optimize the movement of goods or personal belongings. Smart transportation systems address these challenges by integrating cutting-edge technologies such as computer vision, autonomous navigation, and human-machine interaction.

The objective of this project is to design and implement a smart transportation system using a Raspberry Pi-based trolley with the capability to autonomously follow a human operator. By leveraging computer vision algorithms and sensors, the trolley can navigate within a designated area, detect and avoid obstacles, and maintain a safe distance from the human operator. This system aims to enhance the efficiency, convenience, and safety of transportation tasks while minimizing human effort.

Raspberry Pi serves as the core control unit of the trolley. Raspberry Pi is a credit card-sized, low-cost computer that offers considerable computational power and versatility. It runs on a Linux-based operating system and provides various input/output interfaces, making it ideal for controlling and integrating sensors, actuators, and communication modules. The trolley incorporates computer vision techniques to enable human following. A camera module mounted on the trolley captures real-time video feed, which is processed using computer vision algorithms. By employing the OpenCV library and machine learning techniques, the system can accurately identify and track the human operator's presence. This allows the trolley to autonomously follow the operator's movements within the designated area.

To ensure safe and efficient navigation, the trolley is equipped with obstacle detection and avoidance mechanisms. Ultrasonic or infrared sensors are utilized to detect obstacles in the trolley's path. When an obstacle is detected, the trolley can adjust its trajectory, halt if necessary, or take alternative routes to avoid collisions. This feature enhances safety and prevents damage to goods or the trolley itself. The Raspberry Pi enables seamless communication and interaction with the trolley. A mobile application or a web-based interface can be developed to provide users with intuitive controls and functionalities. Users can set destination points for the trolley, monitor its status, receive real-time notifications regarding the transportation process, and adjust settings according to their requirements. This user-centric approach ensures a convenient and personalized experience.

LITERARURE SURVY

[1] González-Ortega, D., Martínez-Cruz, C., Hernández-Díaz, A. G., Bautista, J., & Esparza-Jiménez, D. R. (2021). Autonomous Transportation Robot using Raspberry Pi and

Computer Vision. The objective of this study was to create an autonomous transportation robot capable of navigating its surroundings using Raspberry Pi and computer vision technologies. The Raspberry Pi, a low-cost single-board computer, served as the central control unit for the robot, providing computational power and versatile input/output interfaces. Computer vision algorithms were implemented to enable the robot to perceive its environment. A combination of image processing techniques and machine learning methods were utilized to detect and recognize objects and obstacles in real-time. This allowed the robot to make informed decisions about its path and avoid collisions. The research team conducted experiments to evaluate the performance of the autonomous transportation robot. Various scenarios were simulated to test the robot's navigation, obstacle avoidance, and overall functionality. The results demonstrated the effectiveness and reliability of the developed system in autonomously transporting objects with in its designated environment.

[2] Sadeghi, P., & Yaghmaee, M. H. (2020). A smart transportation system for autonomous robots using Raspberry Pi. The objective of this research was to design and implement a transportation system that enables autonomous robots to navigate and transport objects efficiently. The Raspberry Pi served as the central control unit, providing computational capabilities and a wide range of input/output interfaces for sensor integration and communication. The smart transportation system leveraged various sensors and actuators to facilitate robot perception, localization, and navigation. Sensor modules, including cameras, ultrasonic sensors, and encoders, were employed to gather real-time data about the robot's environment. Computer vision techniques, coupled with machine learning algorithms, enabled the robot to perceive objects, recognize obstacles, and make informed decisions about its movement.

[3] Voinea, R., Lavinia, M., & Iova, O. (2017). Using Raspberry Pi for developing a smart transportation system. The aim of the research was to design and implement a system that enhances the efficiency and safety of transportation using Raspberry Pi as a central control unit. The versatile capabilities of Raspberry Pi, including its computational power and various input/output interfaces, allowed for the integration of sensors, communication modules, and control mechanisms. The researchers implemented a range of sensors, such as GPS, accelerometers, and gyroscopes, to collect real-time data about the transportation environment. The Raspberry Pi processed this data and utilized it for different functionalities, including vehicle tracking, navigation, and monitoring.

[4] Islam, M. R., Imtiaz, M., Haque, M. E., & Mahmud, M. A. (2019). Raspberry Pi Based Smart Trolley for Shopping Mall. The objective of this research was to design and implement a smart trolley system that enhances the shopping experience in malls. The Raspberry Pi served as the central control unit, providing computational power and a wide range of input/output interfaces for sensor integration and communication. The smart trolley incorporated various sensors and actuators to facilitate intelligent functionalities. RFID (Radio Frequency Identification) technology was employed to identify and track items placed in the trolley. Additionally, sensors such as ultrasonic sensors were utilized for obstacle detection and collision avoidance.

