International Journal of Mechatronics and Technology, Vol. 01, No. 01, pp. 35-43(2026)

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CONTROL OF 2-WHEEL DRIVE MOBILE ROBOT USING SPEECH RECOGNITION

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(*Received date Nov 20 2025; Revised date Dec 23 2025; Accepted date Jan 10 2026*)

ABSTRACT–In this paper, a design of a 2-wheel drive (2WD) mobile robot that is controlled by using speech recognition is proposed. The mobile robot operates with a speech recognition module that can interpret a set of commands spoken by a human. Based on the command received, the mobile robot makes a certain movement in its environment, as it is guided from a starting point to a destination point. Besides, the mobile robot is equipped with one ultrasonic sensor and two infrared sensors, so that it can avoid collision with objects in the surroundings. The constructed mobile robot fulfils the design objective successfully. The mobile robot is able to be triggered and comprehend a set of commands. Thereafter, the commands are translated into the rotation of the two in-wheel motors, so that the mobile robot can move forward, turn left, turn right, move backward, and stop. The mobile robot will stop moving forward if the sensors detect any obstacles, and it is to be directed to get around the obstacles. The mobile robot is effective in carrying objects with a weight of 400 grams. The mobile robot is reckoned to be a model for next-generation robots that assist humans in transporting objects in domestic and industrial activities.

KEY WORDS: 2-wheel drive, mobile robot, speech recognition, obstacle avoidanc

1. INTRODUCTION

A robot is a machine that resembles a living creature in being capable of moving independently (as by walking or rolling on wheels) and performing complex actions (such as grasping or moving objects). The development of robots involves collaborative work between the mechanical part, the electronic part, the computing part, and the information part. Robots are expected to become intelligent machines that can assist humans in their daily lives.

A robot can be designed to exhibit a much higher physical limit compared to a human. This can make a robot very helpful to perform tasks in hazardous environments, such as a room with high or low air temperature or terrains contaminated with radioactive materials (Karthikeyan, Sundaram, and Rajesh, 2022). Moreover, a robot can replace humans to do repetitive, simple tasks, such as transporting objects from one place to another (Agung, 2024). By letting this be done by a robot, the time and energy saved can be diverted to focus on other things.

The communication between a robot and its user can be created via a wired or wireless connection. A wired connection can be established by using metal wire or fiber optics wire, keeping the physical connection between the user and the robot. Wireless connection can be constructed via radio frequency, infrared, or Bluetooth, requiring a specific module for a transmitter at the user's side and a receiver at the robot's side (Yang and Zhang, 2020).

Another form of wireless communication that can be used to deliver commands from a user to a robot is speech, using acoustical air as a medium of communication. This requires a speech recognition technology, one that is increasingly associated with recent electronic device developments. Through the use of speech recognition, a machine or a program is able to identify spoken language in the form of words and phrases (Jamal, Al-Qurabat, and Idrees, 2025). In the case that speech is used to control a robot, the transmitter is simply the user's voice. This connection will be effective as long as the robot is operated within the audible range of the user.

For the purpose of transporting objects, a robot is required to be capable of moving around its environment.

This kind of robot is called a mobile robot. A mobile robot can move by using legs, wheels, or tracks. Wheeled mobile robots become very popular because of their relatively low mechanical complexity and energy consumption. Wheeled mobile robots are already applied in the area of surveillance, inspection, exploration, and transportation. In designing a wheeled mobile robot, the movement can be programmed by complex kinematic and dynamic models, able to perform complicated tasks such as picture drawing (Husain, Al-Mawed, and Abdel-Hafez, 2024). At the other end, the movement of a wheeled mobile robot can be done based on a certain self-navigating algorithm and an obstacle avoidance mechanism, by using ultrasonic sensors (Dhar et al., 2021).

Considering the facts mentioned above, the author is motivated to construct a 2-wheel (2WD) drive mobile robot that is able to carry a load and to execute movement commands given by speech (Pratama, Nasution, and Manyele, 2024). The mobile robot is intended to perform repetitive carrying tasks for relatively light objects such as a key, a small box, or a cup of water.

A microcontroller is normally used as the brain of the mobile robot (Reddy and Kumar, 2023). The mobile robot is to be equipped with a speech recognition module that can convert a number of words into distinct codes that can be linked to certain movement commands. The mobile robot should also have a collision-avoiding mechanism, utilizing ultrasonic sensors and infrared sensors.

