

Design and implementation of Arduino based robotic arm

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ABSTRACT

This study presents the model, design, and construction of the Arduino based robotic arm, which functions across a distance as it is controlled through a mobile application. A six degree of freedom robotic arm has been designed and implemented for the purpose of this research. The design controlled by the Arduino platform receives orders from the user's mobile application through wireless controlling signals, that is Bluetooth. The arm is made up of five rotary joints and an end effector, where rotary motion is provided by the servomotor. Each link has been first designed using solid works and then printed by 3D printer. The assembly of the parts of the robot and the motor's mechanical shapes produce the final prototype of the arm. The Arduino has been programmed to provide rotation to each corresponding servo motor to the sliders in the designed mobile application for usage from distance.

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1. INTRODUCTION

Autonomous systems and robots can contribute in plenty of functional operations over the world. The robotic arm can solve many limitations of humans in industrial fields especially with the aid of the distance controlled feature. Robotic arms' functions and their operations are extensively used in research laboratories and industries to automate processes and reduce human errors. Some of the tasks achieved by robotic arms include assembly lines and motions that demand the force control with feedback to its controller [1], [2].

Robotic systems have grown broadly due to their increasing applications in all fields of industry and their ability to decrease errors and wastage of material. Many different robotic systems have been developed for invasive proposes [3], [4]. The robotic arms could initially be used to move objects from one place to another [5], [6] in any industrial area [7], [8] that needs to achieve tasks repetitively for manufacturing products. Some industrial environments are not suitable for humans, thus robotic arms may be used. For instance, cases in which human workers cannot easily or safely gain access are handling radio-active materials or dealing with work in the deep sea and space [9], [10]. Generally, the two main purposes of the robotic arm systems are to minimize the risk of life by ensuring human safety, and to speed up industrial processes. This is where an automated, simple, and effective Arduino controlled robotic arm comes into play [11], [12]. The arm could be used for numerous tasks such as painting cars, soldering cars access unevenly placed parts for scanning, selecting. Most of the food industry companies use pick and place robots, which is useful in many criteria. In a human-designed environment, the robotic arm can also operate on a mobile base to be sent in a damaged/radioactive building and used to open the doors and manipulate the tools either by itself or through remote control [13], [14]. Table 1 illustrates a technical review on features of some robotic arms designed by researchers.

Table 1. Technical review on designed robotic arms

Studies	Issue (Problem)	Method	Advantage	Disadvantage	Ref.
Low cost platform for automatic control education	Education based development only	It is an on open hardware	Low-cost platform for automation	Open hardware is a risk because of incompatibility	[14]
Development of a multi-purpose, modular, low cost robotic arm for education and unmanned platforms	For education proposes and a low cost robotic arm	Modular robotic arm	3D printable and low cost, multi-purpose	Specific operations with programmed motors need skilled engineers	[15]
Self-calibration of a biologically inspired 7 DOF robotic arm with cable driven.	The design of a 7 DOF robotic arm with cable-driven movements is limited to only one direction at a time.	Cable driven method.	Its 7 degree-of freedom robotic arm, which is excellent for the robot to be only more flexible.	Cable driven methods act as a disadvantage as it is not feasible, because of the movement of the robotic arm.	[16]
Multiple-Degree-of Freedom Counterbalance Robot Arm Based on Slider-Crank Mechanism and Bevel Gear Units	High probability of locking. Requires high precision control for rotation of pre- specified angles.	Slider crank mechanism	Slider crank mechanism decreases the gravitational torque.	It is not feasible, as the slider causes vibrations during the movement	[17]
Design Analysis of a Remote Controlled "Pick and Place" Robotic Vehicle	High standard of maintenance required	Pick and Place.	This design is useful in dangerous places or work areas, its more accurate and faster for complicated and complex duties	Precise programming needed (time, training, specialist knowledge).	[18]

Generally, any autonomous system must contain three main ingredients, mechanical, electrical, and software. The connection among those three ingredients has an effect on the reliability, quality, scalability, and cost of the autonomous system. Therefore, it is important that the three components of automation systems are designed to coexist through an integrated design paradigm [19]–[22]. This sums up the model, design, and construction of an Arduino based robotic arm controlled by a mobile application.

