AStar-Algorithm based Voice-Controlled Wheelchair for Quadriplegic Patients

Mohamed R. Abdelkader
Electronics and Communications Dept., Faculty of Engineering, Helwan University

Eslam T. Abdullah
Electronics and Communications Dept., Faculty of Engineering, Helwan University

Rana A. Mohamed
Electronics and Communications Dept., Faculty of Engineering, Helwan University

Rehab K. Salam
Electronics and Communications Dept., Faculty of Engineering, Helwan University

Omar Y. Mohamed
Electronics and Communications Dept., Faculty of Engineering, Helwan University

Azza M. Anis
Electronics and Communications Dept., Faculty of Engineering, Helwan University

ABSTRACT
Physical disabilities caused by ageing, accidents, and diseases, pose significant challenges for individuals, hence affecting their mobility and communication abilities. Besides, the conventional control mechanisms proved ineffective for individuals with hand injuries or paralysis. Therefore, assistive devices such as wheelchairs have received much interest in recent years. In this paper, a voice-controlled wheelchair based on AStar-algorithm is proposed to overcome these limitations. The proposed design consists of a microcontroller interfaced with an ultrasonic sensor, a rotary encoder, a gyroscope, and motors for rotating the wheels in a specific direction. Moreover, an android application is created to send voice commands via a bluetooth module to interact with the microcontroller unit. The proposed system allows users to communicate easily to their desired destination using voice commands, then the wheelchair will autonomously find the shortest path and guide a user accordingly. The validity of the design is confirmed by Proteus simulations. After that, the capability of mobile application for fast communication between a user and the design is verified. Finally, a prototype for the proposed voice-controlled wheelchair is implemented and tested for different destinations.

Keywords
AStar-Algorithm, Voice-Controlled, Wheelchair, Sensors, Microcontroller, Motors, Android Application

1. INTRODUCTION
According to the world health organization reports, around 15% of the world population are handicapped [1]. Therefore, the use of a wheelchair is necessary to assist handicapped patients with quadriplegia, amputee, and paralyzed. Besides, the easiness, comfort, and safe use of a wheelchair are important factors that directly affect the users' social efficiency and the quality of their life. The first automated electric wheelchair was invented by George Klein for the World War II veterans [2]. After that, many researchers have developed wheelchairs that controlled with several techniques based on hand-gesture [3–6], eye-tracking [7–9], electroencephalogram (EEG) signals [10–13], and others. The main challenge for hand-gesture control is the misrecognition of gestures and not suitable for patients with paralyzed hands or who have limited limb movement [14]. As for eye-tracking systems are expensive and not viable for large-scale applications [15]. In addition, the processing techniques of EEG signals is difficult to implement and may harm the physical health of a user [16]. At the same time multiple designs based on voice recognition have been introduced [17-23]. However, many limitations including complex data processing, high cost, and additional hardware requirement made these systems not much suitable. Hence, it is essential to develop advanced designs that allow more comfortable collaboration with the wheelchair. In this paper, a voice-controlled wheelchair prototype is presented. The proposed wheelchair communicates with a mobile application by voice commands. The mobile application sends voice commands via a bluetooth module to a microcontroller unit. Then, the microcontroller controls the motor driver and allows motion in all directions. Moreover, AStar-algorithm is applied to compute the shortest path for the wheelchair to reach its desired destination. The proposed wheelchair enables users to navigate their desired locations effortlessly with only one voice command. user just says the direction and the wheelchair moves to the desired direction. The paper is arranged as follows: the hardware design of the proposed wheelchair and its flowchart are presented in Section 2. The results of the proposed prototype are verified in Section 3. The conclusion is introduced in Section 4.