2. THEORETICAL BACKGROUND AND DESIGN SPECIFICATIONS

2.1. Microcontroller

A microcontroller is a small computer on a single integrated circuit (IC) containing a processor core, memory, and programmable input/output peripherals (Rizvi, 2019). Any equipment that requires some sort of intelligent control based on various inputs involves a microcontroller (Alciatore and Hitand, 2019). A basic layout of a microcontroller is shown in Figure 1.

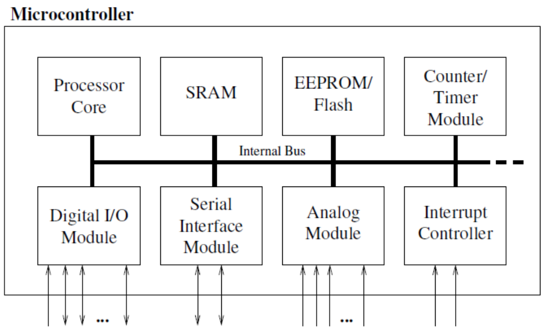

Figure 1. Basic layout of a microcontroller

In this research, the microcontroller considered suitable to support the 2WD mobile robot designed is the Arduino Mega 2560. The appearance of this microcontroller can be seen in Figure 2. It is a microcontroller board based on the Atmel AVR ATmega 2560 MCU (Arduino, 2026).

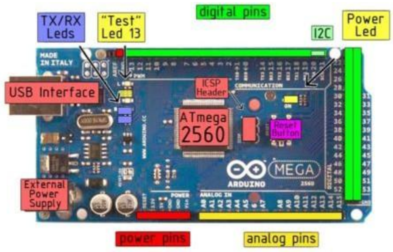

Figure 2. Arduino Mega 2560 pinout (Arduino, 2026)]

The algorithm to operate and control the mobile robot is programmed by using the software Arduino Integrated Development Environment (Arduino IDE), which is compatible with Arduino Mega 2560. The Arduino IDE is a cross-platform application written in Java. The Arduino programs themselves are written in C or C++. From now on, the Arduino Mega 2560 will be referred to as Arduino Mega.

2.2. Speech Recognition

Speech recognition is the mechanism conducted by a computer program to convert speech into a sequence of words.

In a speech generation-perception process, as modeled in Figure 3, a speech is initiated by a text (word sequence) generation in a speaker’s mind. The text W is transformed by a speech generator (human vocal mechanism) to produce a speech waveform. The waveform is transmitted through the air and is perceived by a listener’s hearing system. Then, a signal processing happens to yield a received acoustical signal X. The listener’s mind starts to decode the received information content into a word sequence W ˆ and finally comprehends it.

The problem of speech recognition is to simulate and to model how a listener processes a speech produced by a speaker. The perception process can be seen as an inverse of the speech production process. Extensive elaboration of speech recognition methods can be found in, which is considered an essential reference in the area.

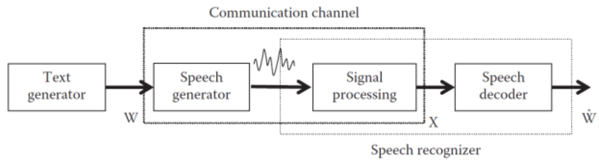

Figure 3. A model of the speech generation-perception process

EasyVR 3.0 shield, as seen in Figure 4, is a multi-purpose speech recognition module. The EasyVR 3.0 shield module is powered at 3.3V-5V and can be used with any host with a UART interface (Fortebit, 2023). The EasyVR 3.0 has one trigger word and 3 standard wordsets for each of the languages English, Italian, Japanese, German, and French. In addition, a speaker-dependent trigger and a wordset, as well as voice passwords, can be spoken in any language.

Figure 4. EasyVR 3.0 shield

The EasyVR Commander software is the environment provided by the manufacturer of the EasyVR 3.0 shield to program the shield (Fortebit, 2023). By using the EasyVR Commander, with the open window shown in Figure 5, the EasyVR 3.0 shield can be easily configured if directly connected via USB to a personal computer or plugged to an Arduino Mega as a host board.

The EasyVR 3.0 shield, from now on, will be referred to as EasyVR or EasyVR shield, interchangeably, and is regarded as a suitable component to equip the proposed 2WD mobile robot with a speech recognition ability. The shield is readily available and can fulfil the requirement to have a wordset with enough commands, to be used to control the movement of the mobile robot.

