# Development of 4-DoF Robotic Arm Control System with Voice Command for Grasp Assistance

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## ABSTRACT

The objective of this research was to develop and examine the robotic arm system and speech recognition system controlled by microcontroller for object grasp control with voice command. The efficiency tests were movement efficiency of robotic arm, efficiency of speech recogniton system, and performance of robotic arm control with voice commands.

The results revealed that robotic arm control with voice command system has the efficiency of robotic arm joints control for accurate movements in workspace as designed with 4 joints. In the speech recognition system, 10 voice commands were remembered to encode to the robotic arm control system efficiently with more than 90% accuracy. In consequence, the system that was developed can be used for grasp tasks in a robot workspace.

**Keywords:** Robotic arm/ Speech recognition/ Microcontroller

## 1. INTRODUCTION

For the past decade of societies among industrial robot, people also pay attention in research of robotics which emphasize interaction with humans or users. The main characteristic of this typical robot is having a robotic arm as the main component for support work or service in many ways as they were programmed.

Refer to ability in picking up the object as same as industrial robot robotic arm only the smaller size and abate performance, user able to adapt the smaller robotic arm in their housework. Most of them will create direct interaction with the user, for instance give robot the demand by remote controller or switch on control panel. Nevertheless, in humanity daily life some activities require specific skills but not all of us have the same level of ability such as repair or maintenance.

If there was an operating assistant and supporter, they would fill the gap of laxation in some abilities to improve the performance.

As soldering electronic device which need the perfect solder mark as designed without any default otherwise the circuit will be work for full efficiency so the user must have the concentrate and accuracy to place marked component, but user had to hold soldering and lead tools with both hands while it is hardly to place them in correct position. If there are assistants or professional supporters in that process, it will decrease the production time and increase the effectiveness of work.

From the above example, researchers had accommodated the concept of arm type robot standard logic and system to be supporter in grasping object in several works which necessary hold more than two equipment.

Furthermore, researcher had included the memorizing of user voice as command in controlling arm robot in various movements that increase efficiency in interaction with robot and convenient for user in any activities which require assistant in grasping object.

The control of robotic arms is the subject of a wide range of studies and applications that were on exhibit in the middle of the most recent years [1]. A physically controlled arm that has been designed to behave like a human arm is known as a programmed arm [2-4]. A voice-controlled robotic arm that assists people in their daily routines is a working prototype [5-6].

These prototype systems suggest robotic arm that can understand voice commands from people. The robot capacity to communicate with people using their natural mode of communication is improved by speech recognition technology which is a valuable advantage [7-9].

The manipulator, the voice recognition module, and the microcontroller are the three separate components that make up the overall system. The system uses a voice-encoder module which is affordable and simply functional to convey prepared commands based on activities that are taken. The servo motors, which are positioned and maintained in various directions, are used to control the movement of the robotic arm. Microcontrollers are used to control robot movement and other signal control [10].

Moreover, the voice Google assistant can be implemented on the system. Any language can access this implementation, the effectiveness of using longer sentences and phrases was tested and the result was found to be successful but depend on internet using that restrict some utilization of system [11-13]. Therefore, simple control functions in the offline system can be developed in the non-complex commands from user such as speech voice like 'up' and 'down'. The conversion of human speech into machine-understandable language is done using a voice recognition module. The voice can be recognized by the module which up to 80 voice commands are supported and the user must train the module before the voice command translation [14-15].

## 2. MATERIALS AND METHODS

The development of a robotic arm control system with voice command for grasp assistance involves three systems: the robotic arm system, the voice recognition system, and the main control system. When the user issues a voice command to the robotic arm, the specific keyword is recorded by the voice recognition system, which then analyzes the command into a data signal for response. After that signal will be sent to microcontroller board which control the robot by sending control signal to motor driver board for servo motors driving. The arm robot can adjust to different orientation and grasp object for user supporting in many tasks. The system process will be explained as shown diagram in Figure 1.
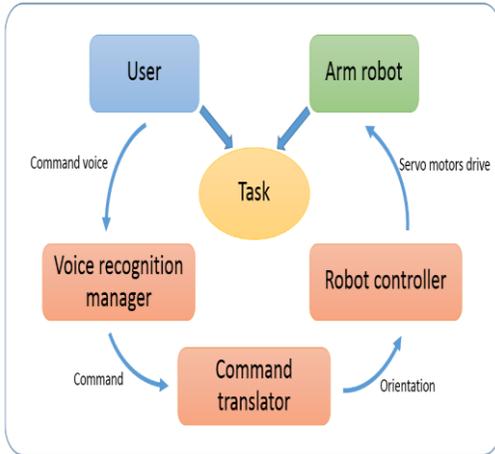
**Figure 1.** Research system blog diagram

