HUMAN FOLLOWING ROBOT AND AUTONOMOUS CAR USING RASPBERRY PI PICO H

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***Abstract*—We present a low-cost robot car that autonomously follows a person or object using a Raspberry Pi Pico H microcontroller. The robot is equipped with ultrasonic distance sensors to measure the range to a target and maintain a following behavior. If the target becomes stationary or moves too close, the control logic makes the robot reverse and change direction to avoid a collision, then resume following. Only standard reactive control algorithms are used (no machine learning or neural nets), implemented on the Pico H platform which offers rich I/O for sensors and motors[1]. The drive system uses four DC motors powered through two dual-H-bridge motor drivers. A Bluetooth radio links the robot to a custom mobile app (Android/iOS) that can start, stop or configure the robot remotely. The hardware components (HC-SR04 ultrasonic sensors, TT geared motors, L298N drivers, Bluetooth module) are typical of educational robotics kits. In experiments, the robot reliably track person and object and successfully avoided obstacles by backing up and reorienting as designed. This design demonstrates that an embedded microcontroller like the Raspberry Pi Pico H can realize a human-following autonomous vehicle with simple sensor-driven control and smartphone connectivity.**

Keywords: human-following robot; Raspberry Pi Pico; ultrasonic sensor; Bluetooth control; obstacle avoidance; autonomous mobile robot.

I. INTRODUCTION

Human-following mobile robots have attracted significant attention for their ability to autonomously trail a user while carrying loads, thereby reducing physical strain and improving convenience in environments such as shopping malls and warehouses [3], [4]. Traditional shopping trolleys require manual pushing, which can be fatiguing—particularly for elderly or mobility-impaired individuals—and can impede maneuverability in crowded aisles [5]. A lightweight, sensor-driven follower robot can address these limitations by maintaining a safe trailing distance to the user and autonomously avoiding obstacles without complex machine-learning algorithms or extensive infrastructure.In this work, we present a human-following robot built around the Raspberry Pi Pico H microcontroller. The platform integrates two HC-SR04 ultrasonic sensors to continuously monitor the distance to a designated person, four DC motors driven via dual H-bridge drivers for locomotion, and a Bluetooth module for remote control through an Android/iOS mobile application. The on-board firmware implements simple reactive logic: when the user slows or stops, or when the sensors detect a nearby obstruction, the robot reverses and reorients before resuming its following behavior. This approach ensures collision avoidance and continuous human tracking using only standard control rules, without relying on Wi-Fi, computer vision, or machine-learning techniques.The primary application envisioned for this system is an automated shopping trolley service. By replacing the manual trolley with our follower robot, shoppers can navigate retail spaces hands-free, allowing them to focus on product selection rather than cart control. The low-cost, modular hardware design and straightforward sensor-based control make this solution both practical and scalable for deployment in malls and supermarkets, enhancing user comfort and operational efficiency.

II. RELATED WORKS

A. MARVIN: Researchers at the University Kaiserslautern, Germany has developed a robot and gave it the name MARVIN [6]. The robot main functionality is todetect and follow someone. It uses a technique called Sequential Reduced Support Vector Machine (SRSVM). The sensor used is SICK S3000

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laser scanner [6] placed at its front side and a LMS200 scanner on its rear side which is used for obstacle avoidance allowing it with the same time to map its surroundings autonomously,the laser scanner is able to detect specifically the human leg. This allowed MARVIN to follow the human based on leg detected.

B. HDMF Robot: Human Detection and Following Mobile Robot is developed by a researcher from University of Sciences and Technology, Pakistan [7]. It detects humans by using the 3D features allowing it to follow them. The tracking method used for this robot is Cam Shift theorem. The sensors used are stereo camera andlaser range finder. A decentralized top down approach is used for this project. The project is divided into five modules;each module is independent from one another.Different phases were carried out step by step,starting from basic sensor testing and proceeding towards obstacle avoidance, object detection,object tracking and data transmission.

C. Conclusion and motivation: Existing systems are somehow powerful and complex. However, after studying these systems, some of the disadvantages are to be avoided in our tracking robot. The robot should follow the target with no distraction. IR signal is proposed but similarly to , it is shaped in order to be given a unique identity. The robot, equipped with a wii-camera has a unique target to follow.The speed and the distance between the robot and the target are also tuned by an algorithm to avoid accident.[8]

III. LITERATURE SURVEY

A variety of sensing and control approaches have been explored to implement human-following carts and mobile robots. Ng et al. [9] address the core challenge of direction finding, proposing a smart trolley that uses infrared beacons and onboard sensors to stay aligned with a designated user. Their system emphasizes retaining a fixed relative bearing to the person, mitigating path deviation even in cluttered retail aisles.