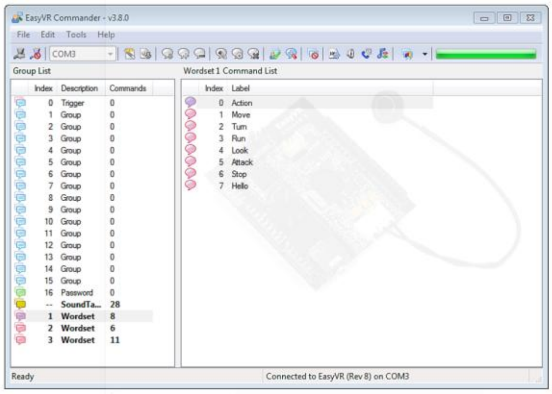

Figure 5. EasyVR Commander window

2.3. DC Motors

A DC motor is a class of electrical motor that converts electrical energy in the form of direct current into mechanical energy in the form of rotational movement.

The main components of a DC motor are the rotor and stator, as can be seen in Figure 6(a). The stator typically has 2 permanent magnets, located opposite each other in a motor case. The rotor is a rotating part of the electric motor itself. It is built around a shaft and has windings of copper wire.

When electric current flows through the rotor's windings, a magnetic field is created and will push and pull against the 2 permanent magnets of the stator. A torque is created, and the motor is rotated. It is depicted in Figure 6(b). The shaft comes out at the end of the motor case, which is attached to other components such as wheels, blades, gears, etc.

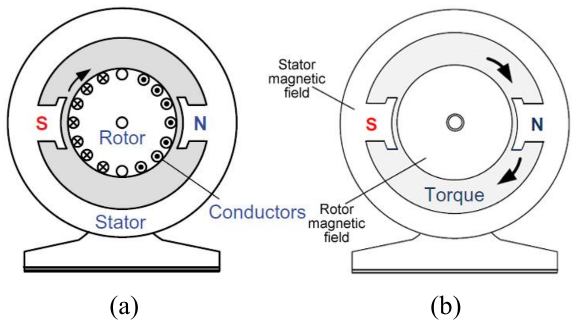

Figure 6. DC motor; (a) The main components, (b) Torque created by the magnetic field (Kim, 2017)

Two in-wheel DC motors, one of which is shown in Figure 7, are used as the prime movers of the proposed 2WD mobile robot. The DC motors operate in the range of 3 V to 6 V, with a maximum torque of 800 gf.cm.

The driver used by the DC motors is IC L293D. It consists of two-quadruple high-current half-H bridge drivers. An H-bridge is an electronic circuit used to control the rotation and direction of the motors and to apply brakes to the motors. It enables a voltage to be applied across a load in any polarity. The L293D is designed to provide bi-directional drive currents of up to 600 mA at voltages from 4.5 V to 36 V.

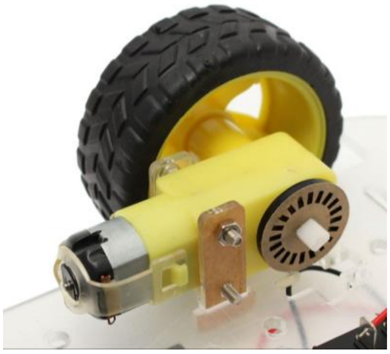

Figure 7. Robot wheel with an in-wheel DC motor

2.4. Ultrasonic Sensor

An ultrasonic sensor will be useful for the proposed 2WD mobile robot, so that it can detect and avoid obstacles in its surroundings. The working principle of an ultrasonic sensor is similar to that of a radar and a sonar. Here, a transmitter generates and propagates ultrasonic waves. The waves are then reflected by nearby objects. The distance to an object is interpreted from the difference between the time when the waves are propagated and the time when the waves are received back.

One possible choice of this device is the HC-SR04 ultrasonic sensor. It is excellent for non-contact range detection, always giving continuous measurement results between the range of 2 cm and 400 cm. The module comes complete with an ultrasonic transmitter (TX) and an ultrasonic receiver (RX) (Cytron Technologies, 2020). The schematic is shown in Figure 8.

