International Journal of Public Administration and Management Research (IJPAMR), Vol. 5, No. 2, August, 2019. Available online at http://www.rcmss.com/index.php/ijpamr; www.academix.ng
ISSN: 2350-2231(E) ISSN: 2346-7215 (P)

Shaibu Hamid-Ameh A.,Ogakwu P.A., Binfa Bongfa, & Ibrahim A. Audu, 2019, 5(2):73-82

DEVELOPMENT OF AN ARDUINO CONTROLLED ROBOTIC ARM

Shaibu Hamid-Ameh A[1].,Ogakwu P.A[2]., Binfa Bongfa[3], & Ibrahim A. Audu[4]
[1,2,3&4] Department Of Mechanical Engineering, The Federal Polytechnic Idah ,
Kogi State, Nigeria

Editorial Comment: *This article is published on the grounds of itspossible contribution to technological development and policy administration*

Abstract

This report contains the development of an Arduino controlled robotic arm having a five Degree of Freedom (5-DoF). The robotic arm is intended for pick and place operation which is to be used for instructional and educational purposes. In designing the robot arm, servomotors were used to power the various joints of the robot arm. The research covers the procedure for selection of the servos used to power each joint of the arm in details. Aluminum was selected to fabricate the components of the robotic arm. The torque exerted at each of the joints was calculated and a servo with the required torque rating was selected for each joint. The Arduino UNO R3 board was selected for the project and the Arduino IDE software was used for the control of the robotic arm. For controlling each movement of the joint we implemented the use of Bluetooth module and an Android device. Satisfactory results were obtained from the project. From the result, it was discovered that the Robot arm picked and placed an object with the parameters: Mass = 60grams, Diameter = 60mm, Height = 80mm. The distance between the initial position and the final position is 300mm.

Keywords: *Development, Robotic Arm, Arduino, Degree of Freedom, Servomotors*

Introduction

1.1 Robots

The study of Robots is a relatively young field of modern technology that crosses traditional engineering boundaries. Understanding the complexity of robots and their applications requires knowledge of electrical engineering, mechanical engineering, systems and industrial engineering, computer science, economics, and mathematics. New disciplines of engineering, such as manufacturing engineering, applications engineering, and knowledge engineering have emerged to deal with the complexity of the field of robotics and factory automation. (Mark. W. Spong, 2004).

Dominik Zunt (1998) opined that the term robot was first introduced into our vocabulary by the Czech playwright Karel Capek in his 1920 play R.U.R (meaning Rossum's Universal Robots), the word "robota" being the Czech word for forced labor. Since then the term has been applied to a great variety of mechanical devices, such as tele-operators, underwater vehicles, autonomous land rovers, etc. Virtually anything that operates with some degree of autonomy, usually under computer control, has at some point been called a robot. (Mark. W. Spong, 2004).

From this humble conception, many authors began getting inspirations from the concept of robot. Science-fiction author Isaac Asimov was the most famous of all the authors, he composed a short story about robots in the 1940s. In the story, Asimov (1950) suggested three principles to guide the behavior of robots and smart machines. Asimov's Three Laws of Robotics, as they are called include:

1. A robot may not injure or harm a human being, or through inaction, allow a human being to come to harm.
2. A robot must obey orders given to it by human beings, except where such orders would conflict with the First law.
3. A robot must protect its own existence as long as such protection does not conflict with the First and Second laws. (Robotics Introduction, 2001)

As time passed, people began formulating an encompassing definition of a robot. The Robot Institute of America (1979) defined a robot as a reprogrammable, multifunctional manipulator designed to move material, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks. As currently defined, robots exhibit three key elements:

1. Programmability, implying computational or symbolic manipulative capabilities that a designer can combine as desired (a robot is a computer)
2. Mechanical capability, enabling it to act on its environment rather than merely function as a data processing or a computational device (a robot is a machine).
3. Flexibility in that it can operate using a range of programs and manipulates and transport materials in a variety of ways. (Michael and SL Anderson, 2011)

Most robots used nowadays are designed for heavy, repetitive manufacturing work. They are specifically designed to handle certain tasks that are difficult, dangerous, or too boring to human beings. Robots can do more work more efficiently than humans can since robots are precise. They always do the same task with such precision over and over no matter how long they have worked. Robots nowadays are becoming more and more important in most industries of the world. In manufacturing sector, Robot arm is so cardinal that it deserves attention.