The mechanical design of the robotic arm uses a four-joint revolute articulated arm and installs the voice recognition system at once. The structure of the robotic arm is made from stainless steel to provide strength and rust resistance, along with a movement design that involves the rotation of four servo motors to drive the joint to the intended point.

Starting with the first joint which contains $\theta_1$ to represent the rotation position of the base of robotic arm. The second joint contains $\theta_2$, which represents the controller point of the overall rotation of the robotic arm for upward and downward movement. The third joint contains $\theta_3$, which represents the rotation point for horizontal movement, and the last joint contains $\theta_4$, which controls the rotation for grasping objects and allows them to be turned to another angle. The direction of rotation for each motor is shown in Figure 2.
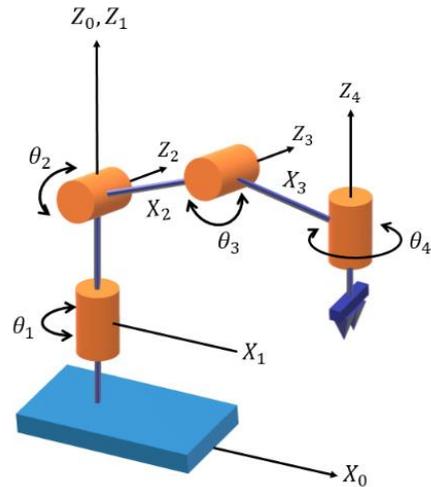


**Figure 2.** Arm robot joints direction design in this research

Referring to Figure 2 , the relationship between each angle can be found from the following equation, where $P_x$, $P_y$, and $P_z$ are the position coordinates, and $a_1$, $a_2$, and $a_3$ are the link lengths of the robotic arm in the workspace. These values can be used to control the angles of the servo motors.

As a result of the design of robotic arm, the workspace of robot will be as shown in Figure 3

$$\theta_1 = \tan^{-1}\left(\frac{P_y}{P_x}\right) \tag{1}$$

$$\theta_2 = \tan^{-1}\left(\frac{(P_z-a_1)(a_2+a_3cos\emptyset_3)-\sqrt{P_x{}^2+P_y{}^2}\,a_3sin\emptyset_3}{\sqrt{P_x{}^2+P_y{}^2}(a_2+a_3cos\emptyset_3)+(P_z-a_1)a_3sin\emptyset_3}\right) \tag{2}$$

$$\theta_3 = \pm \cos^{-1}\left(\frac{P_x{}^2+P_y{}^2+(P_z-a_1)^2-a_2{}^2-a_3{}^2}{2a_2a_3}\right) \tag{3}$$
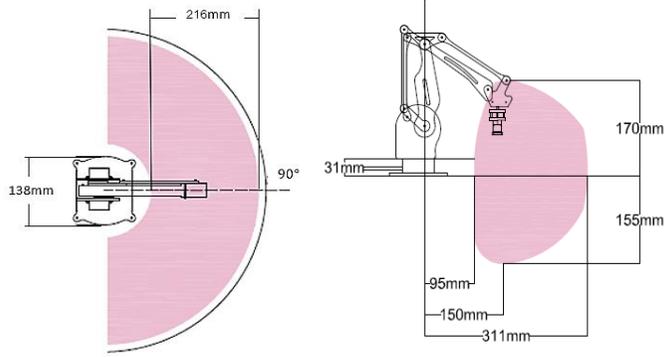
**Figure 3.** Robotic arm workspace.