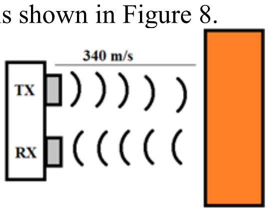

Figure 8. Ultrasonic HC-SR04

The HC-SR04 sends 8 pulses with a unique pattern at a frequency of 40 kHz. Assuming the value of wave velocity equals 340 m/s, the distance to a nearby object within the sensor's 15°-measuring angle can readily be calculated as:

$$\text{Distance} = v \cdot \left(\frac{\Delta t}{2} \right), \quad (1)$$

where v is the wave velocity through air, and Δt is the time interval between transmitting and receiving the waves.

2.5. Infrared LED and Infrared Receiver

Two self-constructed infrared sensors are used to further improve the ability of the 2WD mobile motor to prevent collisions with obstacles during its movement. Each of the infrared sensors is made of an infrared LED TSAL6400 (Vishay Semiconductors, 2025) and an infrared Receiver HS0038B (Vishay Telefunken, 2000). Both components are shown in Figure 9.

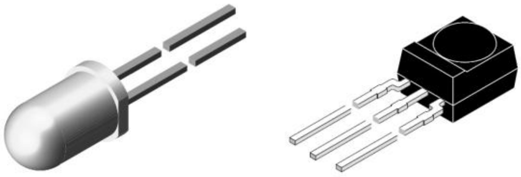

Figure 9. Infrared LED TSAL6400 and infrared receiver HS0038B

The LED is set to modulate at a frequency of 38 kHz for 10 ms every second. The duty cycle of the pulse can be initially set to 50 %. If an object stands in front of the LED's cone, the object will reflect the infrared pulse.

The infrared receiver is mounted close to the infrared LED, heading in the same direction. This receiver has a built-in demodulator, working at 38 kHz, too. If the receiver can detect the reflected infrared waves, then it means that an object is in the detection range of the sensor. Thus, this infrared sensor only gives information on whether the object is closer or farther than a certain calibrated distance. The sensor does not particularly measure a certain distance value.

The duty cycle can be used to adjust the detection range of the infrared sensor. Decreasing the duty cycle will reduce the radiated waves of the LED. Thus, a reflection will only be received when the object is closer in distance. Increasing the duty cycle will do the opposite.

3. DESIGN IMPLEMENTATION

The overall system of the mobile robot is to be controlled by the Arduino Mega. This microcontroller drives the DC motors. Besides, it reads the input from the EasyVR shield, the ultrasonic sensor, and the two infrared sensors. One LED and one RGB LED are used as indicators of the system state. The block diagram of the mobile robot is presented in Figure 10.

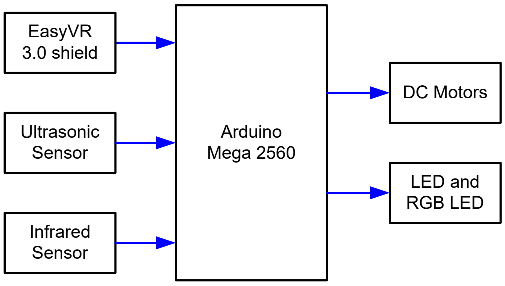

Figure 10. Block diagram of the 2WD mobile robot

The chassis of the mobile robot is made of acrylic, having 3 layers with a total height of 12.8 cm. The layers have a round shape with a diameter of 20 cm, cut straight on both sides. Figure 11 shows the appearance of the chassis, with all three wheels mounted. The left and right wheels are powered by DC motors, while the rear wheel is meant to maintain the stability of the mobile robot.

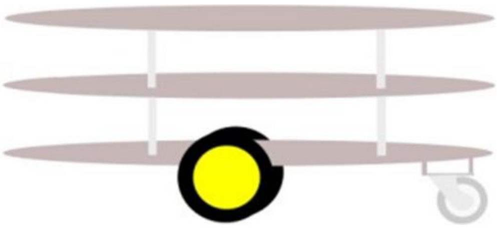

Figure 11. The chassis of the 2WD mobile robot with mounted wheels

The EasyVR shield is compatible with the Arduino Mega. For pairing, both of them can be plugged together. The EasyVR shield is fixed on the middle layer of the mobile robot, while the EasyVR's microphone is placed on the top layer. The shield can receive instructions or commands from a distance of 3 meters.