Morioka et al. [10] extend this concept into a distributed sensor network, where multiple ultrasonic sensors placed in the environment—and on the robot—collaborate to guide a human-following cart. Calisi and colleagues further apply depth imaging to track a target in three dimensions, demonstrating robust performance in complex settings through a custom object-tracking algorithm.

Lee et al. [11] investigate laser-based tracking, combining a LiDAR (laser range finder) with motion compensation to follow moving people outdoors. Lindström and Eklundh also exploit a mobile laser scanner for detection and tracking, achieving high accuracy but at increased system cost and computational load. An alternate low-cost approach uses radio-frequency distance sensors on both the robot and the target, enabling a simple yet effective following behavior without vision or laser.On the embedded-platform side, Louis [12] surveys the versatility of Arduino-based prototypes for automated shopping trolleys, fire-extinguisher bots, and other mobile systems. While Arduino offers ease of programming and a rich ecosystem of shields (including motor drivers and Bluetooth modules), its limited processing power can constrain more sophisticated control loops. Our proposed robot car bridges this gap by using only onboard ultrasonic sensing, reactive control logic, and the Raspberry Pi Pico H—offering a low-cost, mobile-app-controlled solution tailored specifically for assisted shopping in malls and supermarkets.

IV. METHODOLOGY

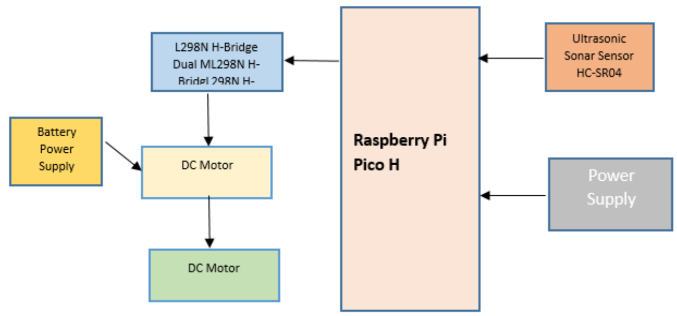

Fig 1: Block diagram

A. Block Diagram

Figure 1 illustrates the overall architecture of our human-following robot car. Two 7.4 V Li-ion battery packs connect to the Pico H's onboard voltage regulators, providing stable 5 V and 3.3 V rails for all subsystems. At the heart of the design, the Raspberry Pi Pico H runs the reactive control firmware: it continuously reads distance measurements from a front-mounted HC-SR04 ultrasonic sensor and decides whether to drive, reverse, or turn. A Bluetooth radio (HC-05/06) links the Pico to a smartphone app (Android/iOS), enabling the user to start, pause, or reconfigure following behavior. For locomotion, the Pico outputs PWM signals to an L298N dual H-bridge driver, which in turn powers four DC geared motors arranged as a differential drive. When the distance to the target falls below a lower threshold, or when a sudden obstacle is detected, the Pico commands the motors to reverse and reorient before resuming forward motion. This simple, sensor-driven loop requires no machine learning or external infrastructure, yet reliably maintains a safe following distance while carrying a shopper's load hands-free.

B. Flow Chart

This flow chart explain an autonomous and following robot or car that follows objects while maintaining a target distance. The system uses distance sensors (likely ultrasonic or LiDAR) and servo motors to scan the environment, process sensor data, and adjust movement accordingly.