2. RESEARCH METHOD

The following describes the design and implementation of a robotic arm controlled with Arduino via Bluetooth, including the characteristics of the robotic arm, extension of the arm, orientation, and the speed. Understanding the geometry of the robotic arm is essential to calculate the angles for its positioning [23]. It is important to know the lengths of each link and the start and end points of the arm in the area of work which is then referenced with respect to the base of the robotic arm or to another point. This motion is described through kinematics whose two types are forward and backward. If the origin point of the robot in the three-dimensional space is (0,0) and the origin cannot be reached, it is described as singularity. The extension of the robotic arm must reach the objects beyond its base to operate its positioning and to control its wrist position. The orientation must be precise in terms of its speed in order to carry objects by the tools provided [24].

The general design of robotic arm in this paper is shown in the Figure 1. This figure illustrates the joints and motors with all their mechanical parts and their movements according to the commands given by the Arduino platform. This design consists of 6 servo motors, which means it has 6 degree of freedom (DOFs), and each motor is controlled independently by the Arduino.

Designing the mechanical parts of the robotic arm is an important and essential process. In order to shape the robotic arm, mechanical parts must be based on how the motors carry their own weight along with the weights of the objects involved. The design of the mechanical parts of the robotic arm requires a software and a 3D printer that shapes the mechanical parts as necessary.

Solid works 3D printer modeling software, an open source, has been used to produce the parts of the robotic arm. The 3D printer specification that has been used to formulate the parts of robotic arm includes the following: Single nozzle, nozzle diameter 0.4 mm, layering pitch 0.05 to 0.40 mm, modeling speed 10 to 200 mm/s, and automatic filament supply to nozzle. Also, the interface with 3D printer used USB 2.0, Ethernet, Wi-Fi, or USB memory.

The complete design of the robotic arm has been shown in Figure 2. This prototype robotic arm has 6 degrees of freedom. For the first 3 joints, the waist, the shoulder, and the elbow, the MG945 servo motors have been used; Figure 3 and Table 2 clarify the characteristics of MG945 servo motors. While for the other 3 joints, the wrist roll and wrist pitch, as well as the gripper, the smaller MG90S micro servo motors have been used. Figure 4 and Table 3 clarify the characteristics of MG90S micro servo motors.

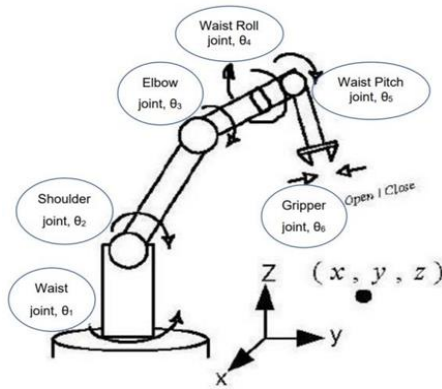


Figure 1. Design of robotic arm



Figure 2. Complete design of the robotic arm in SolidWorks IDE



Figure 3. MG945 servo motor [25]



Figure 4. MG90S micro servo motor [25]

Table 2. Specification of MG945 Servo Motor

Parameter	Value
Weight	100 g
Stall Torque	10 kg/cm (4.8 V): 12 kg/cm (6 V)
Operating Speed	0.23 sec/60 degree (4.8 V): 0.2 sec/60 degree (6.0 V)
Operating Voltage	4.8 V a 7.2 V
Dead Band Width	5 micro s
Dimension	40.7x19.7x42.9mm
Temperature Range	0-55 Degree

