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Arduino based voice controlled wheelchair

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Abstract: A voice controlled wheelchair prototype was developed using a commercially available manual wheelchair to assist people with both upper and lower limb disabilities. An Arduino microcontroller processes the voice command from the speech recognition module and controls the motor movement of the wheelchair. Bluetooth module was also used to do away with messy wiring and an optional joystick command was also incorporated into the prototype design. The success rate of the wheelchair to recognize the voice commands in English, Chinese and Malay was high. The overall cost of the prototype was kept low to make it affordable.

Keywords: wheelchair, voice recognition, wireless, Arduino, Bluetooth, infrared, microcontroller, disability

1. Introduction

The wheelchair is the most ubiquitous equipment used by people with lower limb disability. It enables them some degree of freedom in mobility and independence as opposed to those with both upper and lower limb disabilities. Most of the wheelchairs available in the market are manual in nature with some available with motorized option. Anything beyond that is custom made which is costly and not within the reach of most people. People with severe lower and upper disabilities have to resort to costly electronic controlled wheelchairs or be totally dependent on another person to move them around in their manual wheelchairs. Motorized wheelchairs controlled through joystick, softball, finger, tablet, chin and head are readily available at a high cost but most of them do not cater for those with upper limb disability. The advances in speech recognition technology have made it possible to control any electronics based device using voice command. This technology is capitalized for voice controlled wheelchair to assist those with both upper and lower limb disabilities. A variety of voice controlled wheelchairs have also been developed by other researchers [1-5]. The World Health Organization (WHO) has estimated that of the 75 million people who need assistive technology such as wheelchair, only 5% to 15% of those have access to one [6].

Figure 1 shows the block diagram of the voice controlled wheelchair. There are three main parts in the wheelchair: (1) wireless communication that incorporates voice recognition module, (2) microcontroller and (3) motor controller. The voice recognition module converts the voice from analog to digital with built-in digital signal processing system that recognizes the voice commands. This model is pre-programmed for each command and calibrated to the user's voice. The microcontroller processes the voice recognition module output to control the left and right motors which in turn controls the movement of the wheelchair.



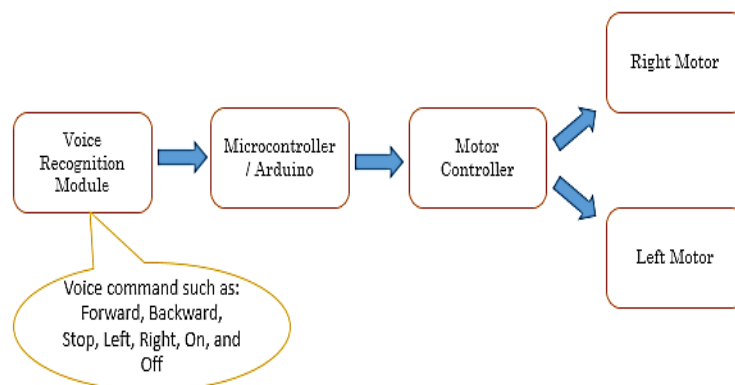


Figure 1. Block diagram of voice controlled wheelchair.

2. Methodology

The voice recognition module is the key feature of this project that is used to setup the desired voice command and output. It consists of three phases, which is voice customization, voice capture and voice recognition. Voice customization is the process of matching the desired voice recorded to the desired output signal. Voice capture is the phase that records the desired person's voice command and saves the voice based on the customization configuration. The voice recognition phase is the final phase where when voice command has been recognized, this module will send a specific signal to the microcontroller for the necessary operation. Figure 2 shows the block diagram of the voice recognition module.

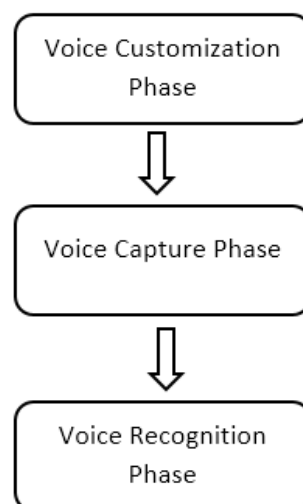


Figure 2. Block diagram of voice recognition module.