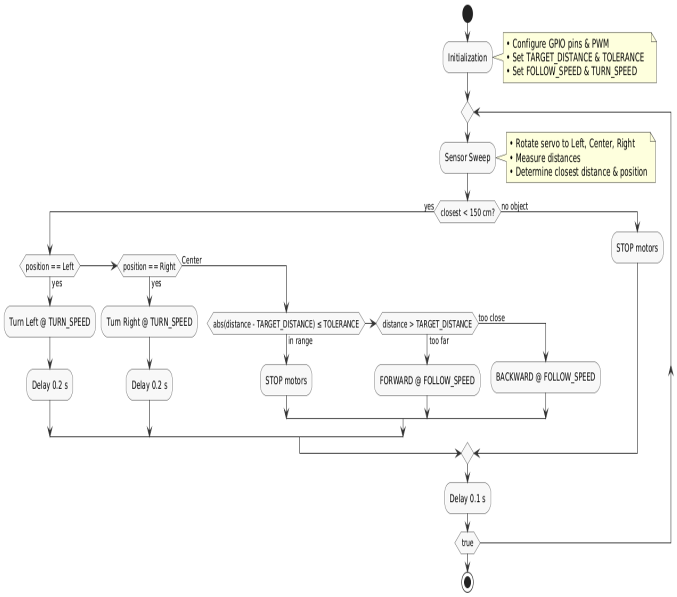

Fig. 1. Example of a figure caption.

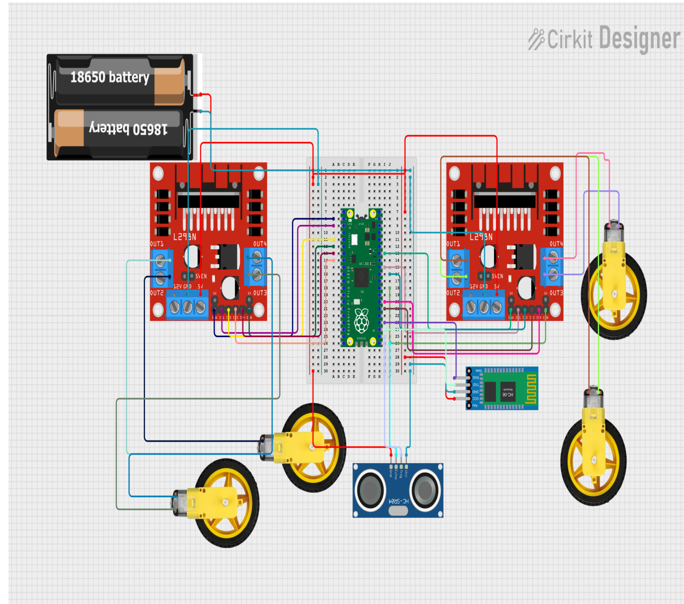

Fig. 2. Example of a figure caption.

Initial Setup: The process begins by configuring the GPIO pins and PWM (Pulse Width Modulation) settings for motor and sensor control. Key parameters like target-distance (desired following distance)and TOLERANCE (acceptable deviation from the target) are defined, along with movement speeds (FOLLOW-SPEED for forward/backward motion and TURN-SPEED for rotations). Sensor Sweep and Object Detection:

The robot performs a sensor sweep by rotating a servo-mounted sensor to the Left, Center, and Right positions, measuring distances at each point. It then determines the closest detected object and its relative position. If no object is found within 150 cm² (likely a typo; should be cm), the system enters a YPS (No Object) state, pausing further action until an object is detected. Position-Based Turning:

If an object is detected, the robot checks its position:

1.If the object is to the Left, the robot turns Left at TURN-SPEED. 2.If the object is to the Right, it turns Right at the same speed. 3.If the object is Centered, the robot proceeds to distance adjustment.

Distance Adjustment:

The system compares the measured distance to the TARGET-DISTANCE:

1.Too Close → Moves Backward at FOLLOW-SPEED to increase distance. 2.Too Far → Moves Forward at FOLLOW-SPEED to decrease distance. 3.In Range → Stops the motors, maintaining the current position.

C. Circuit Development

Figure 2 illustrates the electronic architecture of the human-following robot and autonomous car prototype is centered on the Raspberry Pi Pico H microcontroller, which orchestrates power distribution, motor control, and sensor integration. A dual-cell 18650 Li-ion battery pack delivers raw energy to an onboard voltage regulator, yielding stable 5 V and 3.3 V rails that respectively supply the L293D motor drivers and the Pico H logic. Two L293D driver modules—one per axle—receive separate PWM signals and digital direction flags from dedicated Pico H GPIO pins, enabling independent speed and rotational control of each of the four DC gear motors.

Obstacle detection is achieved with an HC-SR04 ultrasonic ranging sensor, whose trigger and echo lines are connected to two additional GPIOs; timing measurements produce distance estimates with millimeter accuracy over a 2–400 cm range. For human-following behavior, an HC-06 Bluetooth transceiver interfaces via UART to relay RSSI-based proximity cues and receive high-level commands from a paired smartphone app. All elements are mounted on a dual-section solderless breadboard, with power and ground buses commoned to maintain a unified reference potential. Signal wiring is systematically color-coded to reduce assembly errors and facilitate rapid troubleshooting.