Table 3. Specification of MG90S Micro Servo Motor

Parameter	Value
Weight	13.4 g
Dimension	22.8x12.2x28.5mm
Operating Speed	0.1 sec/60 degree (4.8 v), 0.08 sec/60 degree (6 v)
Operating Voltage	4.8-6.0 Volts
Dead Band Width	7usec
Stall Torque	1.8 kg/cm (4.8 V), 2.2 kg/cm (6 V)
Temperature Range	-30 to+60 Degree C

Figure 5 shows the pin diagram of Arduino Uno Microcontroller platform. It has 6 analog input and 14 digital output/input pins, one 5 V input, a 3.3 V input also it consist of a reset button and two inputs: one receives power and the other receives the command from the Arduino IDE. HC-05 module is a simple to use

Bluetooth SPP serial port protocol (SPP) module, designed for clear wireless serial association setup. The interface Bluetooth module is a completely qualified Bluetooth V2.0+enhanced info rate (EDR) 3 Mbps Modulation with complete a pair of.4 GHz radio transceiver and baseband [26]. With complementary metal–oxide–semiconductor (CMOS) tech, CSR BlueCore 04-External single-chip Bluetooth system with adaptive frequency hopping feature (AFH) can be used, as shown in the Figure 6.

Figure 7 illustrates the flow graph of the designed robotic arm. This figure explains the complete process of the designed Arduino controlled robotic arm. When the operation starts, the robotic arm is in its initial condition. If a command order from the mobile application user is not valid, then the arm will stay at its initial condition. However, if the command order is a valid order, it will be sent to the specific motor and the motor will move accordingly. After the order is complete, the robotic arm returns to its initial condition until a new order is received allowing the process to repeat in a continuous loop until the power is turned off.

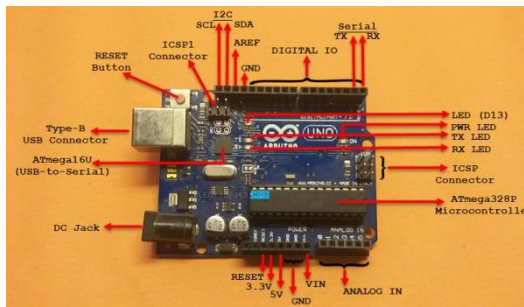


Figure 5. Pin diagram of Arduino Uno microcontroller platform

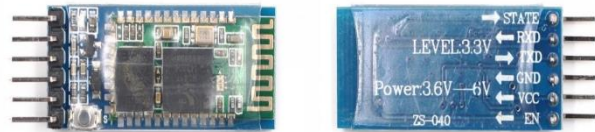


Figure 6. HC-05 serial Bluetooth module [26]

