



City Research Online

City St George's, University of London

Citation: Jadeja, Y. & Pandya, B. (2019). Design and development of 5-DOF robotic arm manipulators. *International Journal of Scientific and Technology Research*, 8(11), pp. 2158-2167.

This is the published version of the paper.

This version of the publication may differ from the final published version. To cite this item please consult the publisher's version.

Permanent repository link: <https://openaccess.city.ac.uk/id/eprint/34166/>

Copyright and Reuse: Copyright and Moral Rights remain with the author(s) and/or copyright holders. Copies of full items can be used for personal research or study, educational, or not-for-profit purposes without prior permission or charge, unless otherwise indicated, provided that the authors, title and full bibliographic details are credited, a hyperlink and/or URL is given for the original metadata page and the content is not changed in any way. For full details of reuse please refer to [City Research Online policy](#).

Design And Development Of 5-DOF Robotic Arm Manipulators

Yagna Jadeja, Bhavesh Pandya

Abstract: A robotic arm is an artificial arm to achieve desired tasks. Now a day, there is a more and more purpose to develop artificial arms for various non-human situations where human communication is impossible. Human's pickups stuff without considering the steps involved, and using wired and wireless, robotic arm is controlled manually. This paper focuses on design, and to control the robotic arm's angle by using Cortex ARM M3 LPC1768 Microcontroller including ultrasonic sensor and a digital controller using computer system. The robotic arm can move freely having 5 Degrees of Freedom (DoF) with a Servo motor situated at each joint. The function of Servo motor is position-controlling using a microcontroller. With the help of this Servo motor, Robotic Arm can position the link that required at the particular angle. By using rotary-encoder the feedback of the angle can be measured. The purpose of this paper is to introduce the level of intelligence that can be implemented to industries in order to reduce the human errors as well as enhance the quality and rapid production in manufacturing and processing. The major advantage of the Robotic Arm is that it can work in hazardous circumstances such as high temperature, pressure which is not suitable for the humans. The Robotic Arms can be update and modify easily. Robotic Arm reduces the overall cost and risk associated with the injuries of workers. The operation of designed robotic arm has been experimentally verified. Simulation results are presented and discussed.

Keywords: Robotic arm, Servo motor, Degrees of random.

I. INTRODUCTION

Nowadays, robots are more and more being integrated into working tasks to supplant people particularly to play out the tedious job [1]. Usually, robotics is often divided into two parts, industrial and service robotics. International Federation of Robotics (IFR) characterizes a service robot as a robot which works semi- or fully individually to do services helpful to the prosperity of people and equipment, barring fabricating activities. At present these robots are utilized in numerous fields of applications including office, military undertakings, medical clinic tasks, hazardous condition, and farming. Also, it may be tricky or hazardous for people to do some particular works like grabbing dangerous substances, defusing bombs or in a most dire outcome imaginable to pick and place the bomb some place for regulation and for rehashed pick and spot the activity in ventures. So a robot can be supplanted human to do work [2]. A robotic arm is a robot controller, generally programmable, with comparative capacities to a person arm. The associations of such a controller are coupled by joints permitting either rotational movement, (for example, in an articulated robot) or translational (direct) displacement. The connections of the controller are often thought-about to frame a kinematic chain. The kinematic chain of the controller in the business end known as the end effectors and it is undifferentiated from the human hand. The end effectors care often intended to play out any ideal work, for example, welding, grasping, turning, and so on., contingent upon the application [3]. The Robot has significant role in modern era, since; it has ability to perform in various conditions which is not possible for human. The robotic arm besides provides advantage in industrial level by increasing the speed, accuracy. So to attain a complex task, a robot often employed to emulate the human behaviour [4]. Human gets tired and emotionally breakdown in harsh environment, but a Robot can easily utilized without getting tired and face commands emotionally. The advancement in computer technology and programming makes the robot more sophisticated that are expected to obey and perform repeated task continuously. The robotic arm has changed the shape of the industry [5]. The enhancement of robotic technology by pretends the human activities have opened the door for extensive use of robotic

technology in various field. The robotic technology and AI has changed our daily life. The main philosophy of creating a robot is to design a robot that can be utilized in our daily. The utility of the Robot is also significant in health care sector and minimise the risk of human errors. At present, the uses of industrial robot can be seen in many industries that manufacture vehicles, tools, electronic devices, cuisine and many more [6]. In many industries the implementation of robot assembly lines has made the operation, processing and production faster and accurate than before. Recently, robot is capable to perform almost all kind of repeated task that usually done by the humans [7]. The implementation of robotic technology in industry has facilitated the industry by reducing the risk of accident and human error. So, more time is available for human to spend on skilled professions such as programming and development planning. There are various areas where a robot has already replaced the human and reduced the health hazard and accidental risk. Particularly in automotive and metal industries the role of robot has increased tremendously. In aerospace industries, robots are very effective, since it can work in the space, different pressure, underwater and etc [8]. In many space missions such as mars mission, lunar mission and other space probe, robots are playing significant role which is not possible for human being or if possible the process is highly effective and risky. The modern simulation technology has also made the robotic technology more effective. The development in artificial intelligence and cognitive science has contributed in making robotic technology more usable and effective. The concept and design of the robotic arm is not a new concept but still a lot of research and development is required to make the robot usable in our daily life. The study and research in the area of circuitry, degree of freedom (DoF), algorithm, programming, metallurgy and system design is necessary for the development of the robotic technology [9]. The challenges with the robotic technology are to make compatible with human task and hand's actions like grabbing, replacement and doing critical task. At present robotic arms are playing role in repeating task but still lot of work needs to be done in order to make robot capable to perform complex task. At present robotic arm has a primary processor – LPC1768 (Cortex Arm M3) Mbed microcontroller.