From Figure 3 , the robotic arm workspace in horizontal plane X-Y covers the 21.6cm radiance of half ring shape area with limitation of base rotate at $180°$. The original setting point of base rotation was 90°, allowing it to rotate 90° to the left and right sides. In the side view, the robotic arm has the ability to grasp objects within the shaded area, which ranges from the shortest length of 95mm to the longest length of 311mm away from the base rotation point. When the robotic arm is installed to work on the edge of a desk, its workspace will be 170mm above and 155mm below the desk. To reduce the weight and task load on the second joint, a mechanical method was used to install the motor at the base of the robot, with power transmission by a shaft to drive the arm, as shown in Figure 4.

In the electronic circuit design, a 12VDC switching power supply is used for the main power supply of other devices. The voice recognition module V3 translates the voice signal from microphone and transmits the data to Arduino through serial communication via Rx pin 2 and Tx pin 3. The Arduino then compares the code with the programmed command and transmits a signal out via pin 4,5,6, and 7 to control all four servo motors, which drive the movement of the robotic arm. The grasp function is made using a suction cup and vacuum pump, which is controlled by pin 8 of the Arduino and transfers energy through the In/Out pin of the driver motor board. The system always uses a 3.5mm microphone to connect to the voice recognition module, as shown in Figure 5.
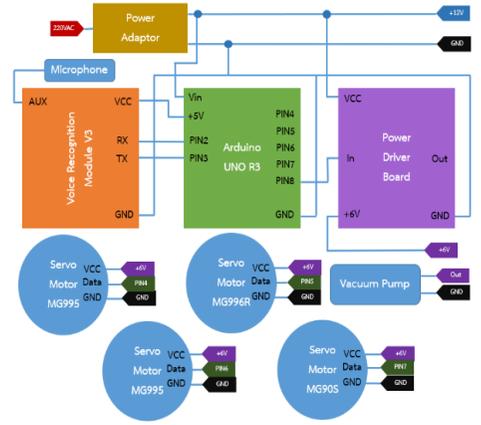


**Figure 4.** Structure of improved robotic arm



**Figure 5.** Electronics circuit diagram

The voice recognition system starts by training the voice recognition module V3 to memorize voice commands for controlling the movement of the robotic arm in different posture, using 10 designed phases of voice commands. The voice recognition module V3 conveys the command code to the microcontroller board Arduino for system control. The controller is programmed with the variables of the devices, the initial servo motor angle value for the orientation of the robotic arm, and parameters for modeling equations as well as position coordinates in the operating area of the robotic arm ($P_x$, $P_y$, $P_z$). The system waits for voice commands from the voice recognition module V3, compares the speech, converts each of the 10 commands to an integer number between 0 and 9, stores the value in a variable called 'data', and uses that variable to analyze the conditions for adjusting the driving angle of the servo motors and the operation of the vacuum pump. The robotic arm system will carry out the previous movement until a 'Stop' command is given. The system works in a cycle, repeating the process of waiting for voice commands until the system is terminated. The order of system operation can be seen in Figure 6
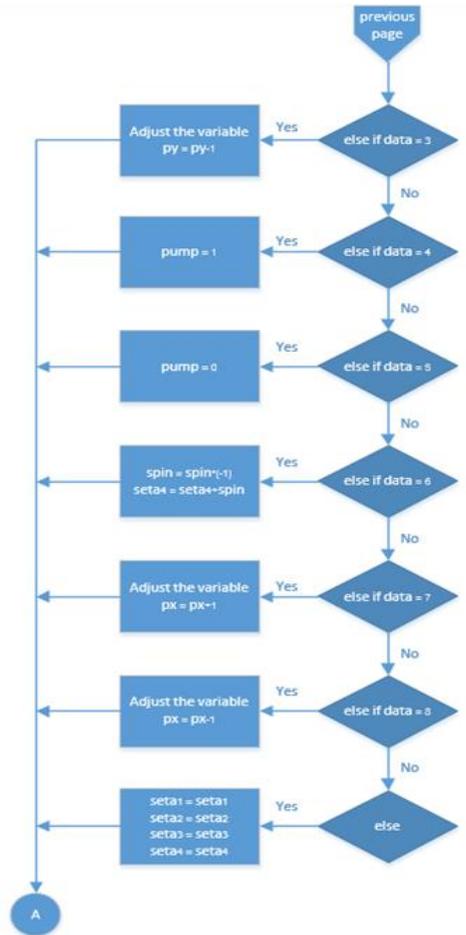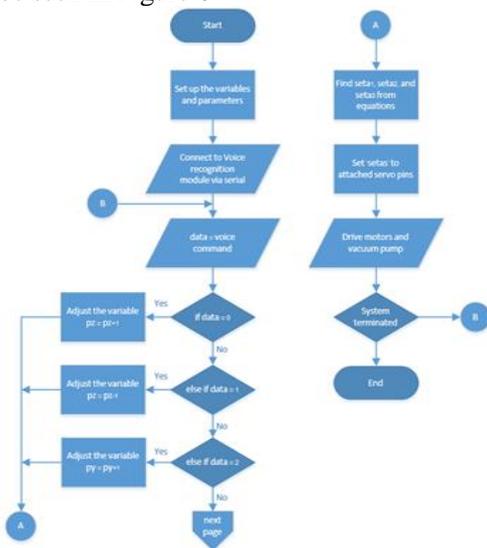