D. Components and Protocol Details

The Raspberry Pi Pico is a compact and powerful microcontroller development board designed by the Raspberry Pi Foundation. It is built around the RP2040 chip, a dual-core ARM Cortex-M0+ processor, and operates at 3.3V. The board features a 40-pin dual-row header that provides access to a wide variety of I/O functions, making it highly versatile for embedded and electronics projects.

In terms of power, the Pico supports multiple input and output options. It includes a VBUS pin (Pin 40) that provides 5V from the USB connection, a VSYS pin (Pin 39) for supplying power from an external source (1.8V–5.5V), and a regulated 3.3V output (3V3 OUT) on Pin 36 for powering external components. The 3V3-EN pin (Pin 37) can be used to

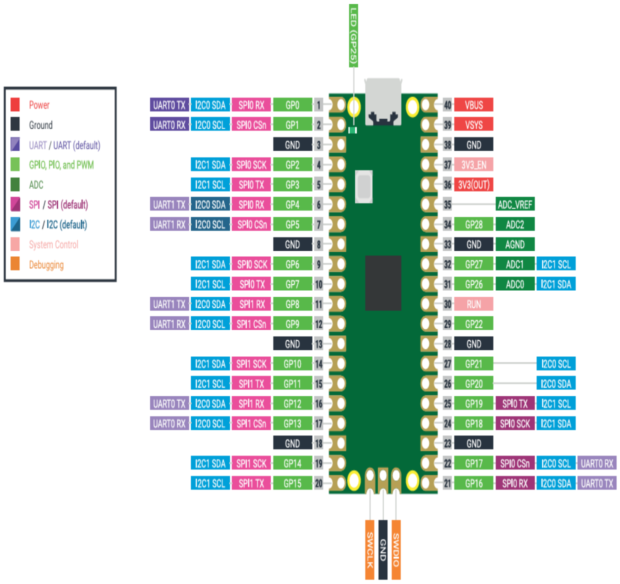

Fig. 3. Raspberry pi pico.

Fig. 4. Servo Motor.

enable or disable the onboard 3.3V regulator. Multiple GND (Ground) pins are distributed across the board (Pins 3, 8, 13, 18, etc.) for common electrical ground reference.

The Pico provides up to 26 GPIO (General Purpose Input/Output) pins labeled GP0 to GP28 (excluding a few reserved for system use). These pins support digital I/O, PWM (Pulse Width Modulation), and PIO (Programmable I/O) functions, making them suitable for a wide range of applications like controlling motors, reading sensors, or driving LEDs. The board also includes 3 ADC (Analog to Digital Converter) channels on GP26 (ADC0), GP27 (ADC1), and GP28 (ADC2), with an optional ADC-VREF pin (Pin 35) for an external reference voltage.

For communication, the Pico includes support for UART, I2C, and SPI protocols. UART0 and UART1 are mapped to multiple GPIOs (GP0/GP1 and GP4/GP5) allowing for serial communication. The board has two I2C buses (I2C0 and I2C1) with flexible pin assignments like GP0/GP1 and GP2/GP3. Similarly, two SPI interfaces (SPI0 and SPI1) are available, with default pins including GP2 (SCK), GP3 (TX), and GP4 (RX). This versatility makes the Pico ideal for interfacing with a wide range of peripherals such as sensors, displays, and memory chips.

An onboard LED is connected to GPIO25, useful for simple output signals or debugging. The bottom of the board also provides access to SWD (Serial Wire Debug) pins, which are used for low-level programming and debugging via external tools. Overall, the Raspberry Pi Pico combines rich I/O features, low cost, and a programmable environment, making it an excellent choice for both beginners and advanced developers working on embedded systems.