2. PROPOSED WHEELCHAIR
The block diagram of the proposed wheelchair is presented in Figure 1. The main part of the design is a microcontroller unit that communicates with input and output terminals. The input modules to the proposed wheelchair includes an ultrasonic sensor to detect obstacles and provide a user with alerts regarding their presence. A rotary encoder for detecting position and speed by converting rotational mechanical displacements into electrical signals. A gyroscope sensor to measure the angular velocity and the acceleration along the three axes for enabling precise motion tracking and orientation sensing. The sensors gather the required data from the surroundings environment. Then, the microcontroller analyses the sensed signals and utilizes the AStar-algorithm to calculate the shortest path for the desired destination. After that, the microcontroller outputs signals related to desired destination into two motors through a driver for rotating the wheels in a specific direction or bringing them to a stop as instructed.

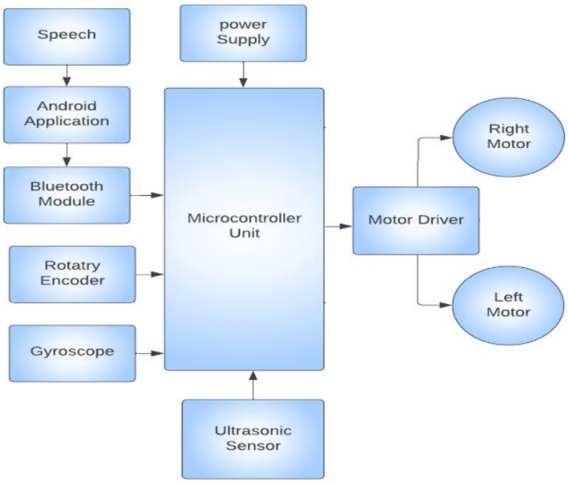

Fig 1: Block diagram of the proposed system

There is also a bluetooth module for the interaction between the wheelchair and an android application. Figure 2 shows the flowchart that outlines the communication between a user and the wheelchair. In the beginning, the mobile application, "Wheel Chair Controlles", is started. The bluetooth of a user's mobile is connected to the bluetooth module of the prototype. Then, the presence of any obstacles is verified; if there are any obstacles, the wheelchair stops automatically.

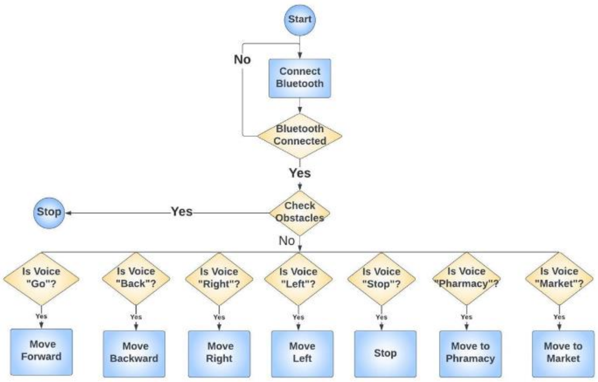

Fig 2: Flowchart of the proposed system

As long as there are no obstacles, the microphone remains active, waiting for the voice commands. After that, the user gives commands such as "Go," "Right," "Left," "Stop," or "Back" to move into a specific direction. The user can also say one of his frequently visited locations such as "Market" or "Pharmacy", and the wheelchair will automatically navigate to the shortest route to that destination.

3. RESULTS AND ANALYSIS

The results of the proposed design are implemented by Proteus simulations. The interconnections between modules and their functions are verified. Figures 3 and 4 show the obstacle detection process in the surrounding environment when interfacing the ultrasonic sensor with the microcontroller unit. By employing the rotary encoder's sensing capabilities as shown in Figure 5, the microcontroller unit captures then interprets the changes in the position, hence facilitating accurate real-time tracking.