The voice instructions are recorded via serial communication with the PC using Access Point communication software with baud rate of 9600. After the connection of the voice recognition module to the PC is successfully implemented, the existing voice instructions are deleted by sending hex command AA 01. The recording is started with the desired voice command in group 1 by sending the hex command AA 11. After this command has been sent, user is required to record a total of five voice commands in order to complete the group recording. On completion of the voice capturing phase, verification is required by sending the hex command AA 21 to import group 1 into the voice recognition module. The recorded voice command is verified again by repeating the five commands that has been recorded earlier. Figure 3 shows the returning result of the voice verification after each command has been verified successfully by the module. The five voice commands used are: *Forward*, *Backward*, *Turn Left*, *Turn Right* and *Stop*. The HC-05 Bluetooth module is used as the wireless transmission medium between the microcontroller and the voice recognition module in controlling the

wheelchair movement. This will eliminate the need for long and messy wiring.

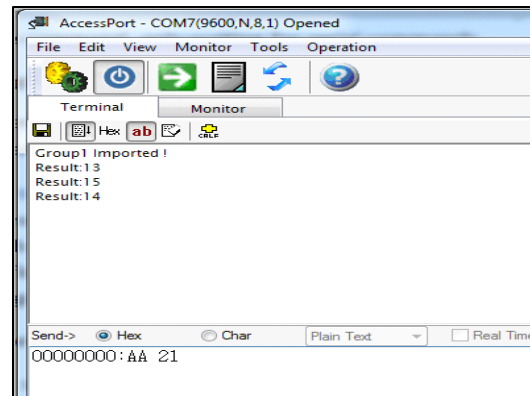


Figure 3. Result of voice verification.

The prototype consists of three main parts, the wireless communication (voice recognition module and HC-05 Bluetooth modules), main operation system (ATMEGA 328P microcontroller, joystick, motor controllers and motors) and sensor system (Hall Effect sensors and IR range detectors) as shown in figure 4. The wireless communication includes HC-05 Bluetooth module and voice recognition module powered up by a Li-Po battery. Also this hands free device has integrated a bulk converter which converts the Li-Po 3.7 V battery into 5 V constant output for both the Bluetooth and voice recognition module. In addition, Li-Po charging module is also integrated into this hands free part for the ease of user to recharge the battery. The main operation system consists of an Arduino microcontroller and two motor drivers.

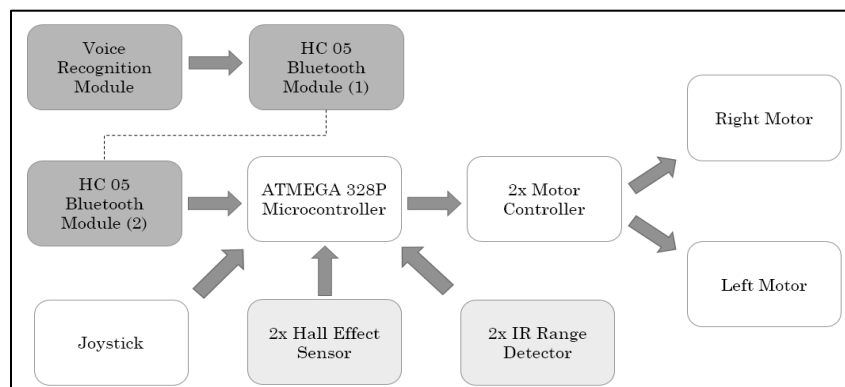


Figure 4. Key components of voice controlled wheelchair

The Cytron MD13S motor drive is used to control the speed and direction of the DC brushed motor. The pulse width modulation (PWM) pin is to control the speed and the DIR pin is used to control the direction of the motor. The PWM pin is connected to 5 V and the DIR is fed to the PWM signal of the microcontroller. When the PWM signal is at 50% duty cycle, the motor will stop running. If the PWM has less than 50% or more than 50% duty cycle, the motor will turn clockwise or counter clockwise based on the polarity connection between the motor and MA/MB pins of the motor drive.

