On the Design and Fabrication of a Voice-controlled Mobile Robot Platform

Saleh Ahmad, Mohammed Khalid Alhammadi, Abdulla Adel Alamoodi, Ahmed Nasser Alnuaimi, Saif Aref Alawadhi and Abdulla Ahmed Alsumaiti
Mechatronics Engineering Technology, Higher Colleges of Technology, D54, Academic City, Dubai, U.A.E.

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Abstract: The 'voice' is the most popular form of communication for human beings is. In the field of service robots, the application of speech recognition is a natural choice. Service robots minimize the physical work that people render with their day-to-day tasks. The development of a mobile robot platform that can be controlled using speech commands is presented in this paper. The human voice commands are recognized by the AI JARVIS voice recognition software and translated into motion commands sent to the mobile robot platform using RF communication. Not only does the mobile robot recognize the voice commands and execute them, but it also provides acknowledgment by voice output. The designed mobile robot can carry out various movements, turns, and shifting objects from one location to another. The voice commands are processed using the modified AI JARVIS voice recognition software. Using an RF module's wireless end-point networking, voice signal commands are directly transmitted to the Robot. The mobile robot is developed on a Microcontroller based platform. Performance evaluation showed promising results from the initial experiments. Possible improvements in the future deployment of such a robot in households, hospitals, and other sectors are also explored.

1 INTRODUCTION

The most common means of communication in humans is through voice. About every communication is held using voice signals to communicate. Using a microphone, sounds, and speech signals can be translated into electrical signals. Voice recognition is a technique used to translate voice signals into a text format for a device or instructions for a computer. It is possible to use this voice recognition system to control and generate speech acknowledgment. Voice-controlled robots understand and execute the necessary acts with thousands of voice commands.

Voice recognition is a challenging task since each person has a unique speech pattern. However, significant progress has been made due to the recent developments in Artificial Intelligence (AI) algorithms. Voice controller mobile robots can be used in various sectors such as manufacturing, defense, medical care, etc. In hospitals, these robots can be used to deliver medicines or medical equipment, sanitize/disinfect rooms, patrol corridors, and provide voice instructions (Ozkil et al, 2009) and (Mettler et al, 2017).

Several virtual speech assistants, such as *Google Assistant* and *Amazon Alexa*, are available to allow users to interact comfortably with smart devices with only their voice. However, these speech assistants are difficult to customize to suit the needs of this work. There are several research publications in the area of voice control of robots (Chaudhry et al 2019 - Uehara et al, 2010).

In (AbhinavSalim et al, 2017), the presented work explains the use of voice control to control a robotic arm. The voice commands are first trained using the speech recognition module by the operator. The commands are stored as numbers with a range between 1 and 9. If the operator says one of the predefined commands near the microphone of the speech recognition module, the command will be recognized and the corresponding Binary Coded Decimal (BCD) of the number is sent as an output. According to the BCD command received by the microcontroller, appropriate signals are now sent to the motor driver to rotate the motors in the desired direction.

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The design of a smart, motorized, voice-controlled wheelchair using an embedded system is described in (Ali, 2015). To assist the navigation of the wheelchair, the Arduino microcontroller and speaker-dependent voice recognition processor were used. The wheelchair's direction and velocity are controlled by pre-defined Arabic voice commands.

This paper suggests the use of a virtual speech assistant named AI JARVIS that combines the ease of use and the operational complexity of the other visual assistant's platforms. Figure 1 depicts a block diagram of the voice-controlled mobile robot system.

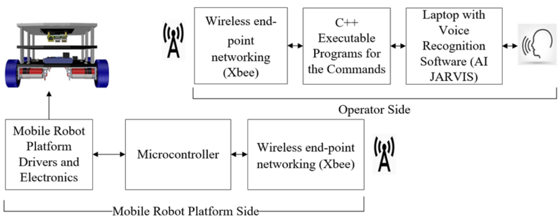

Figure 1: Block diagram of the voice-controlled mobile robot platform.

2 ADAPTATION OF THE AI JARVIS VIRTUAL CONTROL ASSISTANT TO CONTROL THE MOBILE ROBOT PLATFORM

2.1 Robot Platform

AI JARVIS is a virtual assistant designed to give voice commands to personal computers (PCs). The AI JARVIS wizard has the following functions: Gmail email reader, Facebook notification reader; Facebook messaging reader; integrated alarm; reminders; browser control (Chrome and Firefox); Windows player control; control Windows; Editor to open any folder, any application, web page; Editor to add questions and answers to the wizard; Wikipedia search; and Google YouTube search. The AI JARVIS voice assistant software icon is shown in Figure 2.