**Figure 6.** System operation flow chart



**Figure 6.** System operation flow chart (continued from previous page)

## 3. RESULT AND DISCUSSION
### 3.1 Voice recognition efficiency test

This test aims to determine the efficiency, correctness, and accuracy of the translation of user voice commands into code numbers 0-9, which are then used to define the movement of the robotic arm. The method involves speaking the voice commands through the microphone within a maximum radius of 50cm, with a total of 10 designed commands, and speaking each command 20 times. Afterwards, the

information is verified using the Arduino IDE application with the Serial Monitor function to check whether the commands were correctly translated into code numbers, as seen in Figure 7. The results are shown in Table 1.
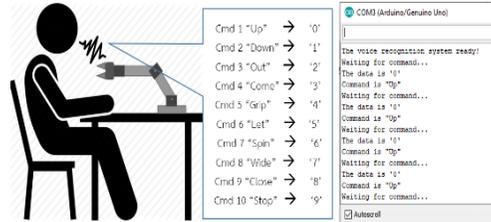


**Figure 7.** An user send voice command to the system with 10 commands

**Table 1. Voice recognition system efficiency test result**

|  | commands | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
|  | up | down | out | come | grip | let | spin | wide | close | stop |
| **Correction** | 100% | 95% | 100% | 90% | 95% | 95% | 100% | 95% | 100% | 100% |

The results showed that the voice recognition system correctly converted the given commands into code numbers without converting them into other, undefined numbers. Therefore, the calculation of the correctness of code number conversion showed that the voice recognition system had an efficiency of above 90%, which is sufficient for use in the robotic arm control system.

## 3.2 Robotic arm system efficiency test

The test used the method of identifying joint rotation degree for individual joint via serial communication and then measured the actual joint rotation degree. The extent of rotation degree and original value of each joint will be shown in Table 2 and the results appear in Figures 8 - 11.

**Table 2.** Rotation range and initial value of each robotic arm joint in degree

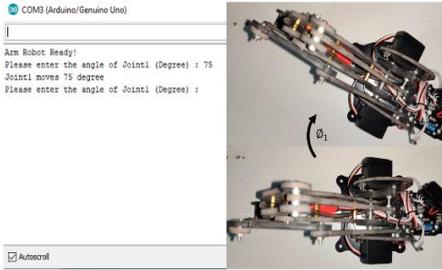| Joint number | Rotation range (degree) | Default (degree) |
|---|---|---|
| 1 | 0 - 180 | 90 |
| 2 | 0 - 105 | 0 |
| 3 | 0 - 80 | 0 |
| 4 | 0 - 180 | 90 |