A robot arm is a robotic manipulator, usually programmable, with similar functions to a human arm. It has about same number of degree of freedom as in human arm. A typical robot arm is made up of seven segments joined by six joints. Usually a servo motor is used in order to track the movement of the robot arm. The reason for this is quite obvious since servo motors are designed to move in exact increments unlike DC motors. With such configurations, a computer may be able to control or maneuver the robot very precisely, repeating exactly the same environment over and over again. (ROBOINDIA Roboindia.com)

1.2 MATERIALS AND METHODS

The electronic component required to power and program the robot arm are shown in table 1 below.

Components	Specification	Qty
Arduino Board	**UNO R3**	**1**
Servomotor	**MG996r**	**5**
	SG90	**1**
Breadboard	**Generic**	**1**
Jumper wire	**Generic**	**30**
Bluetooth module	**HC-05**	**1**
Battery	**9v**	**6**

Table 1. Electrical hardware requirement

1.2.1 Arduino UNO R3 board

Arduino UNO R3 is a single-board microcontroller to make using electronics in multidisciplinary projects more accessible. The hardware consists of a simple open source hardware board designed around an 8-bit Atmel AVR microcontroller, or a 32-bit Atmel ARM. The software consists of a standard programming language compiler and a boot loader that executes on the microcontroller.

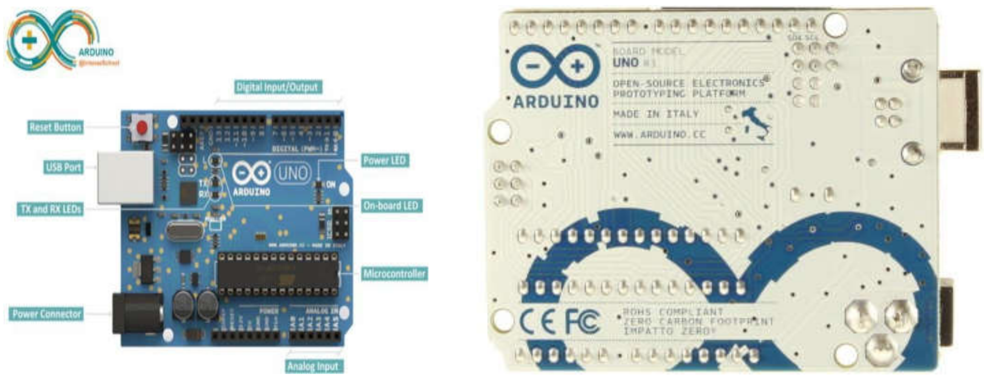

Figure 1. Arduino UNO R3 board (Source: Arduino.cc)

1.2.2: Servomotor

The Servo Motors includes three wires or leads in them. The positive supply and ground is provided by first two cables. The third wire is for the control signal. The wires of a servo motor are color coded. Ground wire is colored by black color. The DC supply is colored by red and it has to be connected to a DC voltage supply in the range of 4.8 V to 6V. For the third cable, all servo motors can have a different color. Generally it is in yellow color, same with the motors which will be used in this project.

Figure 2. Servomotors

1.2.3 Breadboard

This will be used because, this makes it easy to use for creating prototypes and experimenting with circuit design. It is reusable.

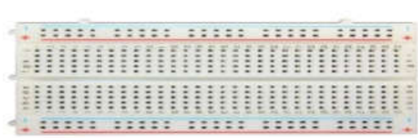

Figure 3. Breadboard (Source: Hub360.com.ng)

1.2.4 Jumper wires

This will provide connection between components and it is necessary to build circuits on the breadboard.

Figure 4. Jumper wires (Source: Hub360.com.ng)

1.2.5 External power source

This is used to give external power for the system. In some cases different voltage limits are needed so ARDUINO cannot provide more than 5V and the current is so low. Therefore, this part supplies the required voltage and the current.