II. LITERATURE REVIEW

B.O.Omijeh et al [10] the design analysis of a Remote Controlled "Pick and Place" Robotic vehicle has been displayed. This work solve the way that man would consistently need to adhere to security protections at the work environment and even in its condition, to be capable to deal with some particular jobs, such as sending the automatic vehicle to the unsafe condition to acquire tests for chemical investigation. A characteristic of the automatic Vehicle is able equipped for going over different landscapes and crossing deterrents. In one representation, the plan in this work incorporates a Robotic arm of five Degree of Freedom with its base lying straightforwardly over the vehicle, a body having four drive wheels coupled to the closures thereof. The wheels are specifically powered to push the vehicle. A model of the Remote Controlled "Pick and Place" Robotic vehicle was worked to approve structure details. The outcomes acquired were extremely agreeable. The utilization of Robots is exceedingly prescribed for Industries, particularly for wellbeing and profitability reasons. Difficult and confused obligations would be accomplished quicker and all the more precisely with this plan. A.Reshamwala et al [11] the fundamental thought behind making any robot is to lessen human exertion. Based on the necessities, various kinds of mechanized and self-controlled robots are being actualized. As a lot of robots which are as of now existing in the market experiencing controlling issues and to beat this one of the developing innovations named Haptic Technology is examined in this paper. This paper likewise talks about a methodology for showing of a robot arm for physically challenged people who can't walk. For those persons who cannot effortlessly lift easy things (for example. lifting a glass of water). So the advancement of a Robot Arm which is constrained by the remote medium is the topic of the paper and to make this done by haptic innovation. Fundamentally, a robot arm is partitioned into two sections for example haptic glove and a robot arm. The region where robot arm moves relies on the scope of Zig-honey bee module and robot arm is constrained by the haptic glove. Haptic gadgets must be littler so they are lighter, more straightforward and simpler to utilize. So by keeping all requirement and constraints this paper talks about an ease robot arm utilizing Haptic innovation which plays out numerous undertakings utilizing less number of assets and it is anything but difficult to utilize. Szabo .R et al [12] built up a technique for how to command a 5 DoF automated arm. The automated arm has 5 servomotors and can be reached out with an additional servo motor to rotate the gripper. The automated arm has an SSC-32 control board, which can control every one of the engines. The control board has an ATmega168 microcontroller which directions on RS-232 interface with a PC will control the engines. The microcontroller gets explicit directions which can be deciphered and can control the engines along these lines to move the mechanical arm. Guo-Shing Huang et al [13] concentrated on the practical design and control of the automated arm, which is mounted on the portable robotic body. Automated arm framework is joined with a binocular vision framework for the holding plate. Utilizing 8052 MCU of Atmel arrangement controls every axis of the robotic arms. Authors have presented the experimental results that the developed system of dual robotic arms can get

organizes from binocular vision and hold the payload. This investigation finished a sign transmission, the speed and rakish control from PC to double automated arm framework. Szabo.R & Gontean et al [14] exhibited an automated arm control technique with stereo vision. No an excessive number of robots in the business are controlled with a camera and the robots which are controlled with at least two cameras are considerably harder to discover. Authors have made a dream acknowledgment application which can perceive certain key focuses on the automated arm. These focuses are set at the joints, over each engine. These focuses have various colours, so the recognition of them was a task of colour recognition. Authors have utilized stereo separation computation to realize how much development does the automated arm needs at the base joint. D. Bassily et al [15] depicted building up a human-machine correspondence interface between the Leap Motion controller and the 6-DOF Jaco automated arm. A algorithm was created to permit an ideal mapping between the client hand developments, followed by the Leap Motion controller. The framework ought to take into account a progressively regular human-PC association and a smooth control of the automated arm. The uses of this human-robot connection talked about in connection to Ambient Assisted Living, where some utilization case situations were presented. The creators accept that the Leap Motion Controller innovation would without a doubt advantage and empower the acknowledgment of different human-machine collaboration application in the field of AAL and ADLs, because of its conservative size, upgraded exactness, and low buy cost. P.Adeeb Ahammed et al [16] to build a robotic arm controlled by natural human arm movements whose data is acquired through the use of accelerometers have been proposed. The improvement of this arm depended on ATmega32 and ATmega640 stage alongside a PC for sign handling. At long last, this model of the arm might be required to defeat the issue, for example, putting or picking unsafe articles or non-dangerous items that were far away from the client. The proposed framework dependent on the microcontroller is observed to be progressively minimal, easy to understand and less unpredictable which can promptly be utilized so as to play out the task in everyday life. Mohammad Javed Ansari et al [17] to designing and developing of a microcontroller (ATmega) based robotic arm has been described. The automated arm reacts to the motion just as can be modified to come an unmistakable way and undertaking. The framework feels the development of the client's arm and robotic arm replicates the given info signal. The signal is detected by various potentiometers which are inserted onto a glove. The development in potentiometer controls the situation for the servo engines driving the pieces of the arm. Piotr Kopniak et al [18] introduced new developed natural interface for automated arm remote controlling. The interface was worked with the utilization of inertial movement trackers. There are utilized two kinds of motion trackers. The first tracker is Xsens Xbus Kit tracker and the second is Razer Hydra Controller. Hydra controller is accustomed to deciding automated arm restriction in 3D space. One of the most troublesome issues which were settled in an adequate way and spoke to in this article is handling increasing speed information to appraise the straight position of the robotic arm satisfactory to the operator's motion. The results of algorithms' parameter

values selections and results of practical evaluation of the interface.

III. PROPOSED METHODOLOGY

In this research, the robot that has been developed and has a stationary robotic arm that is articulated in nature along with robotic arm that is 5DoF in nature. There are also joints that can be found in shoulder, base, wrist, elbow, and slider as well as in gripper. The mechanical works has been done by the technicians that include works in shoulder, gripper, elbow and so on.