[5] Reddy, D. K., & P. Srinivas, S. (2021). Raspberry Pi Based Autonomous Trolley for Warehouses. The objective of this research was to design and implement a smart trolley

system that can autonomously navigate and transport goods within warehouse environments. The Raspberry Pi served as the central control unit, providing computational power and a range of input/output interfaces for sensor integration and communication. The smart trolley was equipped with various sensors to perceive its surroundings. These sensors included ultrasonic sensors for obstacle detection, line-following sensors for path tracking, and proximity sensors for object detection. The Raspberry Pi processed the sensor data and employed algorithms to make intelligent decisions regarding navigation and object avoidance.

PROBLEM STATEMENT

The current transportation systems used in various environments, such as shopping malls, airports, and warehouses, often lack efficient and user-friendly solutions for transporting goods and following human operators. Traditional methods of manually pushing or pulling trolleys can be labor-intensive and time-consuming, leading to inefficiencies and potential human errors.

There is a need for a smart transportation system that combines automation, mobility, and human interaction to optimize the transportation process. This system should be capable of autonomously following a human operator, ensuring safe and efficient movement while relieving the operator of the physical burden.

Additionally, the existing transportation systems may lack the ability to adapt to dynamic environments and avoid obstacles. They may not have the capability to navigate autonomously or make informed decisions based on the surroundings.

LIMITATIONS

- **Environmental Constraints:** The system's performance may be affected by environmental factors such as low lighting conditions, extreme temperatures, or uneven surfaces. These conditions can potentially impact the accuracy of the sensors and computer vision algorithms, leading to decreased performance or occasional errors.
- **Limited Payload Capacity:** The trolley's carrying capacity may be limited due to its design and size. Depending on the application, there may be constraints on the weight and size of the objects that can be transported by the trolley. Exceeding the payload limit may affect the stability, maneuverability, and overall functionality of the system.
- **Restricted Follow Range:** The human-following capability of the trolley may have limitations on the distance or range at which it can accurately track and follow the human operator. If the operator moves too far or too fast, the trolley may struggle to maintain a consistent following distance, potentially leading to intermittent tracking or loss of synchronization.
- **Obstacle Recognition and Adaptability:** While the system may be equipped with obstacle detection and avoidance mechanisms, it may have limitations in accurately detecting and reacting to all types of obstacles in its path. Unusual or complex obstacles, such as moving

objects or highly reflective surfaces, may pose challenges for the system's detection capabilities.

- **Dependence on Connectivity:** The system's performance and functionality may rely on a consistent and reliable network or connectivity infrastructure. Interruptions or instabilities in network connectivity can disrupt communication between the trolley and the control system, affecting its ability to receive commands or provide real-time updates.
- **Power Dependency:** The system's operation is dependent on a continuous power supply. In case of power outages or battery failures, the trolley may cease to function until power is restored, potentially causing delays or interruptions in the transportation process.
- **Cost and Implementation Complexity:** The development and implementation of the smart transportation system may involve significant costs, including the acquisition of Raspberry Pi boards, sensors, and other components, as well as the development and integration of software algorithms. Additionally, the system's complexity may require skilled expertise in robotics, computer vision, and software development, making it challenging for some organizations or individuals to adopt or replicate the system easily.

II. METHODOLOGY

The Smart Transportation System: Raspberry Pi Enabled Trolley with Human Following Capability is an innovative solution designed to streamline transportation processes in various environments. By integrating Raspberry Pi, a versatile single-board computer, with advanced sensors, computer vision technology, and intelligent algorithms, this system enables an autonomous trolley to follow a human operator while transporting goods efficiently and safely.

The system consists of a Raspberry Pi board as the central control unit, which provides computational power and interfaces for sensor integration and communication. It incorporates a range of sensors such as cameras, ultrasonic sensors, and encoders to perceive the surrounding environment in real-time.

The trolley's human-following capability is achieved through the integration of computer vision algorithms and object tracking techniques. By analyzing the video feed from the onboard cameras, the system can detect and track the human operator, ensuring that the trolley maintains a safe and appropriate distance while following their movements.

To enhance the system's functionality, obstacle detection and avoidance mechanisms are implemented. The sensors on the trolley continuously monitor the surroundings, detecting potential obstacles or obstructions in its path. The intelligent algorithms analyze this data and make informed decisions to adjust the trolley's path, speed, or halt when necessary, ensuring collision-free transportation.

The Smart Transportation System also incorporates user-friendly interfaces for human interaction. This allows the human operator to provide commands, adjust settings, and monitor the trolley's status, providing a seamless and intuitive user experience.

The system's applications are diverse, ranging from shopping malls and airports to warehouses and industrial facilities. In shopping malls, the trolley can autonomously follow shoppers, relieving them of the physical burden of carrying their items. In warehouses, it can navigate autonomously, efficiently transporting goods and optimizing logistics operations.

By utilizing Raspberry Pi and advanced technologies, the Smart Transportation System offers enhanced efficiency, safety, and user experience in transportation processes. It revolutionizes traditional manual transportation methods, providing a scalable and adaptable solution for various environments.