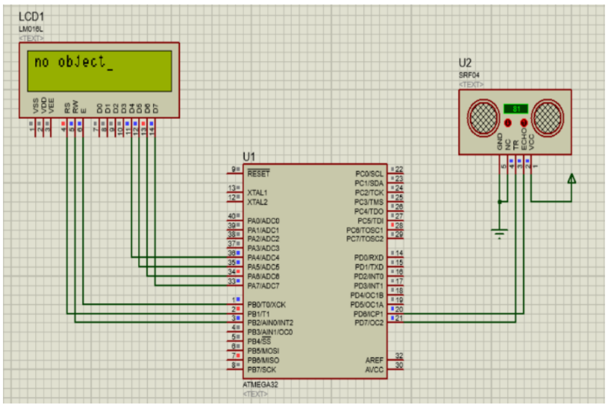

Fig 3: Interfacing ultrasonic sensor with microcontroller (no obstacles)

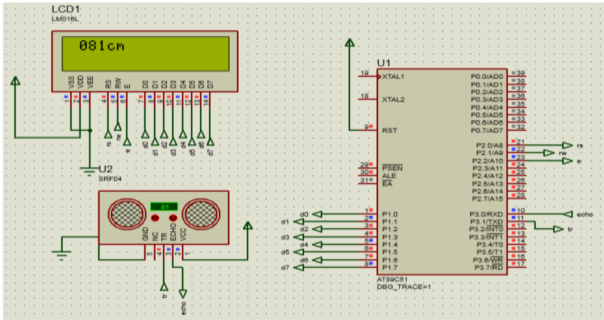

Fig 4: Interfacing ultrasonic sensor with microcontroller (obstacle exist at a distance)

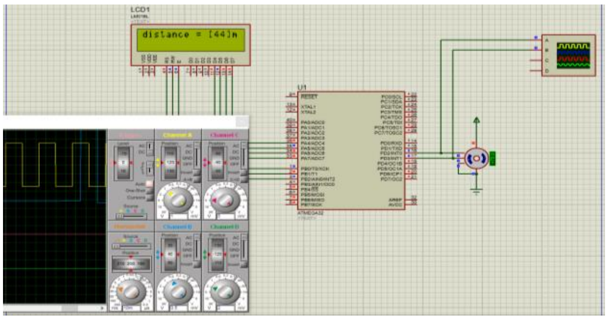

Fig 5: Interfacing rotary encoder with microcontroller

From Figure 6 to Figure 9, the bluetooth and the motors are interfaced with the microcontroller unit. The implemented integration allows smooth and precise control of the motors, enabling them to execute movements in various directions. The motors are tested and successfully run in all directions.