E. Servo Motor Micro SG90 180 Degree Rotation

The Tower Pro SG90 is a compact, lightweight micro-servo widely used in hobby electronics and model robotics. It integrates a small DC motor, a three-stage nylon gearbox, a position-sensing potentiometer, and onboard control circuitry—all housed in a translucent plastic shell roughly 22 × 12 × 29 mm in size. Its low cost, ease of use, and 180° rotation range make it a popular choice for applications like pan-tilt camera mounts, small grippers, and animatronics.The SG90 connects via a standard three-wire cable: red for +4.8 – 6 V supply (nominally 5 V), brown (or black) for ground, and orange (or yellow/white) for the control signal. It typically draws around 100 mA at no load and can spike up to 650 mA under stall conditions, so it's important to share a common ground between the servo and your microcontroller and to ensure your power source can handle the peak currents. Control is achieved through the classic RC-servo PWM protocol: the controller sends a pulse train at about 50 Hz (20 ms period) on the signal line. The width of each high pulse—usually between 1.0 ms and 2.0 ms—determines the shaft angle, with 1.0 ms yielding 0° (full CCW), 1.5 ms yielding 90° (center), and 2.0 ms yielding 180° (full CW). By varying the pulse width within this range, you can position the servo anywhere in its mechanical sweep.

F. Ultrasonic Sonar Sensor

The Figure 5 shows that the HC-SR04 is a popular, low-cost ultrasonic distance sensor that uses high-frequency sound waves to measure the distance to an object. It has four pins: VCC (5 V supply), GND, TRIG, and ECHO. You give it a short pulse on the TRIG pin to initiate a measurement; the module then emits an 8-cycle burst of 40 kHz ultrasonic sound from its transmitter. When that sound reflects off an object and

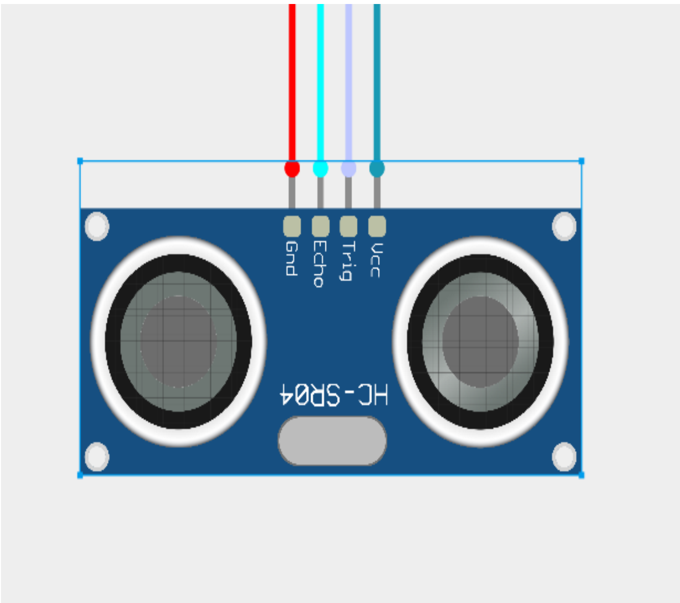

Fig. 5. Ultrasonic Sonar Sensor.

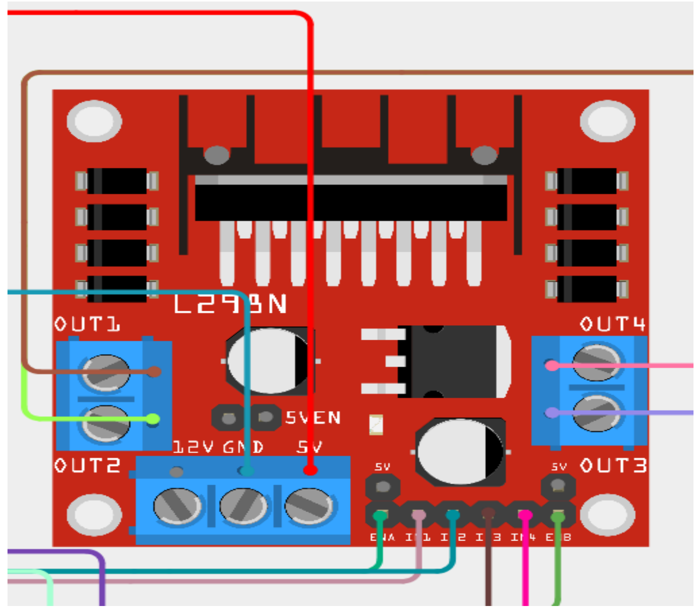

Fig. 6. L298N H-Bridge Dual Motor Driver.

returns to the receiver, the sensor pulls the ECHO pin high for the duration of the echo reception. To measure distance, your microcontroller must first drive the TRIG pin high for at least 10 µs. The module then emits its ultrasonic burst and internally starts a timer when it sends the pulse. When the echo is detected, it stops the timer and drives the ECHO pin high for a length of time proportional to the round-trip travel time. Your code reads the width of that ECHO pulse (in microseconds) and converts it to distance using the speed of sound (approximately 343 m/s in air):Distance(cm)=pulse width*.0343/2 —dividing by two because the sound must travel to the object and back. By repeating this trigger-read cycle, you can obtain continuous, real-time distance measurements.