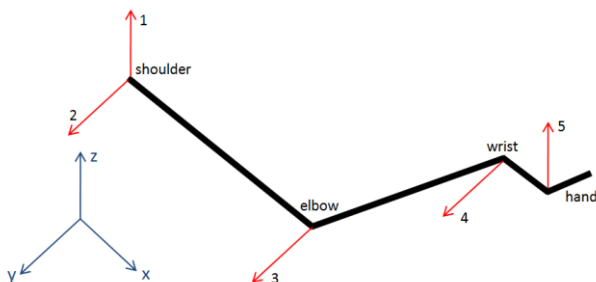


Fig.1. simple representation of the robotic arm

Figure 1 shows the simple representation of the robotic arm. The proposed work is to control the robotic arm using hand gesture in order to make it possible to grab and move the object precisely by coordinating the weight and shape of the object. The robotic arm can move freely by 5 Degrees of Freedom (DoF) with a Servo motor situated at each joint. The joints can be found in shoulder, base, wrist, elbow, and slider as well as in gripper.

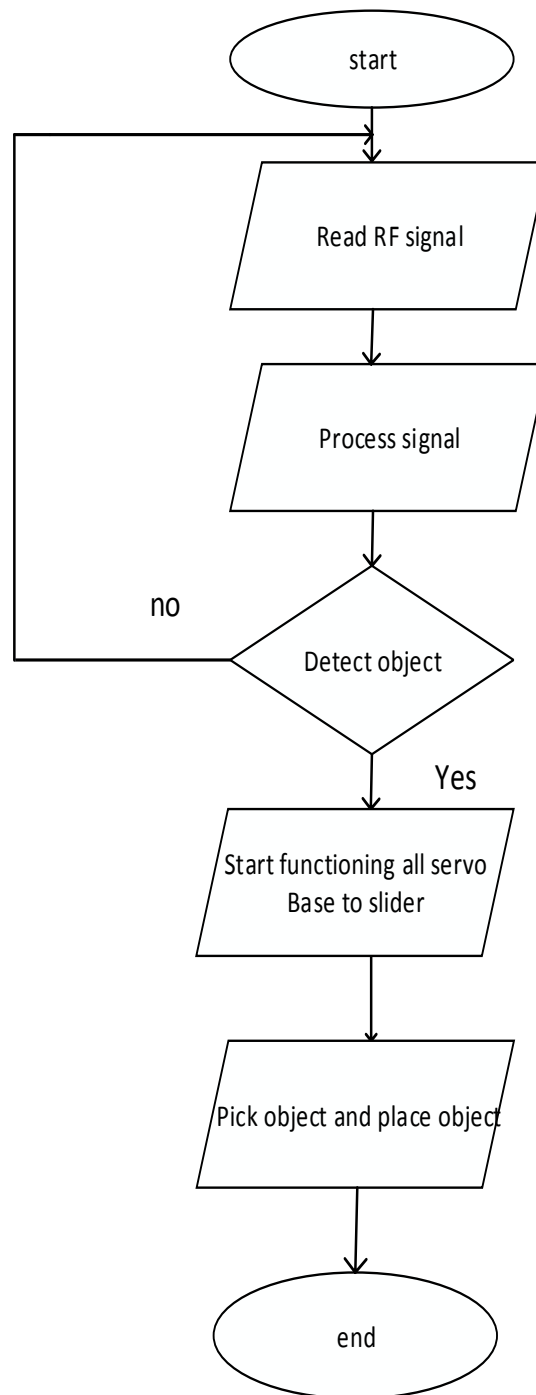


Fig.2. Flow diagram of the system

In this flow chart, the system read the RF signal by Xbee S2C which is used for transmits the data and the signal is processed. After that the object is detected along with finding the distance regarding the object. If it is YES, it starts functioning all servo base to slider and finally, the system is used to pick up the object and place it in a correct position. If the object is not detected, the system will again read the RF signal and the process will continue until it detect the object.

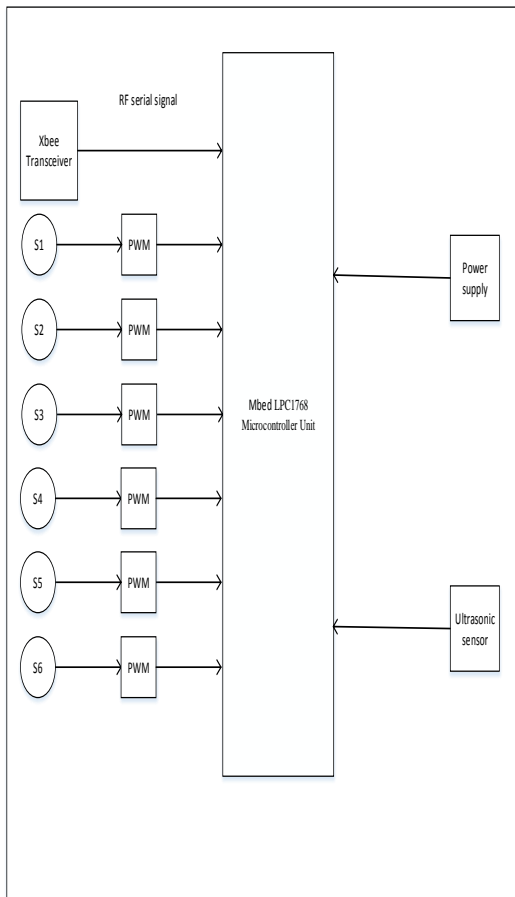


Fig.3. System architecture of robotic arm

The system has highly focussed on the entire design along with proper implementation along with control for adhering the five-degree regarding freedom (DoF) from robotic arm that are utilizing servomotors. Therefore, the control regarding the robotic arm has been achieved by the application of (Cortex Arm M3 LPC1768). The chief duty regarding the microcontroller has to generate the pulse along with the width modulation as per PWM and their signals that are maintained with the application of servo motors in achieving the rotation that are desired. Four servos have also used the control regarding the body motion that has included the base as well as shoulder along with elbow and other wrist with one smaller servo. The objects are highly detected by the ultrasonic sensor, which will highly provide the command towards mbed via Xbee and their transceiver along with entire system that work smoothly.