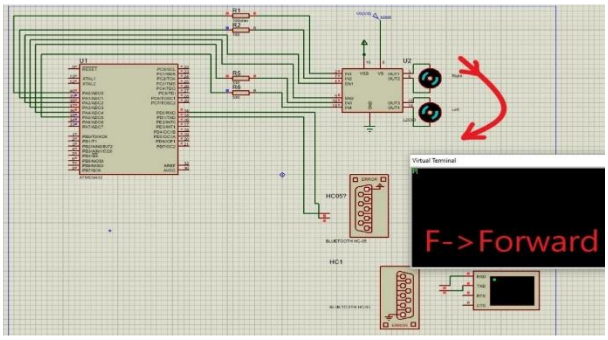

Fig 6: Simulation of motors movement in forward direction

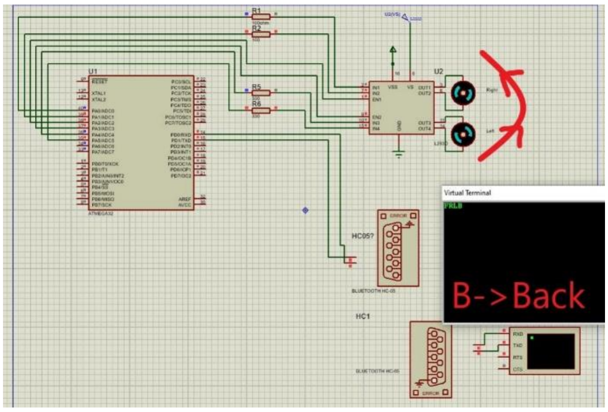

Fig 7: Simulation of motors movement in back direction

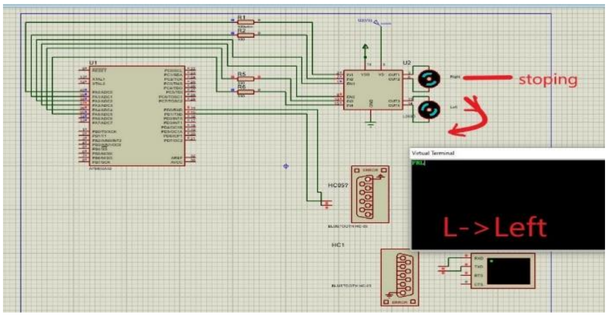

Fig 8: Simulation of motors movement in left direction

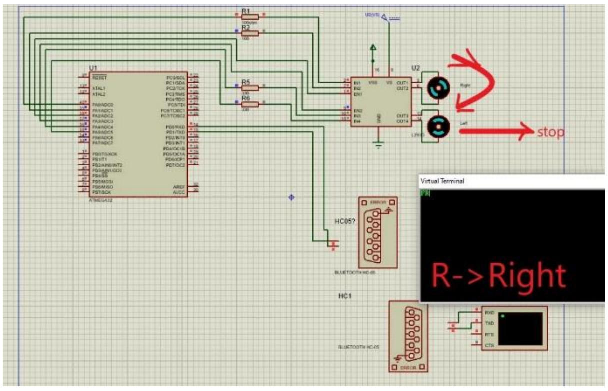

Fig 9: Simulation of motors movement in Right Direction

The proposed AStar-algorithm is applied by Python simulation. The process initiates in Figure 10 by establishing the starting point (indicated in yellow) and destination point (highlighted in blue). The black squares represent obstacles located in the path of the wheelchair.

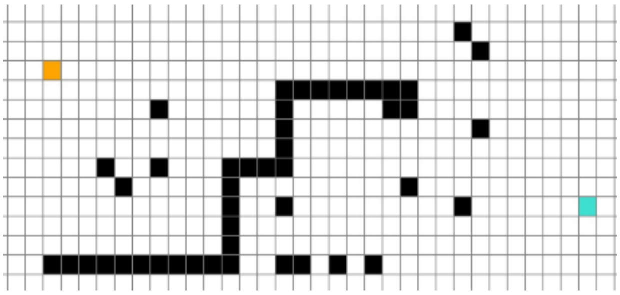

Fig 10: Initiating the AStar-algorithm

Then, the AStar-algorithm determines the optimal path (Figure 11), represented by the purple line. The red squares are locations visited by the simulator, while unvisited locations are distinguished by a green hue.

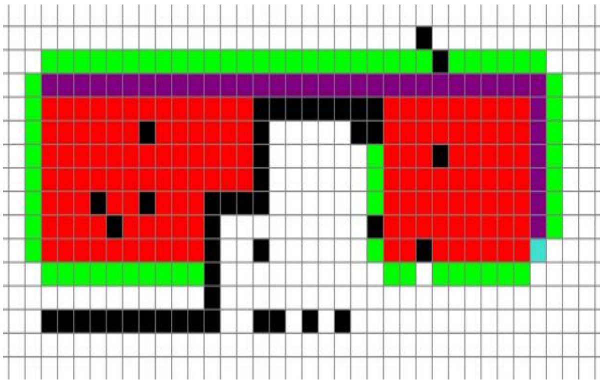

Fig 11: Applying the AStar-algorithm (detecting shortest path)

Figure 12 shows mobile application, "Wheel Chair Controlles", is implemented to transmit voice commands using a bluetooth module. It is designed by a user-friendly interface using the android studio development environment. The universal asynchronous receiver/transmitter protocol is used to establish the communication between the android application and the microcontroller; to receives the voice commands transmitted from the mobile application. It then sends the appropriate instructions to the motor driver module to achieve smooth and multidirectional motion for the wheelchair.