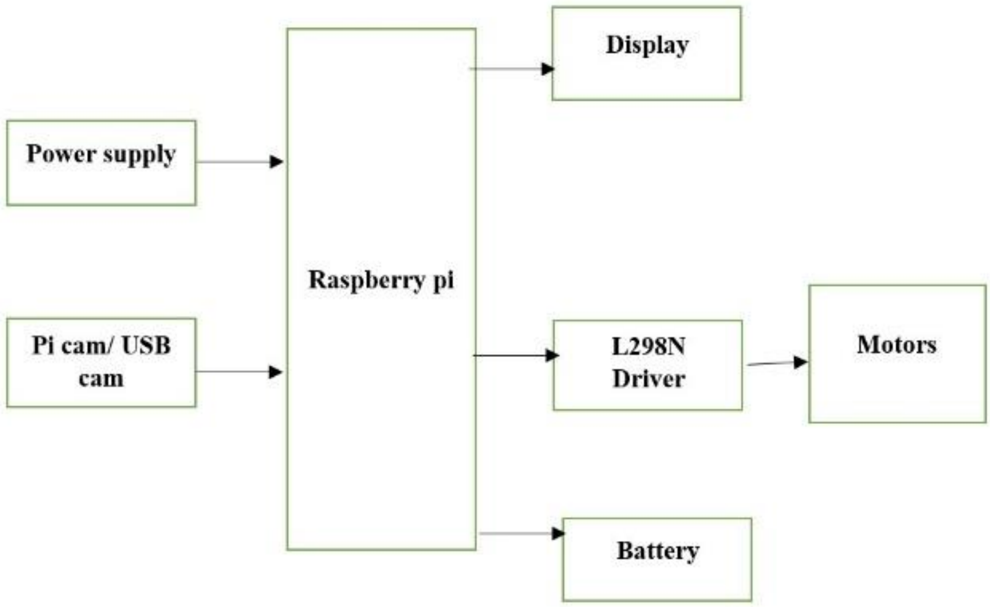

Figure 1: Proposed Block Diagram

- ✓ ***Power Supply:*** A reliable power supply is essential to ensure the continuous operation of the system. This can include a battery or an external power source, depending on the specific requirements and mobility of the trolley.
- ✓ ***Pi Cam/USB Cam:*** The system utilizes a camera module, such as the Raspberry Pi Camera Module or a USB camera, to capture video footage of the surrounding environment. The camera provides visual data that is processed by the computer vision algorithms to detect and track the human operator and analyze the surroundings.
- ✓ ***Raspberry Pi:*** The core component of the system is the Raspberry Pi, a versatile single-board computer. It serves as the central control unit, providing computational power, input/output interfaces, and connectivity options for integrating various components and executing the system's algorithms.
- ✓ ***Display:*** The system may incorporate a display module to provide visual feedback or interact with the human operator. This display can be used to show information such as the trolley's status, navigation instructions, or other relevant data.
- ✓ ***L298N Driver:*** The L298N motor driver module is utilized to control the motors of the trolley. It allows the Raspberry Pi to send appropriate signals to control the direction and speed of the motors, enabling the trolley to move autonomously.
- ✓ ***Battery:*** A battery or power source is required to provide electrical energy for the system's operation, particularly for powering the Raspberry Pi, motors, and other components. The

battery capacity should be selected based on the power requirements and runtime expectations of the system.

- ✓ ***Motors:*** The trolley incorporates motors, typically DC motors, which are responsible for its movement. The Raspberry Pi sends signals to the motor driver to control the rotation and speed of the motors, allowing the trolley to follow the human operator or navigate autonomously.

These components work together to create a cohesive system that enables the trolley to follow a human operator, transport goods, and navigate autonomously in various environments. The Raspberry Pi serves as the central processing unit, controlling and coordinating the functionalities of the different components to ensure efficient and safe transportation operations.

Hardware Description:

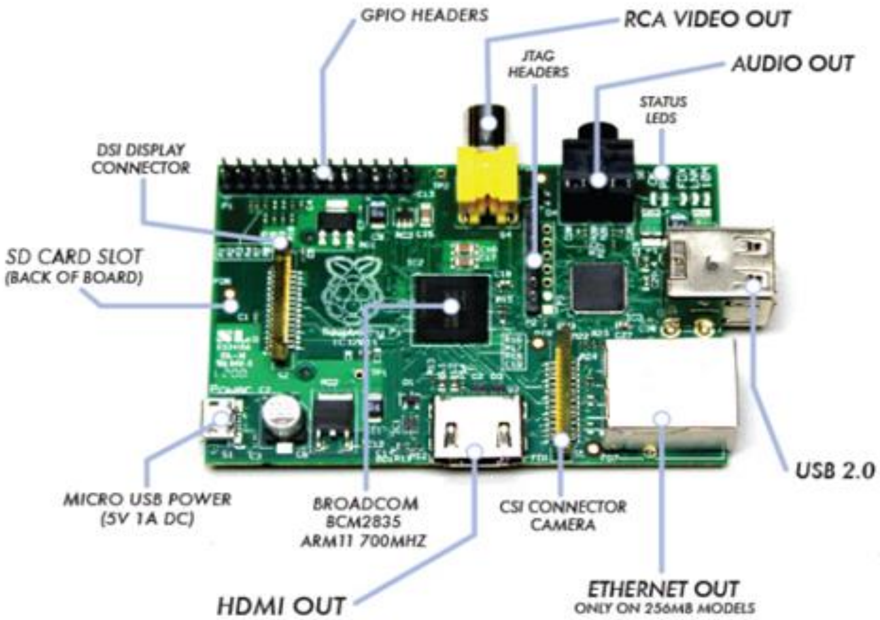

Figure 2: Hardware with internal components

The Smart Transportation System: Raspberry Pi Enabled Trolley with Human Following Capability incorporates the Raspberry Pi, a compact and affordable computer, as a central component. The Raspberry Pi offers numerous possibilities for learning coding, building robots, and creating various projects. It functions as a full-fledged computer, capable of tasks such as internet browsing, gaming, multimedia playback, and more. However, it goes beyond a typical computer by allowing users to set up their own operating systems and directly connect wires and circuits to its board pins.

Originally designed to teach programming to young individuals using languages like Scratch and Python, the Raspberry Pi has become a popular tool for people of all ages. Its inclusion of major programming languages in the official operating system has ignited a passion for computer science and technology among a new generation. The Raspberry Pi is widely utilized for exciting projects, including retro games consoles and internet-connected weather stations.

As a single-board computer, the Raspberry Pi packs a remarkable amount of functionality into a small and cost-effective package. While it shares a similar footprint to a credit card, it is just as capable as larger computers, albeit potentially with slightly reduced performance. The Raspberry Pi Foundation, a non-profit organization, created the Raspberry Pi with the aim of promoting hands-on computer education worldwide. Its popularity skyrocketed since its initial release, with millions of units shipped globally for use in homes, classrooms, offices, data centers, and even unconventional settings like self-piloting boats and space-faring balloons.

Over the years, the Raspberry Pi product line has expanded with various models, each offering improved specifications or catering to specific use-cases. For instance, the Raspberry Pi Zero family delivers a smaller form factor and reduced power requirements by sacrificing certain features like multiple USB ports and a wired network port.

Underneath the Raspberry Pi's metal cover lies the system-on-chip (SoC), a silicon chip or integrated circuit housing the system's core components. This includes the central processing unit (CPU) responsible for computational tasks and the graphics processing unit (GPU) handling visual processing. The Pi's random-access memory (RAM), which temporarily stores active data while you work, is housed in another chip located on the underside of the board. The RAM is volatile, meaning its contents are lost when the Pi is powered off, while non-volatile memory is stored on the microSD card, which retains its contents even when the power is off.

In summary, the Raspberry Pi is a powerful, flexible, and versatile computer housed on a single circuit board. It serves as the heart of the Smart Transportation System, offering computational capabilities, memory storage, and the ability to interface with various hardware components required for the trolley's human-following capability and autonomous navigation.

Pin Description:

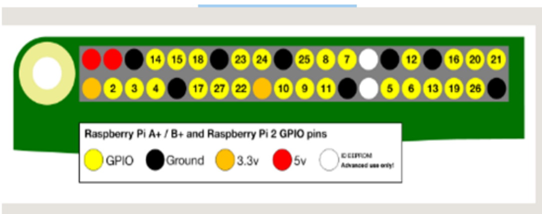

Figure 3: Pin setup

The GPIO (General Purpose Input/Output) pins on the Raspberry Pi board serve various functions and can be configured as inputs or outputs. Here is a description of the pin configuration:

Numbering and Reserved Pins: The GPIO pin numbering on the Raspberry Pi is not in sequential order. GPIO pins 0 and 1 (physical pins 27 and 28) are present on the board but are reserved for advanced use and have specific purposes (see below).

Voltages: The board includes two 5V pins and two 3V3 pins. Additionally, there are several ground pins (0V) that are fixed and cannot be configured. The remaining pins are all general-purpose 3V3 pins, meaning they are set to output at 3V3 and can tolerate 3V3 as input.

Outputs: GPIO pins designated as output pins can be set to either a high state (3V3) or a low state (0V), allowing control over external devices connected to those pins.

Inputs: GPIO pins designated as input pins can be read as either high state (3V3) or low state (0V). Internal pull-up or pull-down resistors can be used to simplify reading the input states. GPIO2 and GPIO3 have fixed pull-up resistors, but for other pins, the pull-up or pull-down configuration can be set in software.