**Figure 8.** Comparison rotaion angle of the first joint



**Figure 10.** Comparison rotaion angle of the third joint



**Figure 9.** Comparison rotaion angle of the second joint
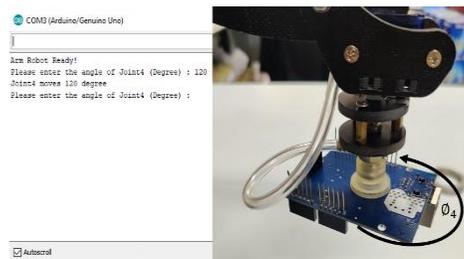


**Figure 11.** Comparison rotaion angle of the fourth joint

Referring to Figure 8, the results of the commanded rotation angle show that the robotic arm is able to effectively move to the set angle when

the rotation angle is set to low speed. The results of the rotation angle control and speed for each joint of the robotic arm can be seen in Figure 12.
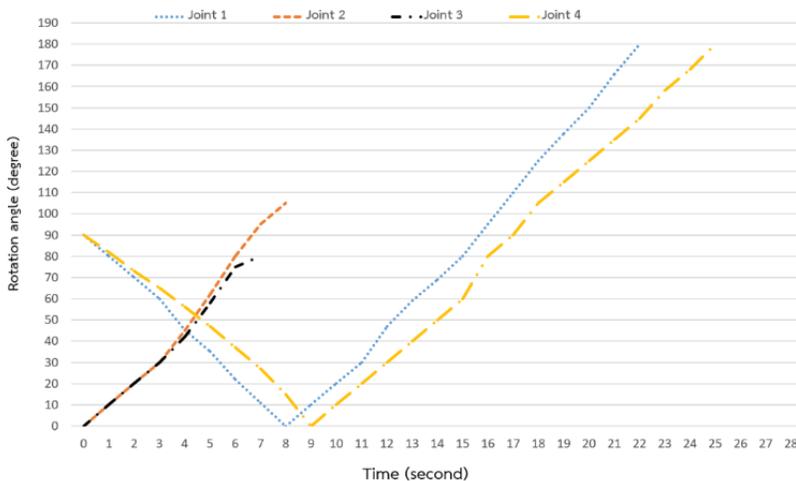


**Figure 12.** Comparison of each rotation speed in each joint

From Figure 12, it can be seen that the speed of the $1^{st}$-$3^{rd}$ joints is similar due to the use of the same type of servo motor and similar control values, except for the $4^{th}$ joint, which has a slower rotation speed than the others.

### 3.3 Robotic arm control with voice recognition system efficiency test

The experiment involved giving voice commands through the microphone to control the robotic arm to work in a quiet place. Each command was given 20 times. The results of this experiment are shown in Figure 10, which demonstrate that the robotic arm was able to operate all commands without any errors.

The operation of the robotic arm will repeat the latest voice command until a new command is given. To give the robotic arm a new voice command, a 'stop' command must be given every time to stop the previous action.

From Figures 10 and 11, it can be seen that the robotic arm can be used for control operation and is able to grasp objects with smooth surfaces weighing 50g-200g using 10 voice commands, as shown in Table 3

**Table 3.** Relation of robotic arm operation and voice command

| Command | End effector movement for object grasping of robotic arm |
| --- | --- |
| "Up" | Move upward follow +Z Axis |
| "Down" | Move downward follow -Z Axis |
| "Out" | Move outward from the user follow +Y Axis |
| "Come" | Move inward to the user follow -Y Axis |
| "Grip" | Order suction pad to grasp the object |
| "Let" | Order suction pad to release the object |
| "Spin" | Order joint 4 to rotate in cw/ccw direction |
| "Wide" | Move outward from arm robot base follow +X Axis |
| "Close" | Move inward to arm robot base follow -X Axis |
| "Stop" | Stop the operating in that posture |
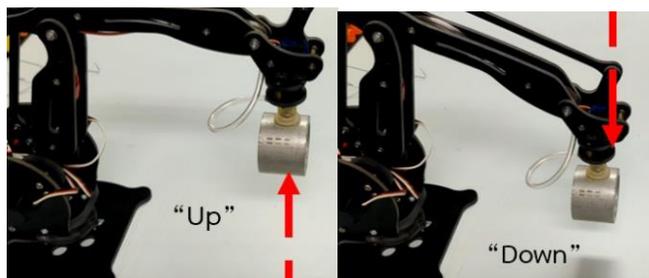