Figure 5. Battery power source

1.2.6 HC-05 Bluetooth module

HC-05 module is an easy to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup. Serial port Bluetooth module is fully qualified Bluetooth V2.0+EDR (Enhanced Data Rate) 3Mbps Modulation with complete 2.4GHz radio transceiver and baseband. It uses CSR Blue core 04.External single-chip Bluetooth system with CMOS technology and with AFH (Adaptive Frequency Hopping Feature). It has the footprint as small as 12.7mmx27mm.

Figure 6. HC-05 Bluetooth module

2.0 Methods

2.1 Fabrication of the robot arm

The components of the arm were cut from aluminum alloy sheet with the use of a nibbling machine and the upright drilling machine. However, the aluminum alloy sheet used has a thickness of 1mm. The use of 1mm aluminum sheet was an added advantage since its lightness led to a reduction in the load the servos had to bear. To further reduce the load imposed at the shoulder joint, two servos were introduced at that joint.

The entire process of designing the robotic arm is represented by a flow diagram shown in Fig. 7.

2.2 Design of the Robot arm

A CAD model of the robotic arm structure was designed and rendered using Autodesk's AutoCAD software. Fig. 8.

Table 2. Design specification of the Robot arm

Specification	Value
Number of axes	5
Horizontal reach	230mm
Vertical reach	130mm
Drives	6 Servomotors
Configuration	5 axes plus gripper All axes completely independent All axes can be controlled simultaneously
Work envelop	(a) Base rotation – 180 (b) Shoulder Rotation -150 degrees (c) Elbow Rotation -180 degrees (d) Wrist Rotation -180 degrees (e) Gripper Rotation -90 degrees