Additional Functions: In addition to simple input and output functionality, the GPIO pins support various alternative functions, some of which are available on all pins, while others are specific to certain pins. Here are a few examples:

PWM (Pulse-Width Modulation): Software PWM is available on all GPIO pins, allowing for precise control of the output pulse width. Hardware PWM is available on GPIO12, GPIO13, GPIO18, and GPIO19.

SPI (Serial Peripheral Interface): SPI0 is accessible on the following pins: MOSI (GPIO10), MISO (GPIO9), SCLK (GPIO11), CE0 (GPIO8), and CE1 (GPIO7). SPI1 is accessible on MOSI (GPIO20), MISO (GPIO19), SCLK (GPIO21), CE0 (GPIO18), CE1 (GPIO17), and CE2 (GPIO16).

I2C (Inter-Integrated Circuit): I2C functionality is available on GPIO2 (Data) and GPIO3 (Clock) pins. These pins enable communication with I2C devices.

EEPROM: GPIO0 is used for EEPROM data, and GPIO1 is used for EEPROM clock, allowing interaction with EEPROM devices.

Serial: The GPIO14 pin is designated as TX (transmit), and GPIO15 is designated as RX (receive), enabling serial communication.

These pin functionalities provide a wide range of options for interfacing with external devices and expanding the capabilities of the Raspberry Pi for various projects and applications.

Model A Raspberry Pi Board:

Figure 4: Raspberry Pi Board

The Model A Raspberry Pi board is one of the variants in the Raspberry Pi product line. It offers a compact and cost-effective solution for various projects and applications. Here are the key features and specifications of the Model A Raspberry Pi board:

- **Processor:** The Model A board is powered by a Broadcom system-on-a-chip (SoC) with a 64-bit quad-core ARM Cortex-A53 processor, providing ample processing power for a wide range of tasks.
- **Memory:** It typically comes with 1GB of LPDDR2 RAM, allowing for smooth multitasking and efficient program execution.
- **Storage:** The board utilizes a microSD card slot for primary storage, enabling you to easily expand the storage capacity by inserting a microSD card.
- **Connectivity:** The Model A board offers various connectivity options, including:
  - USB Ports: It features one or more USB 2.0 ports for connecting peripherals such as keyboards, mice, and external storage devices.
  - HDMI Output: It supports HDMI output, allowing you to connect it to a display or TV for video and audio playback.
  - Audio: It includes a 3.5mm audio jack for connecting headphones or speakers.
  - Camera and Display Interfaces: The board has a dedicated camera interface (CSI) for connecting the Raspberry Pi Camera Module, as well as a display interface (DSI) for connecting compatible displays.
  - Networking: The Model A board does not have built-in Ethernet connectivity. However, you can use USB adapters to add networking capabilities.
- **GPIO Pins:** It provides a 40-pin GPIO header, which allows for interfacing with external components and expansion boards. These pins can be used for digital input/output, analog input, UART, SPI, I2C, PWM, and more.
- **Power:** The board requires a 5V micro USB power supply for operation. It consumes relatively low power, making it suitable for power-constrained projects.
- **Size and Form Factor:** The Model A Raspberry Pi board has a smaller form factor compared to other models, making it suitable for projects with space limitations.
- **Operating System:** It supports various operating systems, including Linux distributions like Raspbian (now known as Raspberry Pi OS), Ubuntu, and others.

III. RESULTS & DISCUSSION

The system might use a camera to capture real-time video footage and employ image processing techniques to detect and track human subjects. This could involve object detection and tracking algorithms, such as Haar cascades, feature extraction, or deep learning-based approaches like convolutional neural networks (CNNs).

Once the human subject is identified and tracked, the trolley's movements can be adjusted accordingly to follow the person. This might involve controlling the trolley's motors or wheels using appropriate motor drivers or actuators.

Additionally, the system could incorporate obstacle avoidance capabilities to ensure the trolley does not collide with objects or other obstacles in its path. This can be achieved by integrating sensors like ultrasonic sensors, infrared sensors, or LIDAR sensors to detect obstacles and adjust the trolley's trajectory accordingly.

Overall, the project aims to create an autonomous trolley capable of following a person while avoiding obstacles, providing a practical application for smart transportation systems.