A. Selecting Electronic Hardware

The electronic section of robotic arm recommended as LPC1768 with Cortex Arm M3 has chosen Mbed microcontroller as the important and main processor. It has been understood since it possess good variety regarding the interfaces which has included the analogue as well as digital pins accumulated with the pulse width and also modulation referred as PWM as well as debugging with the aspects of in circuit. Thus perception of the microcontroller can easily generate the entire PWM signals within the Pin 21 towards Pin 26. Apart from this, the rest equipment adhered from the electronic operations along with sensors have been decided as per the tasks through which the robot has been expected for achieving the margin. The entire circuitry regarding the robot has been initially designed and also tested on the respective bread board for underpinning the final design and will surely transfer towards the PCB which is also referred as printed circuit board.

B. Mbed Microcontroller

The assumptions of mbed microcontrollers have possessed the series regarding the ARM microcontroller in developing the boards that are designed for determining the rapid prototyping. Therefore, the mbed NXP LPC1768 Microcontroller respectively designed in order to prototype the devices, which has included the value of Ethernet, USB along with the other flexibility by acquiring different peripheral interface along with other flash memory. It has been packaged with the small DIP through form factors in order to prototype within the through hole considering PCB and also strip board and also breadboard that has included a built in the overall programming within the USB flash. It has been undertaken on the basis of the NXP and the LXP1768 through adjusting 32 bit ARM cortex by underpinning the core running opportunities at 96 Mhz. It has been included with a flash of 512 kilobyte, with a RAM of 32 kilobyte along with other interfaces, which has included for built in the entire Ethernet and other USB hosts along with device. These are like used interface along with the locations that has been numbered with pins from p5 to p30 and has been utilized through DigitalIn and also Digital Out within the interfaces. It is observed that the Mbed Microcontrollers has highly provided the embedded developers with much more experienced with powerful as well as productive platform. It has directly inherited the proof of concepts required in it. Thus for the respective developers innovative 32 bit microcontrollers has provided the accession of prototyping solution for getting the research in order to built through backing the libraries along with the resources as well as supporting the shared within the mbed community. Figure 5 shows the circuit diagram of robotic arm.