The trigger word for EasyVR is "robot." This trigger word can be regarded as a password, which enables further commands in a certain wordset. The second wordset of the EasyVR shield is chosen to be used. This wordset contains 6 commands, with only 5 commands used: "left" to turn left, "right" to turn right, "forward" to continuously move forward, "backward" to slightly move backward, and finally "down" to stop moving. The user can give any combination of these commands as the mobile robot is guided to move from a starting point to a destination point.

The ultrasonic sensor is installed at the second layer, at the midpoint of the front side. The two sets of infrared sensors are mounted to the left and to the right of the ultrasonic sensor, each making a 30° deviation from the forward direction to the corresponding direction. The configuration of the sensors can be seen in Figure 12.

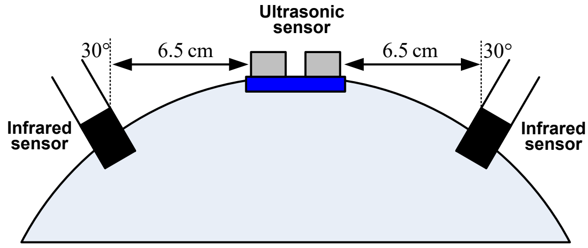

Figure 12. Avoidance sensors configuration

The infrared sensors are calibrated to start detecting obstacles at a distance of 20-cm distance. If any sensor detects an obstacle within this range, the mobile robot will stop. Then, the user must give a new direction so that the mobile robot can move around the obstacle.

The connections of all components to the Arduino Mega are depicted in Figure 13. The power for the mobile robot is provided by a 9798 Lego Mindstorms NXT rechargeable battery. The battery has a capacity of 1400 mAh, with an operating voltage of 7.4 V. All other components are powered by this battery through the Arduino Mega.

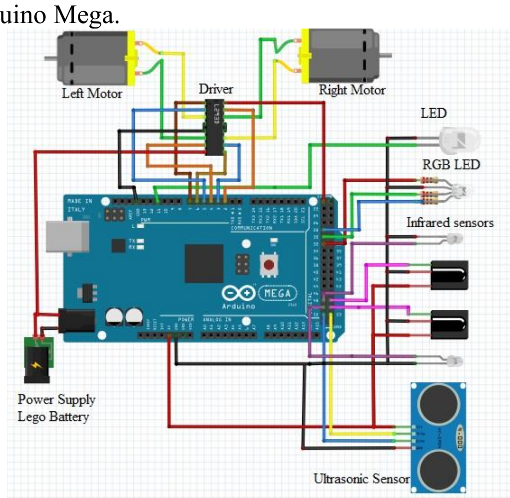

Figure 13. Hardware connections to the Arduino Mega

An RGB LED is used to indicate whether a spoken command can be correctly interpreted by the EasyVR. Furthermore, an LED is used to show whether the second wordset of EasyVR and the obstacle avoidance sensors are all activated.

The flowchart of the proposed 2WD mobile robot is shown in Figure 14. If a trigger word is correctly received by the EasyVR, the wordset and the obstacle avoidance sensors will be activated. This will be indicated by the light of the green LED. Now, the mobile robot is ready to receive one of five possible commands: turn left, turn right, stop, move forward continuously, or move backward slightly. The move forward command is conducted continuously until the robot is automatically stopped by any possible obstacles.

If an obstacle is detected, the mobile robot will directly stop after making an appropriate turn. The turn is to be followed by other turn commands until the needed orientation is reached. Then, the robot can be guided to move forward again. This procedure is repeated until the mobile robot can be guided successfully to reach the destination point.

4. RESULTS AND DISCUSSION

The final result of the 2WD mobile robot construction is now presented. In Figure 15, the ultrasonic sensor and the two infrared sensors are marked with orange and green, as the mobile robot is seen from the front side. The rear view of the mobile robot is shown in Figure 16. The microphone of the EasyVR is marked red, the RGB LED is marked orange, and the green LED is marked yellow.