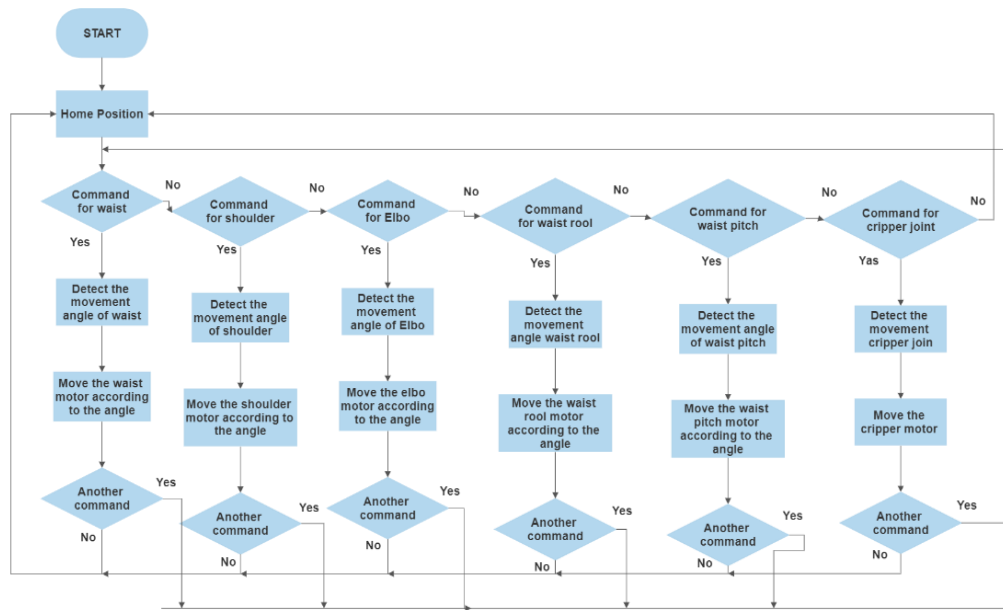


Figure 7. Flow chart of the designed robotic arm

Waist motor movement is to rotate the whole robotic arm on its base from 0 and 180 degree of angle θ_1 according to the servo motors rotation range. Shoulder motor movement requires the most strength in the robotic arm as it carries the entire arm’s weight. It moves up and down depending on angle θ_2 . Elbow motor movement is the movement type for more comfortable maneuvering for the robotic arm. Waist roll motor movement is for the rotation of the arm in its axis between 0 and 180 degrees of angle θ_4 . Waist pitch motor is the up and down maneuver of that joint. Gripper motor movement is the end effector of the arm that reacts with the environment; it only has the ability to grasp objects making its movement only opening and closing.

The designed robotic arm will be fully controlled by the Arduino platform, therefore, understanding the programming side for the Arduino micro-controller and how its workflows is important. The mechanical parts are the assembling body parts of the robotic arm and the electronic parts are the configuration of the motors, managing the connections of motor wires, Bluetooth module, and creating the mobile application. The robotic arm consists of six servo motors, 3 of them are MG945 servo motors and the other 3 servos are MG90S Micro servos, which are attached to the body parts of the robotic arm, also Arduino Uno, and HC05 Bluetooth module.

In order to form a communication between the user and the robotic arm, there must be a type of medium to transfer the user's commands to the robotic arm. In this research a Bluetooth module has been used to make this communication between mobile user and the robotic arm possible. The user sends the orders by the mobile application to the Arduino via Bluetooth and the Arduino generates the corresponding movements using the robotic arm's motors. In order to make the configuration possible it must be programmed so that the Arduino can enable the mobile device's Bluetooth. The programming of the robot needs to be accurate to control each servo motor with its related motion. The designed application has sliders and each slider is related with one motor movement; when the user changes the sliders in the application, the motors will move accordingly.

Arduino IDE has been used for Arduino programming, which is an open-source software owned by Arduino Company. For the mobile application used in this system, it enables the phone's Bluetooth in order to connect with the robotic arm, as shown in the Figure 8. All the servo motors are connected to the 5 V external power supply directly which must be at least 1000 mA dc maximum current depending on the standards of motors that are used in the system, the 2000 mA is recommended. The Bluetooth module is not powered directly by the 5 V adapter, for safety reasons, it's powered through the Arduino board which is connected to the power supply directly. The GND of all the servo motors and the Arduino's GND are connected to each other.

The MIT App Inventor is used for creating the application. The mobile application that is created in this project contains a button for enabling the Bluetooth of the mobile device and 6 sliders for each servo motor to give commands and move them accordingly. For the Mobile application, the user must go to the blocks section in order to code the application. The same idea is applied as the code of Arduino, for 6 servo motors there are 6 sliders in the application to give the angles, thus it has to send a value via Bluetooth to the Arduino in order to move the servo motors.