Figure 2: **J.A.R.V.I.S-J**ust **A** **R**ather **V**ery **I**ntelligent **S**ystem.

The adaptation of the JARVIS virtual control assistant was done by creating programs in visual C#, which allows different types of codes to be sent to the Microcontroller depending on the voice instruction given to the JARVIS virtual assistant. Once the code reaches the Microcontroller, it performs a programming logic that allows activating and deactivating the mobile robot motors and selects their angular velocities which in turn will allow control of the mobile robot movements. The voice commands are given to the AI JARVIS virtual control assistant utilizing a wireless headset microphone.

The steps needed for utilizing the AI JARVIS to control the mobile robot platform by voice are described in this section. The features of the AI JARVIS software will be explained first. After the AI JARVIS software is started, the window shown in Figure 3 will appear. The next step is to configure the required custom commands.

Figure 3: JARVIS software startup window.

To configure new commands, one needs to click on the plus button on the bottom of the right-hand side of the AI JARVIS software as shown in Figure 3. After clicking on the plus button, the popup window shown in Figure 4 will appear.

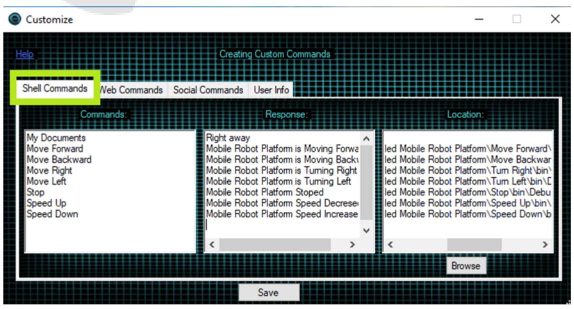

Figure 4: Creating a custom shell command.

There are three types of commands available in JARVIS

1. Shell commands
2. Web commands
3. Social commands

2.1.1 Shell Commands

The shell commands are the most important feature for this work. It allows users to create commands that result in the execution of a custom-made standalone executable C# console application. These C# executable files have been designed to send certain instructions over the RF communication modules based on the user voice commands. These instructions are interpreted by the Microcontroller. Based on the received instruction, the Microcontroller communications with the motor drive to execute the desired movement/action. A sample of the C# script is shown in Figure 5.

```
main.c
// c#   Program for Moving Forward

using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.IO.Ports;
using System.IO;

namespace ConsoleApplication1
{
    class Program
    {
        static void Main(string[] args)
        {
            SerialPort sp = new SerialPort();
            sp.PortName = "com22";
            sp.BaudRate = 9600;
            sp.Open();
            sp.Write("1");
            sp.Close();
        }
    }
}
```

Figure 5: C# script for the move forward shell command.

There are three columns inside the shell command window as shown in Figure 6. The commands in the first column are (what is the command, what the operator is going to say). There is a response next to the command (what is the corresponding response to your command) and then the location (browse for the file or application which is going to be opened by JARVIS based on the command).

First, the command is typed, and then the response that we need and then click on the browse button to choose the application. The application in our case is the executable file of the C# console application that was written to send the desired command to the Microcontroller.

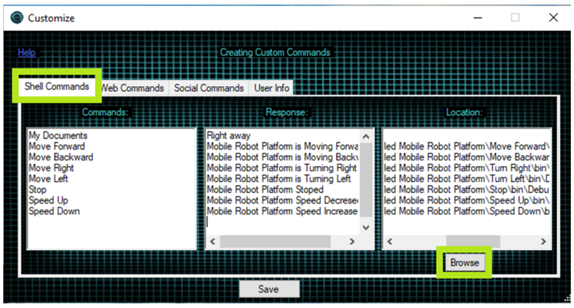

Figure 6: Chosen application for custom commands.

2.1.2 Web Commands

To access such commands, click on the web commands on the top toolbar as shown in Figure 7. Then enter the custom command and the response in the web commands window similar to shell commands and give the URL for the web page that needs to be opened.