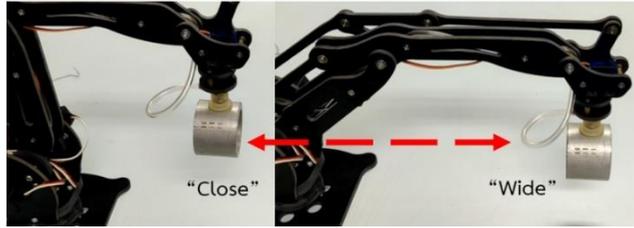**Figure 13.** Robotic arm Operation in "up" and "down" command

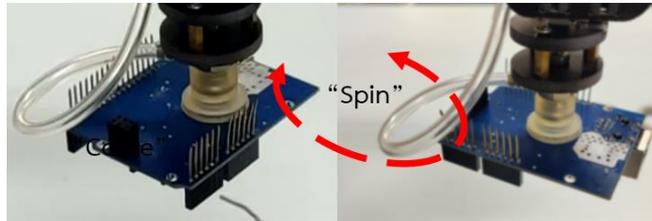**Figure 14.** Robotic arm Operation in "close" and "wide" command



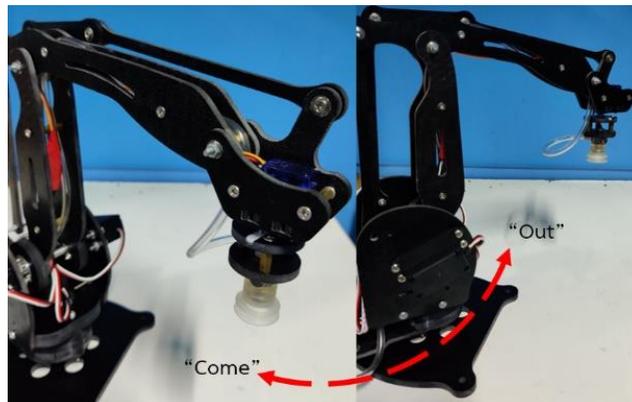**Figure 15.** Robotic arm Operation in "spin" command



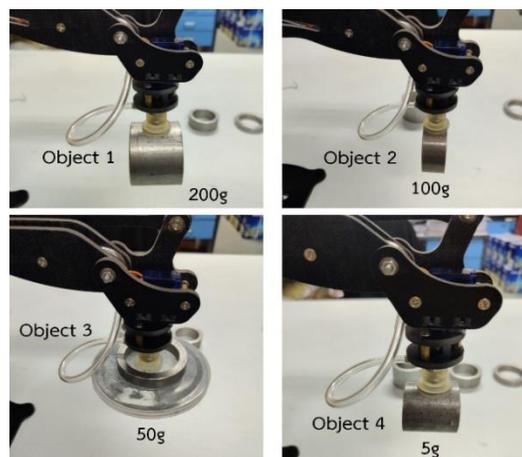**Figure 16.** Robotic arm Operation in "come" and "out" command



**Figure 17.** Grasping object control in different shape and weigth objects

According to the results, the prototype of the robotic arm system was developed using 3 main modules: 1) servo motors, 2) microcontroller, and 3) voice recognition module. It can effectively perform voice control to grasp objects, similar to the research of Akçınar et al. [5], Anggraeni et al. [7], Kandalaft [8], Kanash et al. [10], and John et al. [15] who developed arm robots that can be controlled using speech recognition to provide grasping assistance. In contrast, this research uses an alternate method of grasping objects using a suction pad and can control the orientation of the end effector. Additionally, the robot system can work as a standalone system, receiving action commands from the user without the need for external modules such as mobile phones, as in the work of Ngoc-Hoang Tran [11], Sowmiya et al. [12], and Utkarsh et al [13], which used the Google Assistant and Android application for voice recognition but had constraints due to internet connections.

# 4. CONCLUSIONS

The results of the efficiency experiment of the robotic arm operation show that the arm is able to effectively move in three dimensions across the workplace within an average time of maximum 10 degrees per second. The user can give voice commands for 10 commands to control the robotic arm to grasp and move objects with smooth surfaces weighing up to 200g. During the process of giving voice commands to the robotic arm, it was observed that sometimes it was necessary to repeat the voice commands to instruct the system as desired. The likely cause of this situation was the misalignment of the voice command and the voice recognition module's waiting time for the command

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