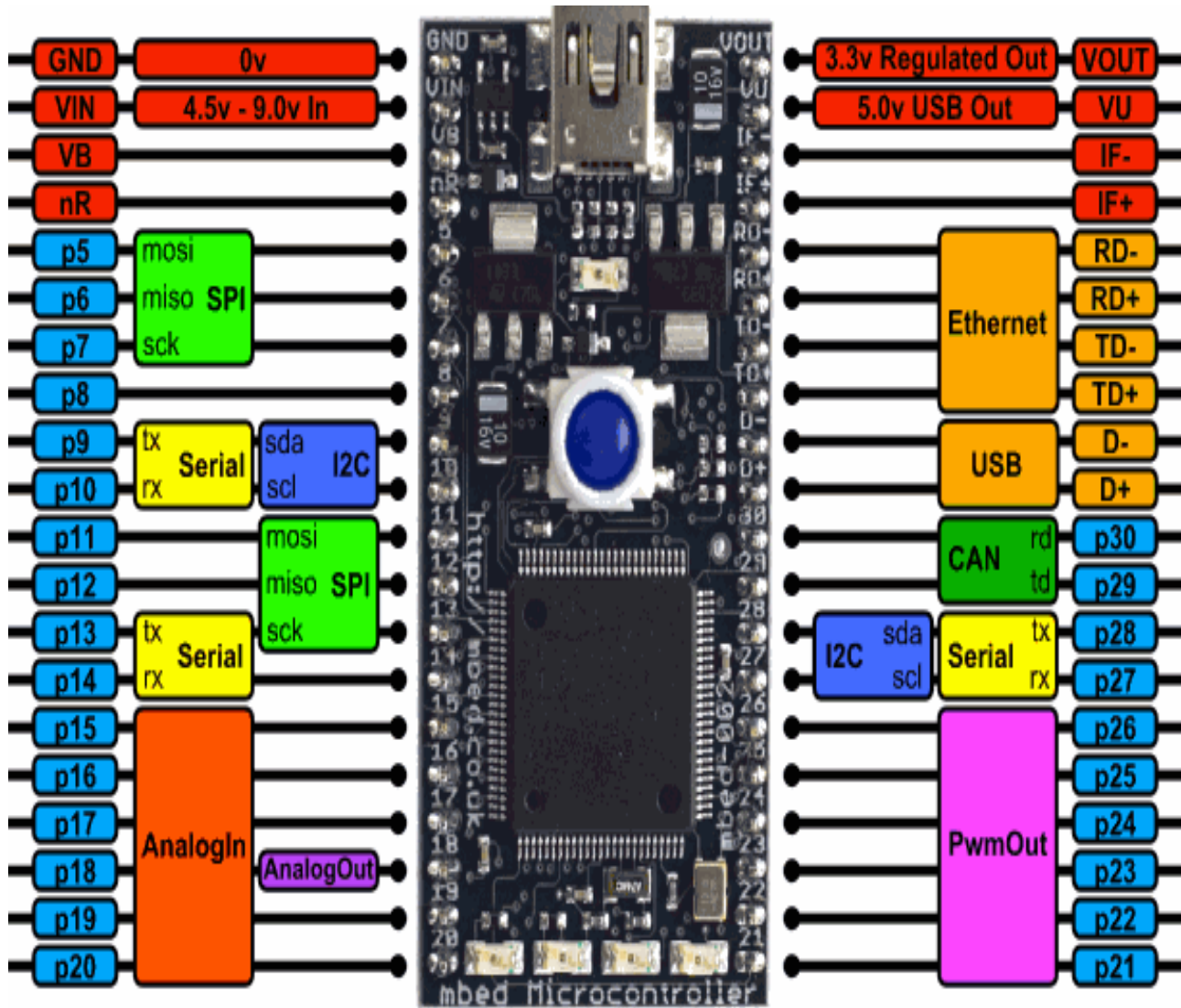


Fig.4. Configuration of Mbed Pin

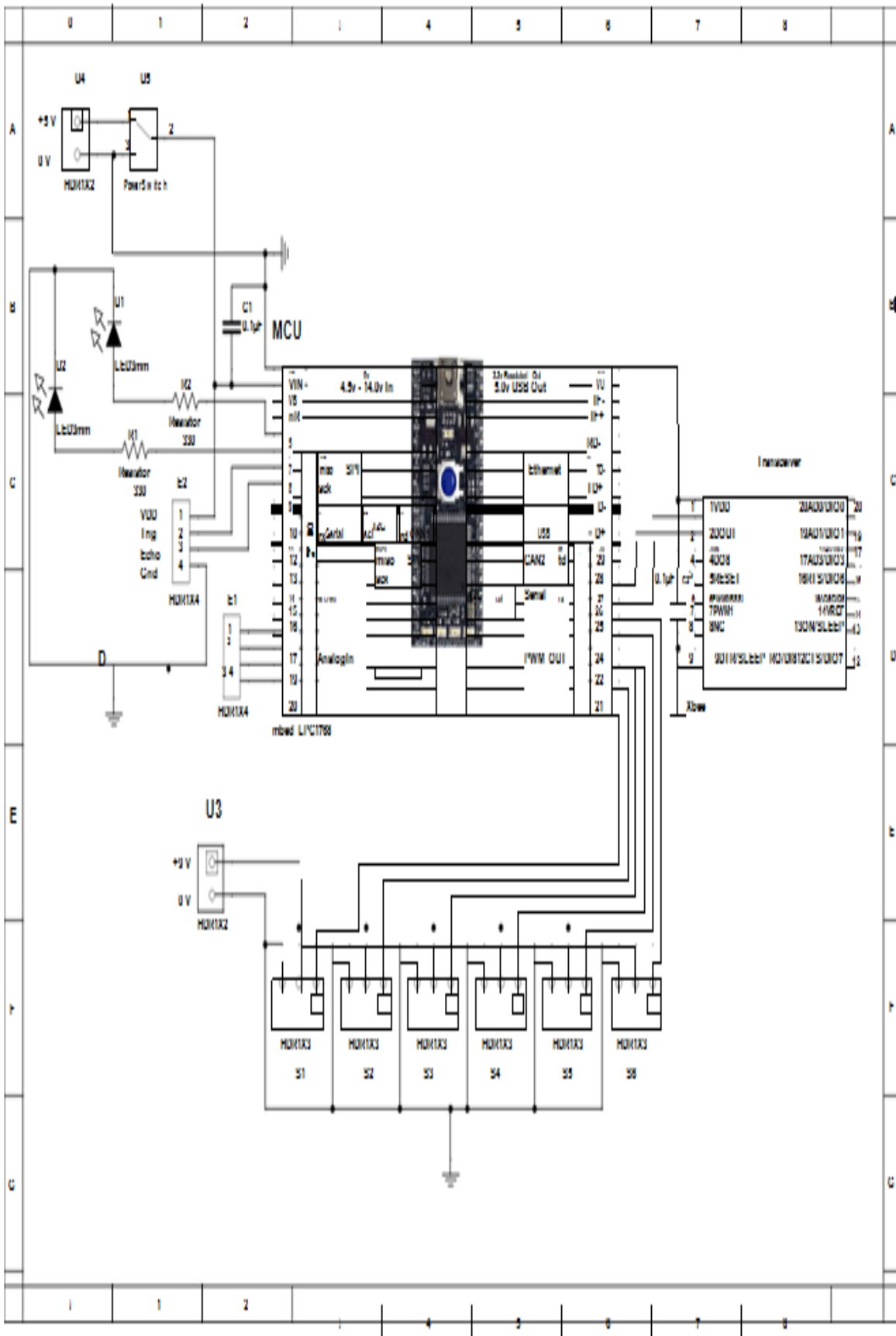


Fig.5. Circuit Diagram of Robotic Arm

Into the respective circuit, the Mbed LPC 1768 has been used to control entire system. Xbee S2C is highly connected through which the data transmitted along with the receiving are entailed. Thus the detecting the objects along with the finding the distance regarding the object has been justified. Therefore, the servomotors will be connected through PWM pins concerning the mbed along with the respective circuit that are powered with the 9 –volt of batteries. These are three pins within the servomotor which is significantly VCC and the other one is VCC along with GND with the third one SIG pin.

C. Servo motors

Servo refers to an error sensing feedback control which is used to correct the performance of a system. Servo Motors are DC motors equipped with a servo mechanism for precise control of angular position. The shaft of servo motor is typical in nature which can rotate within 0 degree to 180 degree. For continuous rotation, the robot can be arranged as well. The assembled robotic arm that has been used for the purpose of the study uses a servo arm that can help in the procedure of full rotation. PWM signals can help in the procedure of controlling the servo motors. Microcontroller has helped in the generation of PWN signals for this particular study and in the Figure 4;. For the purpose of rotating the servo clockwise, in full speed, 2ms of pulse duration is necessary. The procedure of feedback control can also help the servo motor to return to the same position when duration of pulse is set for 1.5ms. The servo circuit mathematical expression is written down as follows:

$$V_a = R_a i + L_a \frac{di}{dt} + E_b$$

$$J \frac{d\omega}{dt} = T_e - T$$

$$E_b = K\omega, T_e = K_i$$

Here,

- i_a =armature current
- V_a = voltage
- R_a =armature resistance
- L_a =armature inductance
- ω =rotor angular speed
- K = torque
- T_e =electromagnetic torque
- T =total load of torque and
- J =inertia of the rotor respectively.