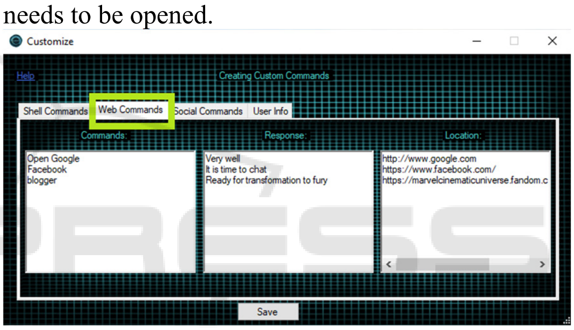

Figure 7: Creating custom web commands.

2.1.3 Social Commands

Social commands, which have two columns, one is the command and the other is the response, are used to interact with AI JARVIS. Figure 8 illustrates how to create a custom social command.

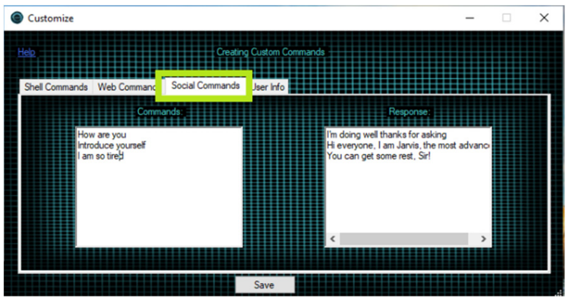

Figure 8: Creating custom social command.

3 MOBILE ROBOT DESIGN

3.1 Motor Sizing Calculations

To ensure the efficiency, durability, and cost of the designed mobile robot platform, proper sizing, and selection of the mobile robot platform motors is of paramount importance. This section describes the steps taken to achieve this task.

Step 1: Calculate the required wheel torque and rotational speed (RPM).

Step 2: Research DC motor manufacturers to determine the availability of gear-head motors that meet the functional requirements and the design parameters. The list of the desired design parameters for the mobile robot platform is given in Table 1.

Table 1: Mobile robot platform design parameters.

Design Parameter	Value
Mass	15 kg (including payload)
Wheel Diameter	0.1 m
Desired Speed	1.3 m/s
Desired Acceleration	0.9 m/s2

To calculate the required motor torque, we will start with Newton's second law, as follows

$$F = ma \tag{1}$$

Where F denotes the total force that needs to be exerted by the mobile robot (N), m denotes the total mass of the robot and its maximum payload (Kg), a denotes the linear acceleration (m/s^2).

Substituting the values of m and a from Table 1.

$$F = 15 * 0.9 = 13.5\, N \tag{2}$$

This force needs to be translated into motor torques, τ_m using the following equations:

$$\tau_m = F * W_r \tag{3}$$

Where W_r represents the wheel radius, $W_r = 0.1/2 = 0.05$ m.

Since we have two actuated wheels, the force required per wheel is, $F = 6.75\, N$.

Substituting the values of F and W_r into Equation (3), we obtain

$$\tau_m = 6.75 * 0.05 = 0.3375 \text{ Nm} \tag{4}$$

The following equations describe how to calculate the required wheel rotational speed (RPM) to maintain a mobile robot platform speed of 1.3 m/s.

We need first to calculate the wheel circumference as follows,

$$W_c = \pi\, x\, W_d \cong 3.142 * 0.1 = 0.3142\, m. \tag{5}$$

The desired mobile robot platform speed, $v = 1.3\, m/s$.

Equation 6 describes the relationship between the mobile robot's linear velocity and the angular speed (Rotation per Second) and wheel circumference.

$$\boldsymbol{v} = RPS * W_c \tag{6}$$

Where RPS denotes the speed in rotation per second and W_c is the wheel circumference.

Substituting the values of v and and W_c into Equation (6), we obtain

$$RPS = {}^{v}/_{wc} = {}^{1.3}/_{0.3142} = 4.137 \tag{7}$$

Since RPS = RPM/60

$$RPM = RPS * 60 = 248.25 \tag{8}$$

Having the designed value for the torque and the RPM, the next step is to research DC motor manufacturers for a suitable gearhead. The following DC motor Gm25-370ca was selected based on the obtained motor torque and RPM.

3.2 Microcontroller and Motor Drive

The Arduino Uno is an atmega328-based Microcomputer. It includes 14 general-purpose digital input/output pins. 6 pins out of the 14 GP I/O pins support pulse width modulation (PWM). This Microcomputer also has 6 analog pins, 16 MHz ceramic resonator, and it includes all the required peripherals within a single board. The mobile robot platform uses the Arduino Uno Microcontroller as the main central processing unit. The power supply to the motors, the Arduino board, and all other electronics is provided by a 12 V rechargeable lithium battery. ZigBee modules are interfaced with the microcontroller and the personal computer (operator side) to establish wireless end-point networking.