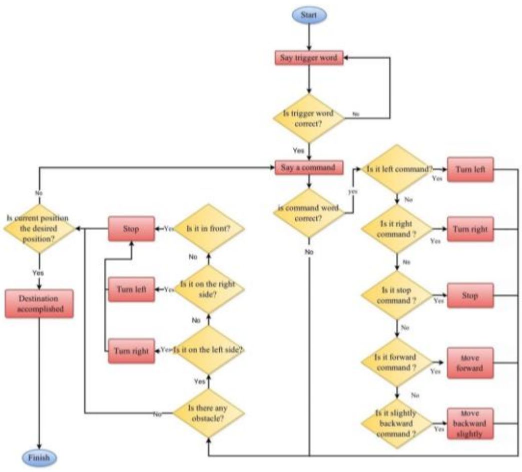

Figure 14. The flowchart of the 2WD mobile robot

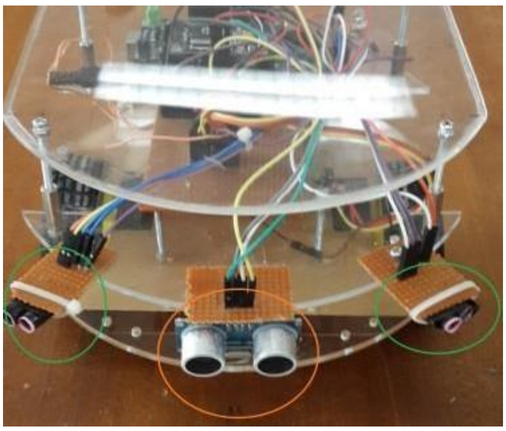

Figure 15. The front view of the 2WD mobile robot

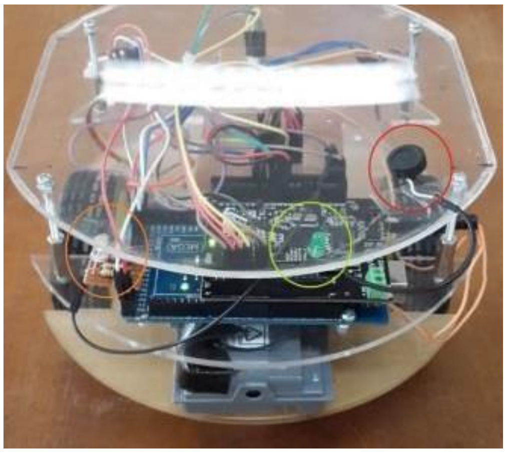

Figure 16. The rear view of the 2WD mobile robot

The functionality of the EasyVR is tested by speaking the trigger word and the command words while observing the LED indicators. In Figure 17, as the trigger word “robot” is said correctly, the EasyVR can detect the word, and the Arduino Mega turns on the green LED. Immediately after this, the mobile robot starts listening to any further commands and the obstacle avoidance sensors are activated.

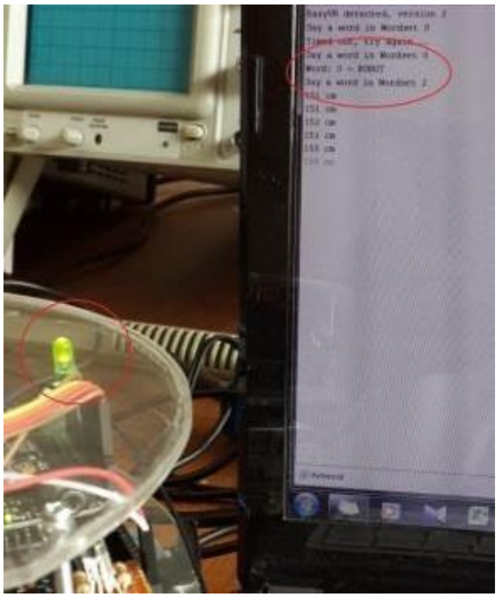

Figure 17. The trigger word “robot” is received by the EasyVR successfully

In Figure 18, after the command “right” is said correctly, the RGB LED will turn on in purple. This is an indicator that the command is correctly understood by EasyVR. The command is then relayed by the Arduino Mega to the DC motors so that the left wheel rotates forward and the right wheel rotates backward. After 1 second, the mobile robot comes back to stand by position, ready to receive the next command.