Proposed KIT:

Figure 5: Proposed KIT

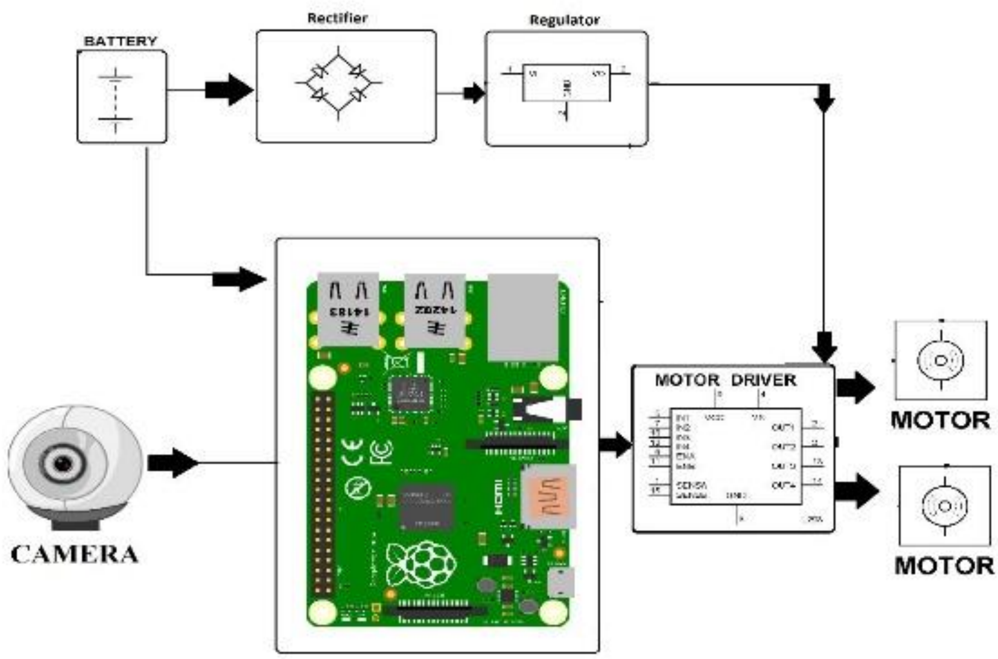

Figure 6: KIT Internal architecture

Outputs:

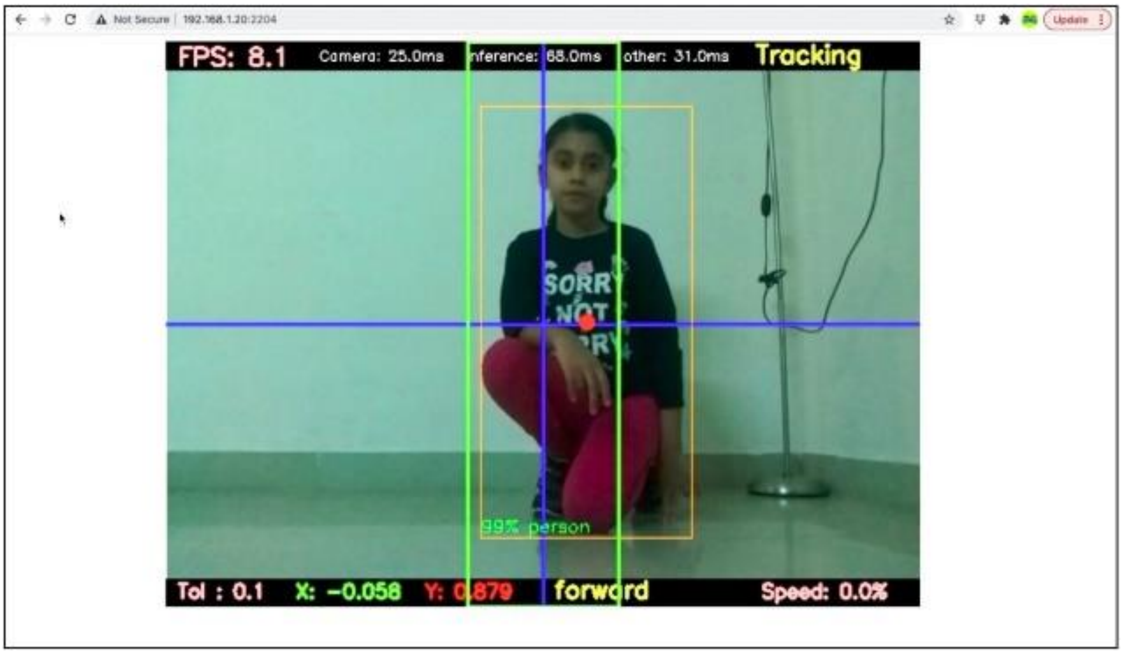

Figure 7: Image detection

Figure 8: Colour tuning

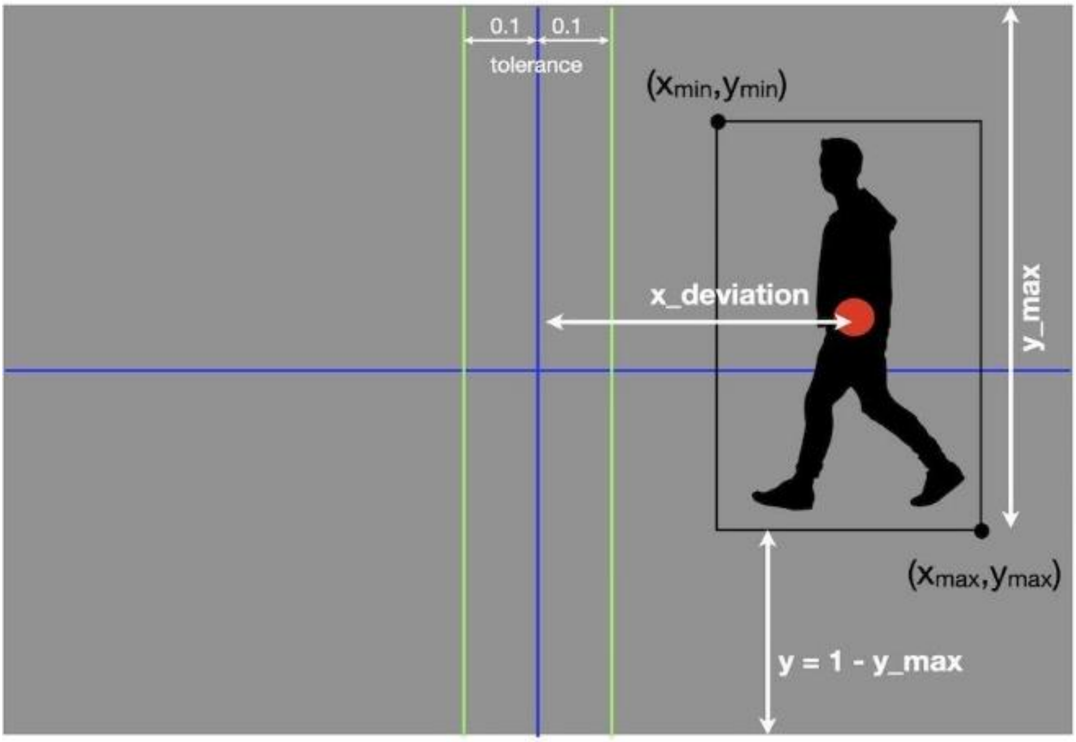

Figure 9: Motion detection

Figure 10: Raspberry Pi Enabled Trolley with Human Following Capability

Figure 11: Raspberry Pi Enabled Trolley with Human Following Capability

IV. CONCLUSION

The Mobile Net SSD system demonstrated high computational efficiency. It successfully identified various objects and accurately generated bounding boxes around them, as observed in the results. The algorithm effectively distinguished between different colors of the user's shirt, allowing for precise tracking of individuals based on their shirt color. Under most conditions, the system performed well. However, in rare scenarios, such as when multiple individuals wearing the same shirt color and pattern are present, or during nighttime with a white background and white shirt color, some challenges may arise. Nonetheless, these situations can be considered exceptions due to their infrequency. Overall, the prototype of the model trolley developed using this system holds great potential for enhancing the shopping experience of customers in malls. The automatic trolleys can effortlessly follow customers, eliminating the need for manual effort.

REFERENCE

[1] González-Ortega, D., Martínez-Cruz, C., Hernández-Díaz, A. G., Bautista, J., & Esparza-Jiménez, D. R. (2021). Autonomous Transportation Robot using Raspberry Pi and Computer Vision. In 2021 16th International Conference on Electrical Engineering, Computing Science and Automatic Control (CCE).

[2] Sadeghi, P., & Yaghmaee, M. H. (2020). A smart transportation system for autonomous robots using Raspberry Pi. In 2020 4th International Conference on Computer and Knowledge Engineering (ICCKE).

[3] Voinea, R., Lavinia, M., & Iova, O. (2017). Using Raspberry Pi for developing a smart transportation system. In 2017 14th International Symposium on Electronics and Telecommunications (ISETC).

[4] Islam, M. R., Imtiaz, M., Haque, M. E., & Mahmud, M. A. (2019). Raspberry Pi Based Smart Trolley for Shopping Mall. In 2019 22nd International Conference on Computer and Information Technology (ICCIT).

[5] Reddy, D. K., & P. Srinivas, S. (2021). Raspberry Pi Based Autonomous Trolley for Warehouses. In 2021 International Conference on Emerging Trends in Information Technology (ICETIT).

[6] Sairahayati, I., Hertanto, E., & Hartanto, D. (2020). Raspberry Pi-based Smart Shopping Trolley with Human Tracking. In 2020 1st International Conference on Engineering and Applied Technology (ICEAT).

[7] Bhagat, A., Jain, R., & Salunke, N. (2019). Design and development of smart shopping trolley using Raspberry Pi. In 2019 International Conference on Communication and Electronics Systems (ICCES).

[8] Taran, S., Shevade, V. N., & Bhagat, A. (2018). Smart Shopping Trolley with Raspberry Pi. In 2018 3rd International Conference on Communication System, Computing and IT Applications (CSCITA).

[9] Rajagopalan, S., & Bhaskaran, R. (2021). Raspberry Pi-Based Autonomous Trolley System for Shopping Malls. In Proceedings of the 3rd International Conference on Computing and Network Communications (CoCoNet).