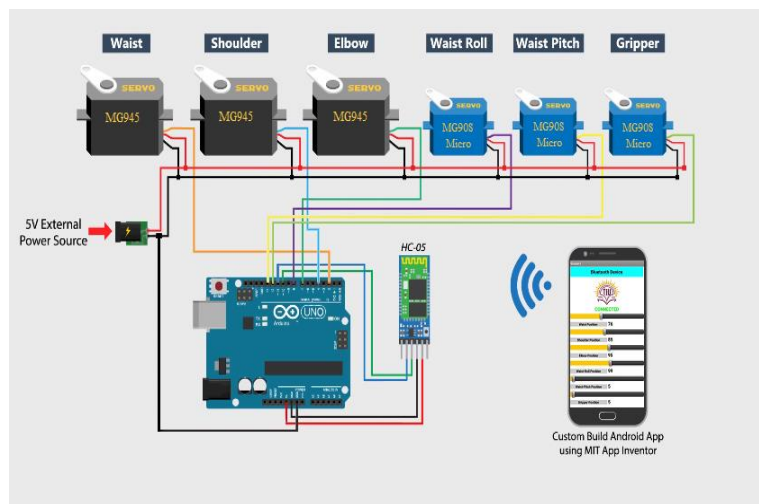


Figure 8. Circuit diagram of robotic arm

3. RESULTS AND TESTING THE SYSTEM

The results of testing the designed robotic arm system are explained as follows. The test of the designed robotic arm has been conducted depending on the speed, force, and balance of the movement, therefore showing that the robotic arm is capable of handling its weight, force, and balance properly. Testing the mobile application proved that it is working well without any errors. First, when the robotic arm is powered ON, all motors of the robotic arm go directly to the home position depending on receiving signal from the mobile application as shown in Figure 9. The application communicates with the robotic arm by the Bluetooth

module as the commands are sent to the robotic arm via Bluetooth and the robotic arm responds to the commands properly, as shown in the Figure 10. The movement’s tests have been explained in Table 4.

In the Figure 10, the test results are presented: (a) waist, (b) shoulder, (c) elbow motors, (d) waist-roll, (e) waist-pitch, and (f) gripper motors. According to the test results of the project, the Arduino controlled robotic arm is capable of doing great work compared to its size and speed of movement. It is easy to use, simple to handle, and can be easily screwed to a stationary place where the work is needed or unscrewed to be moved somewhere else. Ultimately, this is only the beginning of a new era of technology for robots whether it be in our daily lives or in companies as robots can save tremendous amount of time, reduce cost, and contribute to many other benefits.

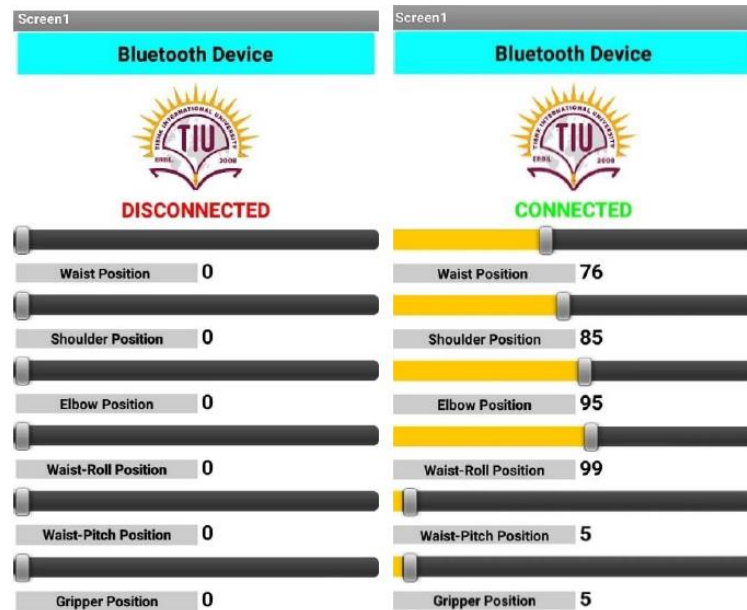


Figure 9. Before and after connecting mobile application to Arduino (home position)