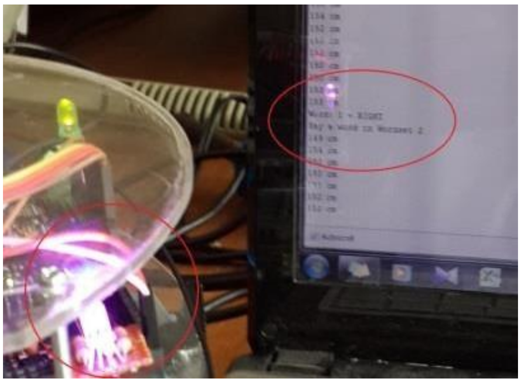

Figure 18. The command “right” is received by the EasyVR successfully

The same procedure is done to check the response of the mobile robot if the command “backward” is given. If the command is understood correctly by the EasyVR, the RGB LED turns on in yellow, as shown in Figure 19. In this case, both left and right wheels will turn backward for 1 second. Then, the mobile robot will wait for the next command.

Figure 19. The command “backward” is received by the EasyVR successfully

The mobile robot is also tested to receive the rest of the commands. The EasyVR can correctly interpret every command, and the Arduino Mega turns the correct wheels to correct directions, accordingly.

In the next step, the mobile robot is tested to receive a series of commands as it is guided to move from a starting point to a destination point. The illustration of the test arrangement is shown in Figure 20. A set of obstacles is placed along the designated path. The mobile robot can move without hitting any obstacles. If an obstacle is detected, the mobile robot directly stops. The user must give the command “left” or “right” several times until a correct direction for the mobile robot is achieved. Later on, the movement can be continued by using the command “forward”, where the mobile robot will continuously move until it detects the next obstacle or any other command is given.

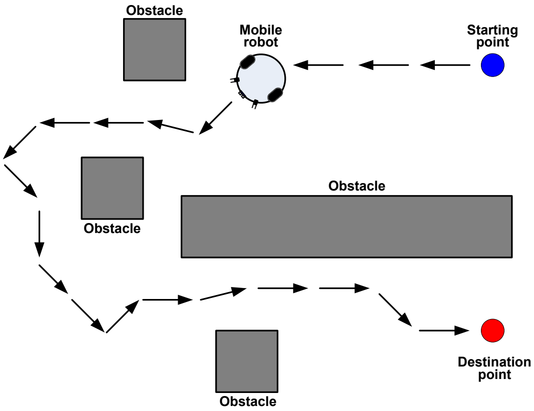

Figure 20. The mobile robot is guided from a starting point to a destination point

The command tests and the guided-movement experiments confirm that the Arduino Mega, as the microcontroller, is successfully integrated and programmed with the EasyVR shield. The EasyVR shield is able to recognize speeches from different speakers without any problem. The obstacle avoidance sensors and the DC motors enable the mobile robot to travel along, according to the command spoken by the user, without any collisions. The DC motors is also proven to be strong enough to move the robot while it carries a load of approximately 400 grams, in the form of 2 units of small-sized smartphones.

During the experiments, it was found that the mobile robot tends to move in a curve path instead of a straight-line path. This is because the two powered wheels are not identical in terms of rotation speed even when the same input is fed to both of them. To overcome this matter, the weight of the mobile robot is centered and balanced, thus giving equal burden to both wheels. Besides, the number of rotations is also balanced by giving different lengths of on-state duration to each DC motor.

The EasyVR shield will work best in a noise-free environment, the given commands cannot be interpreted correctly. The infrared sensors, as opposed to the ultrasonic sensors that can detect the distance of any surface with equal accuracy, cannot work properly to detect the distance of dark-colored obstacles. The dark-colored surfaces are not so reflective for infrared waves compared to the light-colored surface. This causes a shorter distance for obstacles to be detected, less than 20 cm.

5. CONCLUSION

A 2-wheel drive (2WD) mobile robot controlled with speech recognition is proposed in this paper. The mobile robot is also equipped with obstacle avoidance sensors. The mobile robot is successfully tested to move from a starting point to a destination point, guided by spoken commands. Furthermore, the mobile robot is successfully applied to carry small objects. Thus, it can later be deployed to perform repetitive carrying tasks for light and small objects.

The mobile robot is built with components such as Arduino Mega 2560, EasyVR 3.0 shield, one ultrasonic sensor, and two self-constructed infrared sensors. With the use of these sensors, any obstacles can be detected from 20 cm. Then, the robot can be controlled to go around the obstacles. The torque and power delivered by the DC motors are enough to carry a weight of 400 grams.

The achievements reached by the proposed 2WD drive mobile robot become a starting point for further development of mobile robots with larger dimensions built with stronger materials and equipped with stronger prime movers. By then, the mobile robot will be able to carry a relevant load, and will be able to considerably help the user in daily domestic and industrial activities.

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