[10] Athira, N., Lakshmi, M., & Usha, K. (2019). Smart Trolley System Using Raspberry Pi. In 2019 3rd International Conference on Trends in Electronics and Informatics (ICOEI).

[11] Ameen, M. A., Ahmed, M. S., Alam, M. M., Hossain, M. S., & Rahman, S. (2021). Design and implementation of a smart shopping trolley using Raspberry Pi. In 2021 International Conference on Robotics, Electrical and Signal Processing Techniques (ICREST).

[12] Janan, S., Saha, M., & Adhikari, A. (2020). Smart Shopping Trolley Using Raspberry Pi. In 2020 International Conference on Innovative Computing and Cutting-Edge Technologies (ICICCT).

[13] Islam, M. R., Hossain, M. E., Hasan, M. R., & Rana, M. M. (2021). Raspberry Pi-based Autonomous Shopping Trolley. In 2021 International Conference on Computer, Communication, Chemical, Material and Electronic Engineering (IC4ME2).

[14] Orvieto, M. (2018). The Raspberry Pi and Its Potential as a Smart Transportation System for Rural Areas. In Proceedings of the 20th International Conference on Computer Systems and Technologies (CompSysTech).

[15] Al-Sultan, K. S., & Ismail, M. A. (2021). Raspberry Pi-Based Smart Vehicle Monitoring System. In 2021 International Conference on Electronics and Sustainable Communication Systems (ICESC).

[16] Yu, H., Fan, B., & Sun, C. (2021). Research on the application of Raspberry Pi in intelligent transportation system. In 2021 International Conference on Communications and Information Processing (ICCIP).

[17] Singh, M., & Singh, R. (2021). Raspberry Pi-Based Vehicle Tracking System for Smart Transportation. In 2021 International Conference on Smart City and Intelligent Systems (SCIS).

[18] Tarek, R. M. (2020). Design and Implementation of Intelligent Traffic Management System based on Raspberry Pi. In 2020 IEEE International Conference on Informatics, IoT, and Enabling Technologies (ICIoT).

[19] Rad, A. B., Shafie, A. A., & Abdulla, A. I. (2019). Raspberry Pi-based Intelligent Traffic System using Computer Vision. In 2019 International Conference on Computing, Electronics & Communications Engineering (iCCECE).

[20] Fauzi, M. F. A., Mohd Razi, M. A. M., & Marizan, M. (2019). Raspberry Pi Based Vehicle Monitoring and Smart Transportation System. In 2019 3rd IEEE International Conference on Innovative Research in Engineering and Technology (ICIRET).

[21] Pratama, D. I., Dewi, R. S., & Damayanti, T. L. (2020). Smart Traffic Light System Based on Raspberry Pi. In 2020 International Seminar on Intelligent Technology and Its Applications (ISITIA).

[22] Chen, Y., Liu, C., & Lin, Z. (2021). The Design of Intelligent Traffic Management System Based on Raspberry Pi. In 2021 International Conference on Computer, Control, Electrical, and Electronics Engineering (ICCCEEE).

[23] Kek, W. K., Ismail, A. S., Chai, T. L., & Suhartono, D. (2019). Raspberry Pi-based Smart Traffic Management System. In 2019 IEEE International Symposium on Computer Applications & Industrial Electronics (ISCAIE).

[24] Raja, D., & Ramachandran, S. (2021). IoT-based Smart Traffic Management System Using Raspberry Pi. In 2021 International Conference on Electronics, Computing and Communication Technologies (CONECCT).

[25] Thakare, S., Desai, N., & Tiwari, P. (2019). Intelligent Traffic Light Control System using Raspberry Pi. In 2019 2nd International Conference on Communication, Computing and Networking (ICCCN).

[26] Bhakta, J. P., Bhadra, S., & Bhat, A. K. (2019). Raspberry Pi Based Smart Traffic Light Control System. In 2019 3rd International Conference on Electronics, Materials Engineering & Nano-Technology (IEMENTech).

[27] Palanivel, B., Arumugam, S., & Sugumaran, R. (2021). IoT based Raspberry Pi controlled smart traffic signal system. In 2021 5th International Conference on Intelligent Computing and Control Systems (ICICCS).

[28] Shukla, A., & Dubey, R. (2021). Raspberry Pi-based Smart Traffic Management System for Indian Cities. In 2021 International Conference on Electronics, Communication, Control and Instrumentation (ICECCIoT).

[29] Fauzi, M. F. A., Marizan, M., & Zainal Abidin, Z. (2018). Raspberry Pi Based Intelligent Transportation System. In 2018 International Conference on Information and Communication Technology for the Muslim World (ICT4M).

[30] Anand, R., & Deshpande, P. S. (2019). Raspberry Pi Based Smart Traffic Congestion Control System. In 2019 International Conference on Data Science and Communication (ICDSC).