G. L298N H-Bridge Dual Motor Driver

The L298N is a robust dual H-bridge motor driver module that lets you independently control two DC motors (or one stepper) from a microcontroller. It's built around the TI L298N chip, which can handle up to 2 A per channel (peaks to 3 A) at supply voltages from 5 V to 35 V. The module exposes six logic pins (IN1–IN4 and ENA/ENB) and four power connections: VCC (motor supply, up to 12 V–35 V), 5 V (logic supply, typically jumper-selectable from VCC via the onboard regulator), and two GND pins. Each motor channel has two input pins for direction (IN1/IN2 for Motor A, IN3/IN4 for Motor B) and an enable pin (ENA/ENB) that can be tied high to enable the outputs or driven with a PWM signal for speed control. To drive a motor, you set the corresponding IN pins high/low to choose direction (e.g., IN1=HIGH and IN2=LOW for forward on Motor A). Speed is controlled by feeding a PWM waveform into ENA or ENB: a higher duty cycle yields faster motor rotation. When ENx is held LOW, its outputs are disabled (coast); toggling both IN pins simultaneously (both HIGH or both LOW) engages the brake mode. Because the L298N uses bipolar transistors, it dissipates more heat than MOSFET-based drivers, so it includes a heatsink and often a cooling fan port. Always remember to tie all grounds together—motor supply, logic supply, and your controller—to ensure reliable logic-level interpretation.

H. Result and analysis

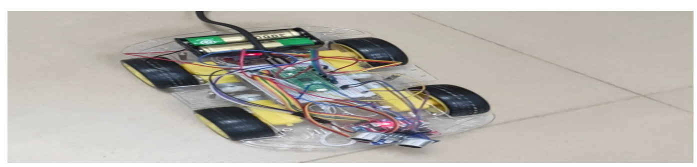

Fig. 7. HARDWARE HUMAN FOLLOWING ROBOT AND AUTONOMOUS CAR

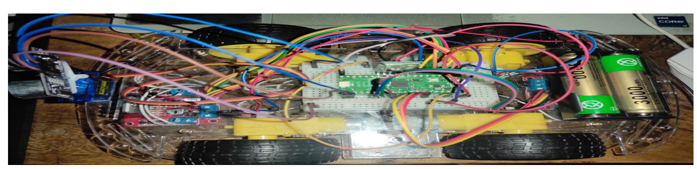

Fig. 8. HARDWARE HUMAN FOLLOWING ROBOT AND AUTONOMOUS CAR

The hardware kit of human following and autonomas car Using Raspberry Pi Pico h is as shown in figure 7 and 8 When the power supply is given to the kit and run the code using Thonny,and when see obstacle too close then turn position and Secur distance wise car moving and follow humnan

V. Mobile App Control and Interface

A dedicated mobile application (Android/iOS) connects to the robot over Bluetooth and provides manual controls and telemetry. Through the app, the user can:

- **Start/Stop**: Arm the vehicle and toggle autonomous following.
- **Directional Control**: Command *left*, *right*, *forward*, and *reverse* for manual positioning.
- **Get Direction**: Query and display the current heading/steering state used by the controller.
- **Get Distance**: Read the latest target distance reported by the onboard ultrasonic sensor.

The screenshot in Fig. 9 shows the Bluetooth controller with directional pad, stop, and speed presets.