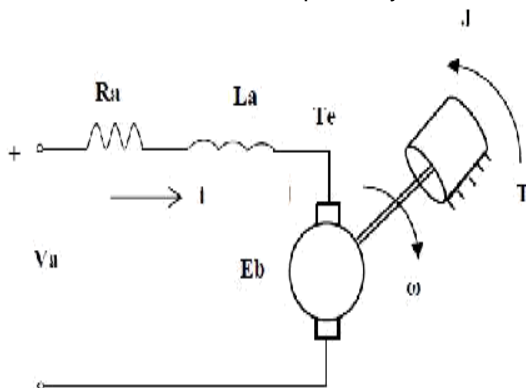


Fig.6. Circuit of service motor

There are altogether four types of service motors that are used for the purpose of building the arm of the robot where

there are diverse ranges of specifications for each of them. For the purpose of constructing the base, the servo motor that is used includes (HS-485HB Servo), for the purpose of building the wrist and the elbow (HS-755HB Servo) motor is used. For the purpose of building gripper motion (HS-85BB+ Servo) is used and for the gripper slide, (Futaba S3003 Servo) is used. This has been shown in Table 1-4 respectively.

TABLE 1 Specifications of HS-485HB Servo Motor

BASIC INFORMATION				
Modulation	Torque	Speed	Weight	Dimensions
Analog	4.8V: 11.00Kg-cm 6.0V: 13.20kg-cm	4.8V:0.28sec/60° 6.0V:0.23sec/60°	110.0gr	Length: 59mm Width: 29mm Height: 50mm
Additional specifications				
Rotational range		Pulse cycle	Pulse width	
180°		20ms	555-2410µs	

The Hitec HS-485HB Servo Motor is one of the most durable and a reliable servo has ever offered. The HS-485HB Servo motor is used for the purpose of constructing the base.

TABLE.2 Specifications of HS-755HB Servo Motor

BASIC INFORMATION				
Modulation	Torque	Speed	Weight	Dimensions
Analog	4.8V: 4.80Kg-cm 6.0V: 6.00kg-cm	4.8V:0.22sec/60° 6.0V:0.18sec/60°	45.10gr	Length: 39.8mm Width: 19.8mm Height: 37.85mm
Additional specifications				
Rotational range		Pulse cycle	Pulse width	
180°		20ms	553-2425µs	

The HS-755HB servo motor is used for constructing the wrist and elbow. The wrist is usually can turn the arm 180° to 360° and the elbow will make the arm go forward or backward.

TABLE 3 Specifications of HS-85BB+ Servo Motor

BASIC INFORMATION				
Modulation	Torque	Speed	Weight	Dimensions
Analog	4.8V: 3.00Kg-cm 6.0V: 3.50kg-cm	4.8V:0.1 6sec/60° 6.0V:0.1 4sec/60°	19.0gr	Length: 29mm Width: 13mm Height: 30mm
Additional specifications				
Rotational range	Pulse cycle		Pulse width	
180°	20ms		553-2300µs	

The HS-85BB+ servo motor are used for constructing the gripper motion. It works by opening or closing to "grab things."

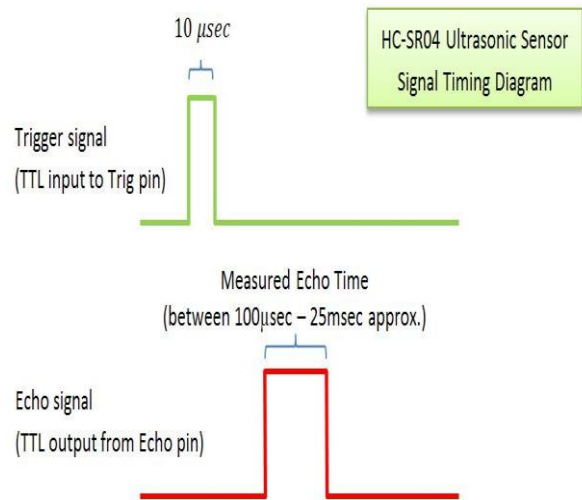
TABLE 4 Specifications of Futaba S3003 Servo Motor

BASIC INFORMATION				
Modulation	Torque	Speed	Weight	Dimensions
Analog	4.8V: 3.20Kg-cm 6.0V: 4.10kg-cm	4.8V:0.2 3sec/60° 6.0V:0.1 9sec/60°	38.0gr	Length: 41mm Width: 20mm Height: 36mm
Additional specifications				
Rotational range	Pulse cycle		Pulse width	
60°	30ms		500-3000µs	

The Futaba S3003 Standard Servo is designed for remote control, but can also be used in other applications. The Futaba S3003 Servo motor is used for the purpose of gripper slider. The basic information and the specification are given above.

D. Ultrasonic Sensor

The ultrasonic sensor has also been utilized in order to determine the entire distance of the object. The happenings can be identified through the transmitter, which sends a signal generally with a much higher frequency of the sound. Thus, the signal has always found the object, which is generally reflected with proper transmitter that reflects echo pin and has received it. The time period in between the entire transmission along with reception for which the signal has allowed for knowing about the distance regarding the object. This will be possible as per the known fact regarding the velocity of the sound within the air.



$$\text{Distance (cm)} = \text{Measured Echo Time (in } \mu\text{sec)} / 58$$

$$\text{Distance (inch)} = \text{Measured Echo Time (in } \mu\text{sec)} / 148$$

Fig.7. Diagram of Ultrasonic Sensor Signal Timing

The trigger has highly maintained as per the input that are sent as per 10 u sec and its pulse. These are followed as per the pulse width considering the echo line and measurement as the pulse that are measured is highly converted through the entire distance in the value of centimetre.