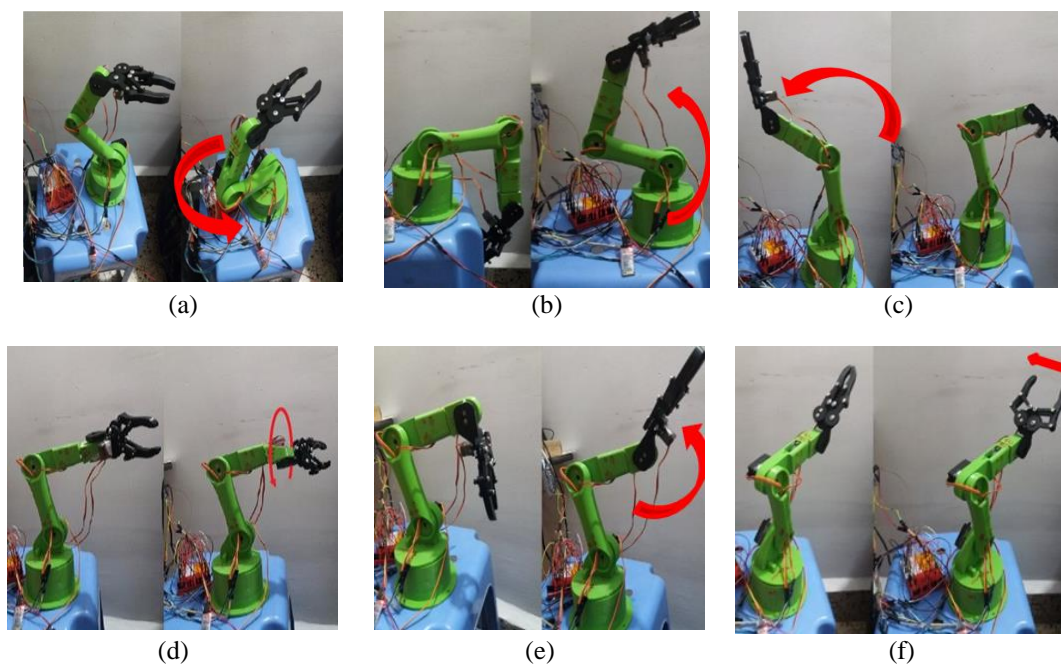


Figure 10. Testing the robotic arm I, (a) waist, (b) shoulder, (c) elbow motors, (d) waist-roll, (e) waist-pitch, and (f) gripper motors)

Table 4. Testing of the designed robotic arm

Command	Action
Waist motor movement is rotating according to the value sent by the mobile application which is in this direction is from 5 degrees to 146 degrees. (Angle range 5-175 degree)	Figure 10(a)
Shoulder joint motor movement is rotating according to the value sent by the mobile application which is in this direction is from 7 degrees to 166 degrees. (Angle range 5-175 degree)	Figure 10(b)
Elbow joint motor movement is rotating according to the value sent by the mobile application which is in this direction is from 5 degrees to 173 degrees. (Angle range 5-175 degree)	Figure 10(c)
Waist-roll joint motor movement is rotating according to the value sent by the mobile application which is in this direction is from 7 degrees to 175 degrees. (Angle range 5-175 degree)	Figure 11(a)
Waist-pitch joint motor movement is rotating according to the value sent by mobile application which is in this direction is from 20 degrees to 167 degrees. (Angle range 5-175 degree)	Figure 11(b)
Gripper joint motor movement is rotating according to the value sent by the mobile application which is in this direction is from 11 degrees to 173 degrees. (Angle range 5-165 degree)	Figure 11(c)

4. CONCLUSION

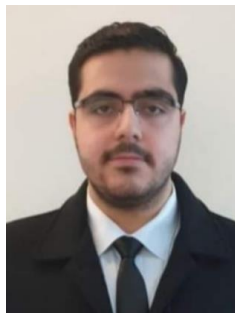
This research is intended to design a robotic arm fully controlled by Arduino platform over a safe distance through a mobile application. This robotic arm can be used in plenty of different industries or in areas which are unsafe for humans. The Arduino has been programmed to provide rotation to each servo motor corresponding to the sliders in the designed mobile application for usage from a distance. The final design has been tested and the results show that this design completes its job accordingly.





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