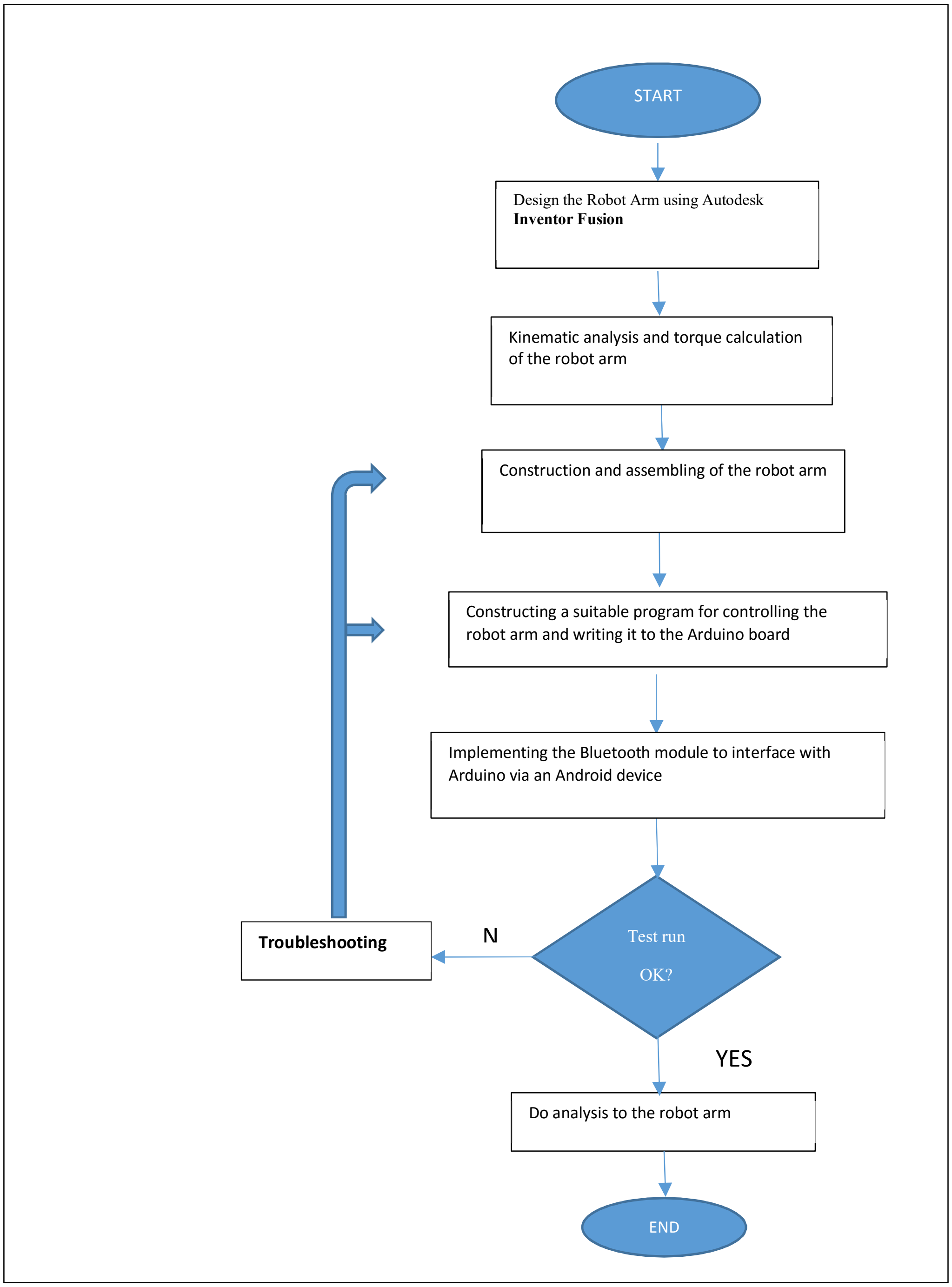

Figure 7. Flowchart for the design of the robot arm

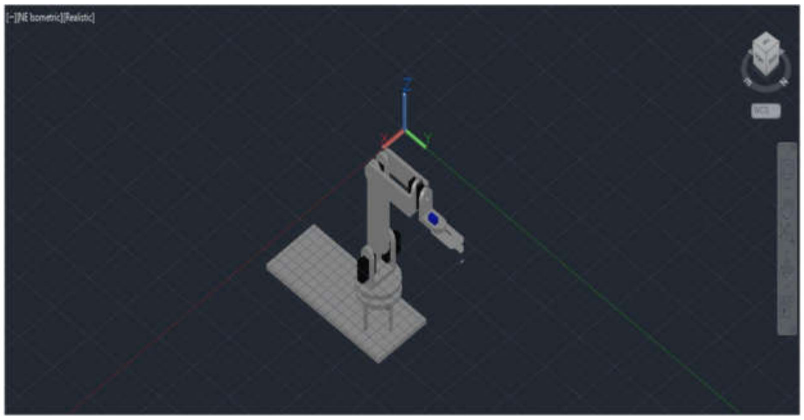

Figure 8. CAD model of the robot arm

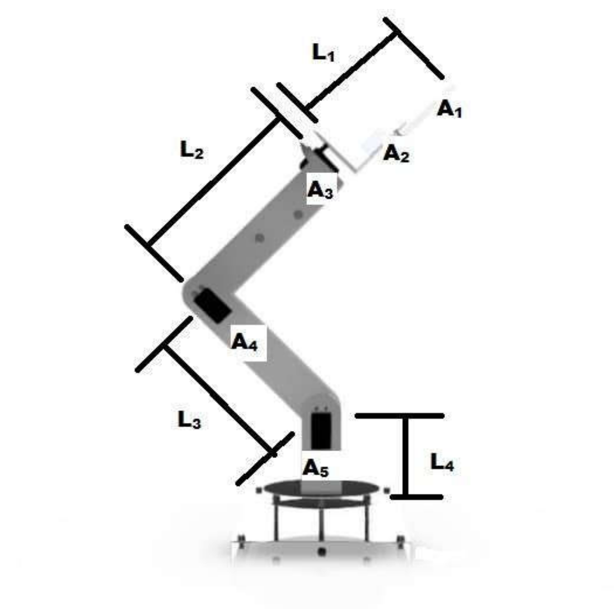

Figure 9. Labelling of the length of the links.

Weight of each link and the weight of servos acting at each joint are summarized in Table 3.