E. Xbee interface along with Mbed

The aspects of the Xbee module have consisted with different hardware along with different part of software. Thus, the modules are directly designated through mounting the receptacle and does not adhered the requirement of soldering that are mounted upon the board. Therefore, the sensors has measured the data and also sent them through considering the XBee module towards the gateway. Therefore, the gateway has empowered it to send the entire data through maintaining the IP network towards the computer and any other important device where proper significance in watching on the measurement of the data through sensors is identified.

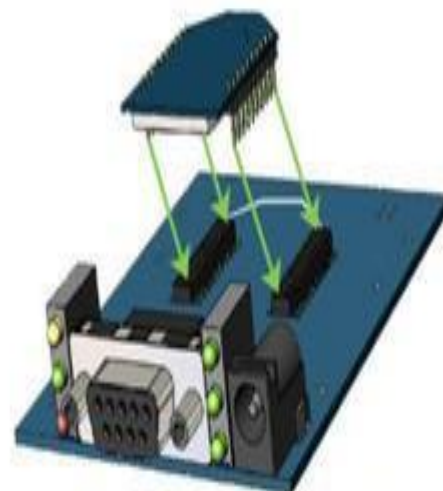


Fig.8. XBee Module Board

F. Software

Robot has been defined as the device that has empowered the intelligence and has actually meant about some important software, which will direct about what needed to be done by providing more input conditions. Therefore, the robotic arm has been functioned through embedding the languages of C programming successfully.

IV. SIMULATION AND ANALYSIS

The robotic arm has different features as well as specification:

- The arm has been possessed through six servo us that are generally controlled by utilizing the one cortex microcontroller which is M3 LPC1768 (Mbed).
- The arm has to be much more user friendly as computer interface must be developed thoroughly.
- It will have to lift the entire objects as per the weight of 100 grams.
- The bases are needed to be equipped with proper and higher torque servo.

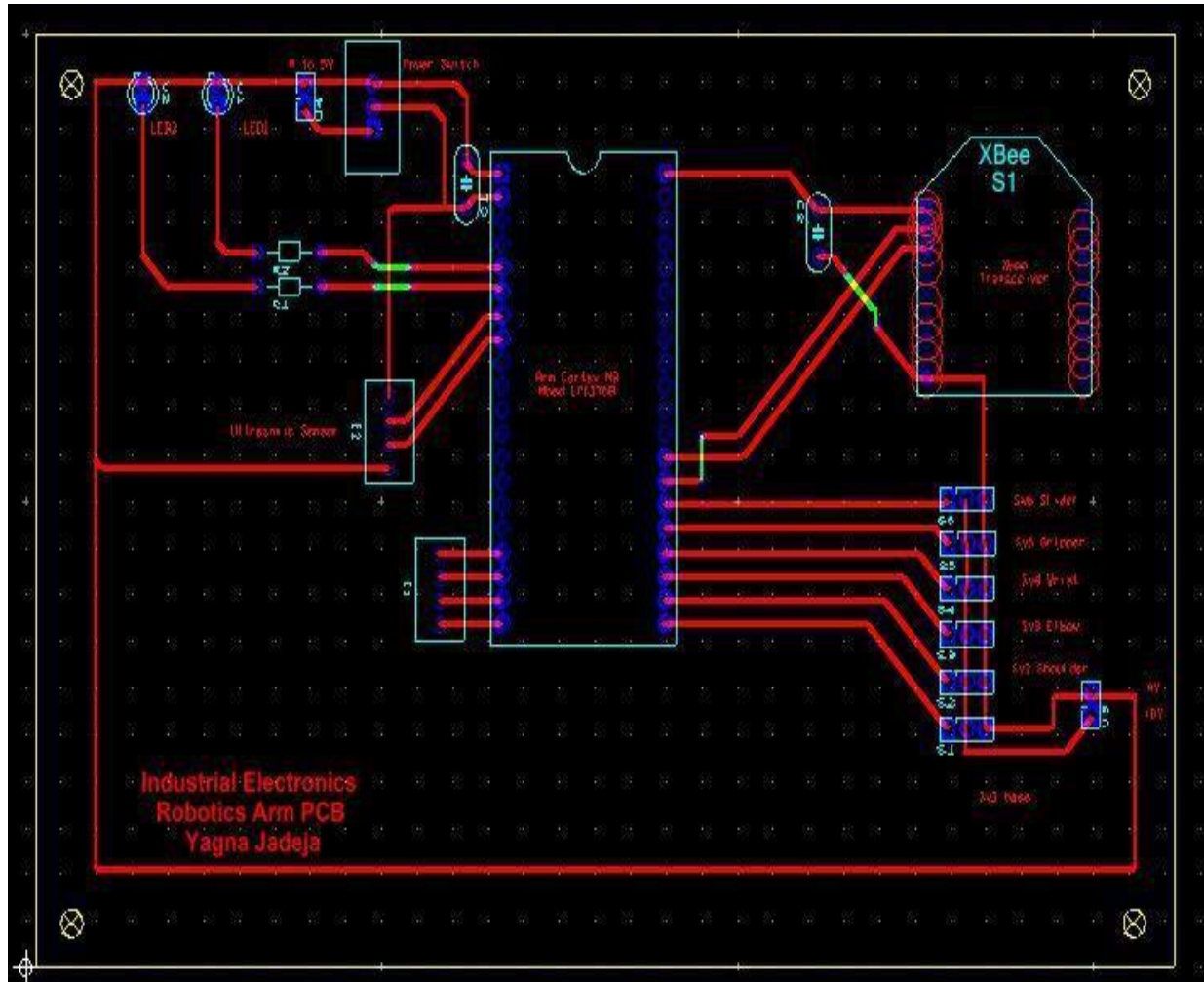


Fig.9. PCB Layout of Robotics Arm in Ultiboard

Based on the results obtained from the circuit designed using software, appropriate components are collected and the final design will surely transfer towards the PCB (Printed Circuit Board).