Infrared (IR) sensors with measuring ranges of 10 cm to 80 cm were fixed to both sides of the wheelchair for obstacle detection. Two Hall Effect sensors were also fixed on both sides of the wheelchair to detect the wheel rotation speed since the DC brushed motor does not have a speed control. These sensors will detect the rotation of the wheel and feedback to the microcontroller to achieve speed stabilization. Twelve magnets were fixed to each side of the wheel before implementing the sensors as shown in figure 5. The diameter of the wheel is 40.64 cm and the 12 magnets were fixed 10.64 cm apart along the circumference of the wheel. In this set-up, when the wheelchair moves approximately 10.64 cm from the initial point, the Hall Effect sensor will trigger a

signal to the microcontroller as a feedback signal. In this step, the microcontroller will start the timer to count another incoming signal. This method will enable the microcontroller to distinguish how fast or slow the wheel is turning thus enabling the speed variation communication from Hall Effect speed sensor to microcontroller, and from microcontroller to control the speed by using PWM in the motor driver.



Figure 5. Positioning of magnets on the wheels.

An analog joystick module was also incorporated as an additional control option for those with lower limb disability only. Atmega 328p microcontroller is used to communicate with the Bluetooth module, joystick control, Hall Effect sensor, IR detectors and the motor controller. Arduino IDE code compiler is used to complete the whole system interconnection and communication. An emergency button was also incorporated using the joystick press key. This is to prevent any voice command malfunction caused by noisy environment.



Figure 6. Chained gear ratio setup.

MY1016 scooter motor used for this prototype provides a rated torque of 250 W (0.9~0.97 N/m). It is a 24 V high RPM motor with no load up to 3300 RPM. A 5-to-1 chained gear ratio system was applied between the motor and the wheelchair to deliver five times the rated torque as shown in figure 6. Power supply to the DC brushed motor and the two motor drives is provided by two parallel 12 V rechargeable lead acid batteries that provide 14 A current. All the above mentioned hardware was implemented onto a conventional foldable wheelchair which is readily available in the market. The I2C OLED display is implemented to provide a more user friendly interface. The user is also able to observe the executed instructions on the display.

3. Tests and Results

The main control part is the function of the prototype-starting period. At first, the prototype will wait for the joystick key to select user preferences. It has total of three user preferences, which can be selected by using joystick. The first user preference, second user preference, and third user preference

has been set as turn left, forward, and turn right respectively. After the user preference selection, the program point will verify both control input, which are joystick and voice. If joystick is detected, it will provide manual control operation of the wheelchair, else if voice is detected, the pointer will go to the voice command control for further operation.

In the voice command control, the voice recognition module will reply the desired signal represented as voice command and detect what is the user input. There are five-user commands: *forward*, *backward*, *turn left*, *turn right*, and *stop*. Each command will have a different motor control direction, which will be changed individually. For instance, if the voice command is *turn left*, the left wheel will be set to reverse, and right wheel will be set as forward, and if the voice command is *turn right*, the left wheel will set to forward, and right wheel will set as backward.

After the voice command is detected, the pointer will further proceed to the speed control part. This function is shared with three voices commands, which are *backward*, *turn left*, and *turn right*. The only differences between the three processes are the direction of the motors. The forward function not only controls the speed of the motor, but also detects the walls (obstacles) on both sides of the wheelchair. This function is highly dependent on the IR sensors to detect the range between the wall and the wheelchair, so that it will complete a feedback loop to adjust the wheel speed, which provides a function for the wheelchair to change direction.

The optimum distance for the Bluetooth communication with the wheelchair was tested to be 10 m with response delay of 0.47 seconds, beyond which the connection becomes unstable. The IR detectors were tested to be capable of detecting obstacles between 10 cm to 80 cm. The voice command recognition success rate was tested for three different languages namely English, Chinese and Malay. Each command was tested 50 times. The results are as in table 1.

Table 1. Voice recognition success rate.

Voice Command	English (%)	Chinese (%)	Malay (%)
Forward	98	96	96
Backward	100	98	96
Turn Left	96	98	98
Turn Right	100	96	96
Stop	100	100	98



Figure 7. Prototype of voice controlled wheelchair.

After incorporating the motor onto the wheelchair, motor stalling was frequently observed and the wheelchair struggled to move after coming to a complete stop or zero speed while loaded with a

weight of more than 65 kg. This shortcoming can be overcome by replacing the current motor with a geared motor in future upgrade of the prototype. The completed prototype of the wheelchair is shown in figure 7.

4. Conclusion

The Arduino based voice controlled wheelchair prototype was successfully built and tested to respond to voice commands. It will greatly improve the quality of life for those with severe disabilities. The cost has also been kept low by adding the design to any manual wheelchair.

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