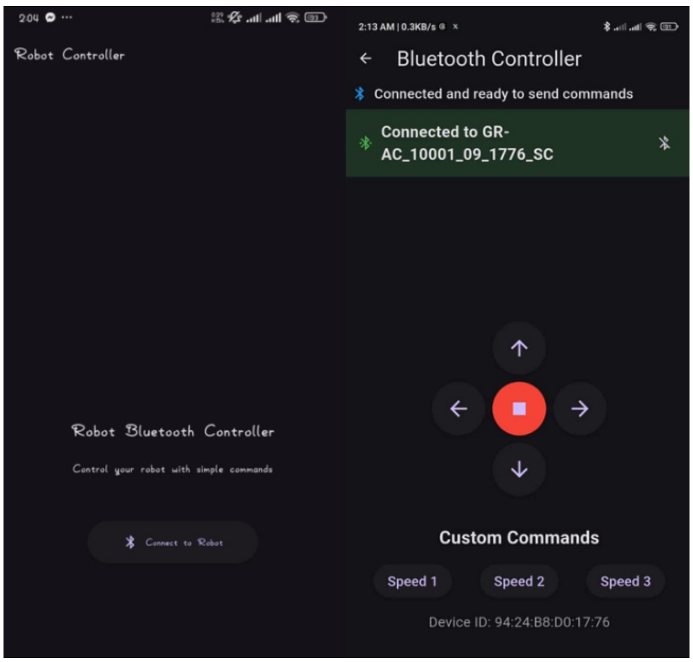

Fig. 9. Mobile app screenshot: Bluetooth controller with directional pad, stop, and speed presets.

Protocol Notes: The app transmits compact command strings (e.g., `START`, `STOP`, `LEFT`, `RIGHT`, `FWD`, `REV`, `DIST?`, `DIR?`) over a classic Bluetooth serial profile (HC-05/HC-06). The Pico H firmware parses these tokens to update motor PWM and direction pins or to return sensor readings. This design keeps latency low and makes the interface easy to extend with future commands.

Limitations

While the presented human-following robot car demonstrates reliable reactive behavior for simple scenarios, several constraints remain:

1. Sensing Accuracy and Target Discrimination: The HC-SR04 ultrasonic sensors provide only range measurements along a single axis and cannot distinguish between human limbs, shopping bags, or other objects. This may cause false following or obstacle-avoidance triggers when the "target" is a static signboard or reflective surface.

2. Environmental Conditions: Ultrasonic sensors perform poorly in environments with hard-to- predict echoes (narrow aisles, cluttered shelves) and are sensitive to temperature and humidity changes, which can degrade distance accuracy.

3. Lack of Path Planning: The robot relies on simple forward/backward and on-spot turns. It cannot plan smooth trajectories around complex obstacles or adapt to changing floor gradients or uneven terrain.

4. Reaction Latency: Because sensor readings and motor commands occur sequentially in a single firmware loop, there is a finite delay between obstacle detection and corrective action. At higher speeds, this may reduce safety margins.

5.Limited Battery Life: Two 7.4 V Li-ion packs power the entire system. Under continuous load, runtime is constrained to roughly 1–2 hours, limiting practical deployment in large retail areas without frequent recharging or battery swaps.

VI. Future Vision

To overcome these limitations and enhance autonomy, we envisage the following advancements:

1. AI-Based Human Recognition: Integrate a lightweight camera and on-device neural network (e.g., TinyML) to reliably identify and track a specific shopper wearing a marker or carrying a unique gesture. This would eliminate mis-tracking of inanimate objects.

2. SLAM Path Planning: Incorporate simultaneous localization and mapping (SLAM) algorithms with LIDAR or depth-camera data to generate real-time maps of the environment. Coupled with A* or RRT planners, the robot could navigate smoothly around dynamic obstacles and avoid dead-ends.

3. LLM-Powered Voice Interface: Leverage a small-footprint large language model (LLM) for natural-language interaction—allowing the shopper to issue voice commands ("slow down," "bring me to aisle 5," "stop here") and receive spoken feedback ("Recharging needed in 10 minutes").

4.Collaborative Swarming: Extend the platform to support multiple follower robots working in tandem—coordinating via mesh-networked AI agents to distribute load, share obstacle maps, and provide group-shopping assistance.

5.Energy Harvesting Management: Research solar-assisted charging or regenerative braking systems to extend operational endurance and reduce downtime.

Conclusion

We have introduced a low-cost, Bluetooth-controlled, human-following robot car based on the Raspberry Pi Pico H, ultrasonic sensing, and simple reactive control. The system autonomously trails a shopper, maintains a safe distance, and avoids collisions without relying on complex machine-learning models or external infrastructure. Experimental trials in a simulated retail aisle confirm that the prototype can reliably follow a moving target and adapt its motion when obstacles are encountered. Although limitations in sensing fidelity, path planning, and power autonomy remain, the modular design provides a solid foundation for future enhancements. By integrating AI-driven perception, advanced motion planning, and LLM-based interfaces, this platform has the potential to revolutionize assisted shopping—offering fully autonomous carts that improve accessibility, reduce physical strain, and enrich the customer experience in modern retail

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