Fig.10. Proposed robotic arm

V. CONCLUSION

The work was time consuming, stressful and no viable financially. Still we managed to achieve the 5 degree free rotation. The robotic arm mechanics were expected to create issues like picking or placing the equipment away from the user, to keep the harmful things away from the user in a fast paced environment. The arm was made successfully and helps to control the robots movement easily. Based on observation, it became clear that it is perfect and easily manageable as well as easy to operate. The main aim of this work has been achieved through hardware and software synchronization within the robotic factory. To conclude, as a future scope the arm can be developed further using better technology, perfect design and made to order for disabled people within heavy industries.

REFERENCES

- [1] Nanditha Nirmal, A.S Revathi, "Robotic Arm Imitating Human Hand Movement," International Journal of Computer Science & Engineering Technology (IJCSET), vol. 7, no. 11, Nov 2016.
- [2] Mohd Ashiq Kamaril Yusoffa, Reza Ezuan Saminb, and Babul Salam Kader Ibrahimc, "Wireless Mobile Robotic Arm," International Symposium on Robotics and Intelligent Sensors 2012 (IRIS 2012), July 2012.
- [3] Rahul Gautam, Ankush Gedam, Ashish Zade, Ajay Mahawadiwar, "Review on Development of Industrial Robotic Arm," International Research Journal of Engineering and Technology (IRJET), vol. 04, Issue. 03, Mar -2017.
- [4] Arian Faravar, "Design, Implementation and Control of a Robotic Arm Using PIC 16F877A Microcontroller," Institute of Graduate Studies and Research, 2014.
- [5] Kunal Sali, Saiprasad Kolhe, Mayank Paliwal, "Automatic Pick and Place Robot," International Research Journal of Engineering and Technology (IRJET), vol. 02, Issue. 03, Mar -2016.
- [6] A. Sharkey, and N. Sharkey, "Granny and the robots: ethical issues in robot care for the elderly," Ethics Information Technology, vol.14, Issue. 1, pp 27-40, March 2012.
- [7] S. Suviatha, C. Lillygrace, M. Nandhini, S. Nithyashree, "Implementation of Robotic Hand Imitating the Real Time Motions," International Journal of Innovative Research in Science, Engineering and Technology, vol. 8, Issue. 3, March 2019.
- [8] Gerlind Wisskirchen, Blandine Thibault Biacabe, Ulrich Bormann, "Artificial Intelligence and Robotics and Their Impact on the Workplace," IBA Global Employment Institute, April 2017.
- [9] Abd-Elbadee Saeed Mohamed Abd-Elmohsin, "Design and Fabricate Handling Arm," Sudan University of Science and Technology, October 2016.
- [10] B.O.Omijeh and R.Uhunmwangho, "Design Analysis of a Remote Controlled Pick and Place Robotic Vehicle," International Journal of Engineering Research and Development, vol.10, Issue. 5, PP.57-68, May 2014.
- [11] A. Reshamwala, R. Singh, "A Review on Robot Arm Using Haptic Technology," International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, vol. 4, Issue. 4, April 2015.
- [12] R. Szabo, and A. Gontean, "Remotely commanding the lynxmotion AL5 type robotic arms", Telecommunications Forum (TELFOR),pp.889-892, 2013.
- [13] Guo-Shing Huang, Xi-Sheng Chen and Chung-Liang Chang, "Development of dual robotic arm system based on binocular vision", Automatic Control Conference (CACS), CACS International, pp.97- 102, 2013.
- [14] R. Szabo, and A. Gontean, "Robotic arm control in 3D space using stereo distance calculation," International Conference on Development and Application Systems (DAS), pp.50-56, 2014.
- [15] D. Bassily, C. Georgoulas, J. Güttler, T. Linner, T. Bock, TU Munchen and Germany, "Intuitive and Adaptive Robotic Arm Manipulation Using the Leap Motion Controller", Conference ISR ROBOTIK, pp: 1 – 7, 2014.
- [16] P. Aadeb Ahammed, and K. Edison Prabhu, "Robotic Arm Control Through Human Arm Movement Using Accelerometers", International Journal of Engineering Science and Computing, 2016, ISSN 2321 3361.
- [17] Mohammad Javed Ansari, Ali Amir and Md. Ahsanul Hoque, "Microcontroller Based Robotic Arm Operational to Gesture and Automated Mode", IEEE Conference Publications, pp: 1-5, 2014.
- [18] Piotr Kopniak and Marek Kaminski, "Natural interface for robotic arm controlling based on inertial motion capture," IEEE Conference Publications, pp. 110-116, 2016.
- [19] Y. Nagai, C. Muhl, and K.J. Rohlfing, "Toward designing a robot that learns actions from parental demonstrations," In Robotics and Automation, 2008. ICRA 2008. IEEE International Conference on pp. 3545-3550.
- [20] A.B. Afarulrazi, W.M.Utomo, K.L. Liew, and M. Zarafi, 2011, "Solar tracker robot using microcontroller," In Business, Engineering and Industrial Applications (ICBEIA), 2011 International Conference on pp. 47-50.
- [21] A. Elfaskhany, E. Yanez, K. Baylon, and R. Salgado, "Design and development of a competitive low-cost robot arm with four degrees of freedom," Modern Mechanical Engineering, vol.1, no. 02, pp.47. FHGH