Table 3. Parameters for the robot arm

Links	**Joints**	**Weight of**	**Weight of**	**Items**
L 5	**J 5**	**W 5**	**A 6**	Base
L 4	**J 4**	**W 4**	**A 5**	Shoulder
L 3	**J 3**	**W 3**	**A 4**	Elbow
L 2	**J 2**	**W 2**	**A 3**	Wrist
L 1	**J 1**	**W 1**	**A 2**	Gripper
			A 1	Payload

Torque (T4) of the J4 motor (MG996R servo) we use the relation:
$T4 = (L1 + L2 + L3 + L4) \times A1 + ((0.5 \times L1) + L2 + L3 + L4) \times W1 + (L2 + L3 + L4) \times A2 + ((0.5 \times L2) + L3 + L4) \times W2 + (L3 + L4) \times A3 + ((0.5 \times L3) + L4) \times W3 + (L4 \times A4) + (L4 \times 0.5) \times W4$

Torque (T3) of the J3 motor (MG996R servo):
$T3 = (L1 + L2 + L3) \times A1 + ((0.5 \times L1) + L2 + L3) \times W1 + (L2 + L3) \times A2 + ((L2 \times 0.5) + L3) \times W2 + (L3 \times A3) + (0.5 \times L3) \times W3$

The torque (T2) of the J2 motor (MG996R servo) is calculated:
$T2 = (L1 + L2) \times A1 + ((0.5 \times L1) + L2) \times W1 + (L2 \times A2) + (0.5 \times L2) \times W2$

In the same manner the torque (T1) of the J1 (SG90 servo): $T1 = (L1 \times A1) + (0.5 \times L1) \times W1$
The lengths are: L1, L2, L3, L4 are 6.8 cm, 13.4 cm, 17cm 8 cm respectively
The weight of the servos are: A2 = 9g, A3 = 56g, A4 = 56g,

Replacing the values of L_s and A_s in the above equations, assuming the weight of load is zero, the torques of the motors were:
T1 = 0.021 kg.cm T2 = 0.6304 kg.cm T3 = 3.4554 kg.cm T4 = 11.8615 kg.cm

The nominal torques of the servo motors as given by the manufacturer are: SG90 (T_1) = 4.1 kg.cm
MG 996R (T_2) = 9.6 kg.cm
MG996R (T_3) = 9.6 kg.cm
MG996R (T_4) = 19.2 kg.cm (two servos were provided at this joint)

From the above, it is seen that the arm is capable of lifting its own weight because the nominal torques of the servos overlap the calculated torques with zero load ($W_{payload}$ = 0). If the load $W_{payload}$ is set to be 25g the torques would be:
T_1 = 0.3 kg.cm
T_2 = 1.356 kg.cm T_3 = 7.84 kg.cm T_4 = 16.43 kg.cm

It is observed that if the load is $W_{Payload}$ = 25g, servos can cope. If the weight $W_{payload}$ is increased to 60g, then the calculated torques would be:
T_1 = 0.86 kg/cm T_2 = 1.887 kg/cm T_3 = 3.04 kg/cm T_4 = 13.27 kg/cm

3.0 RESULTS AND DISCUSSION

The fabricated robotic arm components were assembled using the 3D model as a guide. The servos were inserted at the various joints in such a way that centering all the servo horns would make the arm to assume an upright pose. The centering of the servo horns was achieved by connecting the servos to the Arduino UNO R3 controller and sending PWM (Pulse Width Modulation) signals of 1500ms to them from the Arduino IDE software. The Arduino board was connected to the PC running the Arduino IDE software via a USB cable which also supplied enough current to power the Arduino UNO R3 controller board. The servos on the other hand were powered using six numbers of 9v battery.