Fig 12: A prototype for the proposed wheelchair

Figure 13 shows a real map consisting of some obstacles and a starting point for navigation to any destination, such as a pharmacy or a market. Figures 14 and 15 demonstrate how the mobile application lets users specify a destination, and the wheelchair autonomously finds the shortest route, offering efficient and easy navigation.

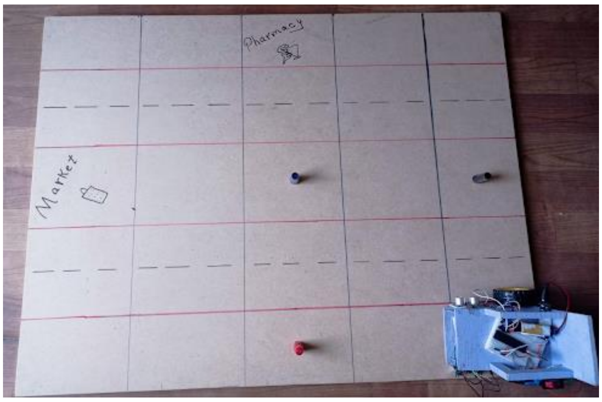

Fig 13: A real test map with some obstacles

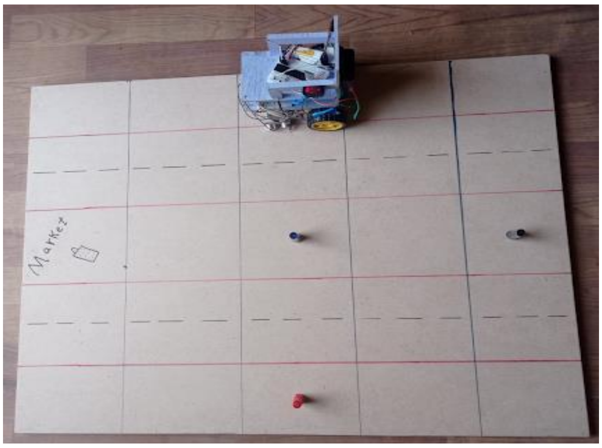

Fig 14: Wheelchair reaches a pharmacy

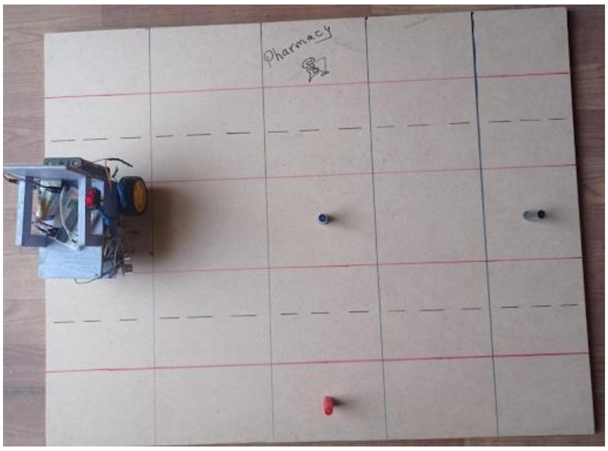

Fig 15: Wheelchair reaches a market

4. CONCLUSION
A voice-controlled wheelchair prototype has been developed. The prototype has been implemented by integrating a selected group of input and output modules to achieve safety, comfort, ease of use, and accurate real-time operation. In addition, the AStar-algorithm has been applied for searching the shortest path in unknown environment with obstacles. Besides, an android application has been created to facilities real-time communication among android users and their desired destinations. The proposed prototype has been tested with different voice commands. The results showed successful and expectation for future scope of the proposed wheelchair for assisting individuals with different physical disabilities.

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