The Dual-Channel DC Motor Driver-12A has been used to drive the mobile robot platform wheels. It is a dual-channel DC motor driver with an extremely small size of 1.97”×1.97”×0.49”. The module comes with two motor channels that can drive two motors simultaneously, and each channel employs an indicator to show the rotation direction of the motor: blue is forward rotation, red is reverse rotation. Support motor voltage ranges from 6.5V to 37V. Each motor channel can output 12A current continuously and the max power of the DC motor the module supports is up to 290W. The momentary peak current can reach up to 70A and last about 100ms. At the same time, the highly timing optimization of the units inside the driver makes the minimum pulse width of PWM input as narrow as 2us, which fully ensured its dynamic adjustment range and greatly improved the quality of controlling motors (DFRobot, 2020, December 09).

3.3 Mechanical Design

The mobile robot platform chassis, motor mounting brackets, the brackets for holding the electronics, sensors, and the IP camera were designed using SolidWorks software. The chassis and the motor brackets were made of 5 mm thick aluminum plates. Figure 9 shows different views of the designed mobile robot platform.

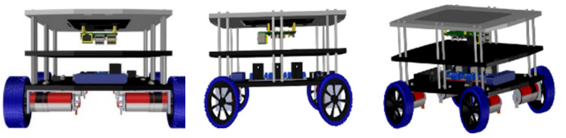

Figure 9: Different views of the mobile robot platform assembly.

3.4 Algorithm

- The AI JARVIS software should be trained to recognize the custom-made voice commands.
- Then the stored voice commands are represented by binary values. For example, Move Forward is represented by 0001, and Move Backward is represented by 0010, etc.
- These binary values are transmitted via a ZigBee module which is at the operator side. This is achieved by executing the executable file of a C# console application for that particular command.
- The transmitted binary values are then received by another ZigBee module which is the mobile robot platform side.
- The Microcontroller interoperates the received binary value and performs the required action (control the DC motors) according to that binary value.

4 EXPERIMENTAL RESULTS

After configuring the required shell commands of the AI JARVIS software to execute the custom standalone executable file of the C# console application. The Arduino code responsible for the command parsing and controlling the robot motors with the motor drive was completed. The AI JARVIS software was tested to evaluate the success rate of the saved commands. The results of this test are summarized in Table 2.

Table 2: Voice commends performance results.

Voice Command	Repetition	Success Rate
Move Forward	100	94%
Move Backward	100	95%
Turn Right	100	91%
Turn Left	100	89%
Stop	100	98%
Speed UP	100	87%
Speed Down	100	88%

Figure 10 shows screenshots of the developed voice-controlled mobile robot platform.

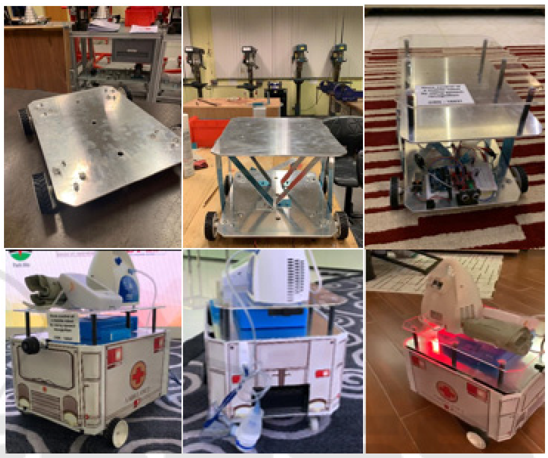

Figure 10: Screenshots of the developed voice-controlled mobile robot platform.

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5 CONCLUSIONS

The proposed prototype of a voice-controlled mobile robot platform has been developed and proven effective in fulfilling user commands efficiently. For teleoperated mobile robot applications, operators who, for some reason, are unable or unwilling to use a joystick controller or a keyboard to operate a mobile robotic system can now use their voices as an alternative. Even though the potentials for future further research and development are still wide open, the current version of the voice-controlled mobile robot platform has already been demonstrated to be useful, easy to use, and flexible. Future research could be directed towards the use of a trained RRN network for voice recognition instead of using the JARVIS software.

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