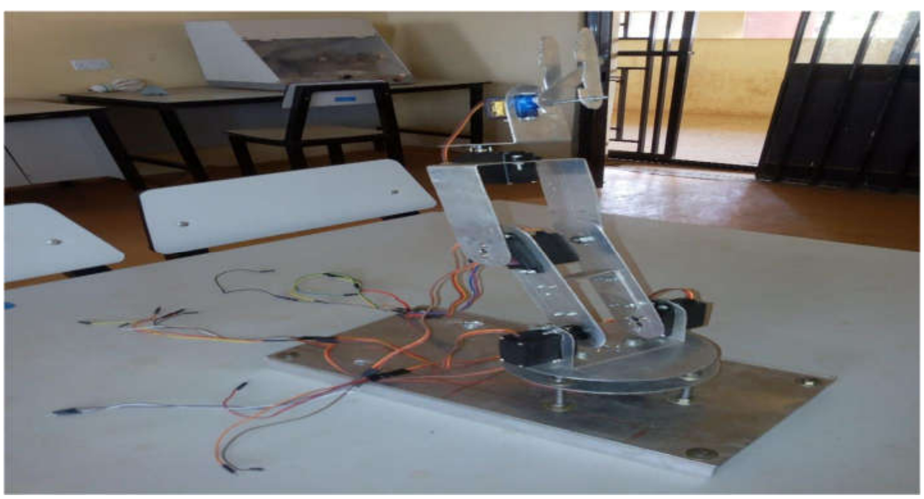

PLATE 1: The assembly of the robot arm

3.1 Programming and Control cases of the robot arm

After the robotic arm was assembled, each servo powering the arm was connected to the Arduino UNO R3 controller. This was achieved by inserting the female outlet of each servo cable to the 3-header pins on the Arduino board. Servo extender cables were used to increase the length of the wrist-rotate and gripper servos cables because they were far away from the Arduino board. The control interface app was then deployed using and Android device via a Bluetooth module. This app was created using the MIT App Inventor. It helps to control the robot arm efficiently to pick an object from its initial position to the desired position.

3.1.1 Pick and Place operation No.1

During the pick and place task, the arm was controlled to pick an object weighing 30grams from the initial position of the object to the measured.

3.1.2 Pick and Place operation No.2

The initial position and the measured position is the same as the Operation No.1, but the weight of the object was varied to 40grams. And it was carried out as perfectly as done in Operation No.1.

3.1.3 Pick and Place operation No.3

The third operation is almost the same as the operation No.1 and No.2, but more power was consumed as the weight was above 60grams. The movement of the object from its initial position to the desired position was achieved.

CONCLUSION

This research was to design and fabricate a robot arm having five degrees of freedom that can be used for demonstrative and educational purposes and this has been achieved. The robot arm is meant to perform a pick and place operation, this pick and place concept makes use of servomotors which is controlled by the Arduino UNO R3 board. In order to control the movement of the servomotors, an Android app to interface with the Arduino board via a Bluetooth module was introduced.

REFERENCES

Mark, W. S., Seth, H., & Vidyasaga, M. (2004). *Robot Modelling and control*. New York, NY: John Wiley & Sons, Inc.

Michael, A., & Susan, L.A. (2001). *Machine Ethics*. New York, NY: Cambridge University Press.

John, J. C. (2005). *Introduction to Robotics*. United State of America, USA: Pearson Education, Inc.

Technology subjects support service. (2006). *Applied Control Technology: Introduction to robotics*. Retrieved from http://www.t4.ie /resources/resources%20by%20 Topic/option/applied%20 control%20 systems/Robotics/introduction%20 to %20 Robotics.pdf

Steve, H. (2003). *Embedded system design*. London: Elsvier science

ROBOINDIA. (2014). *Servo Based 5 Axis Robotic Arm* Retrieved from https: //www.slideshare.net/mobile/ROBO-INDIA/servo-base-5-axis-robotic arm-project-report.

Oridate, A. A. (2014). *Design, Simulation and Fabrication of a 5-DOF Robotic arm*. Ile- Ife: OAU, Ife.

Mohammed, A., William, F., Fernando, G., & Yifan, S. (2012). *Designing a robotic arm for moving sorting scraps at pacific can, Beijing, China*. Beijing, China: Worchester Polytechnic Institute.

Thomas Insights. (2018). Article. Retrieved from http://www.thomasnet.com/articles/ custom-manufacturing-fabricating/automation- electronics.http://www.arduino.cc/introduction-to-arduino.