A

PROJECT REPORT ON

PICK AND PLACE BOT

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CERTIFICATE

This is to certify that the project report entitled

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Is a bona fide work carried out by them towards the partial fulfillment of the requirement of the Savitribai Phule Pune University, Pune for the Third year ESMP subject of the Bachelor of Engineering in Electronics and Telecommunication Engineering. This project work has not been earlier submitted to any other Institute or University for the award of any degree or diploma.

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CONTENTS

Abstract

Project is based on making a mobile pick and place arm to carry objects from one place to other, we firstly looked at various existing designs used in the industry as well as the characteristics of these arms and their selection criteria, then we started our own arm design and we came up with three arm design solutions for the same which have different Degrees of freedoms, load bearing capacities and working envelopes. For the motion two DC motors powered wheels and caster wheel was used, while for arm actuation three Servo motors were used. The base mobile platform is made out of a 5mm thick acrylic sheet. Arduino was used to control the whole bot. HC-05 Bluetooth module was used to remotely and wirelessly control the bot using a Android smartphone application. As the effective range of the HC-05 Bluetooth Module is 10m the Robot can be controlled up to this distance. To power the whole arm a 11.1V 2200mAh battery was used a buck converter was used to provide power to arm servo motors so as to meet the its datasheet specifications. Out of the three arm design solutions the design based on MeArm was found to be best compromise in smoothness of operation, working envelope and load bearing capacity. Thus, we went ahead and modified the MeArm so as to mount it on our mobile base platform to develop the first working prototype. Improvements in range of operation wirelessly, automation, working envelope, vision-based object identification, load carrying capacity, etc. are to be done in the future.

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CHAPTER 1

Introduction and Literature Survey

1.1 Background

A project based on pick and place arm as Mechatronics project was done previously. The work done to meet these needs makes life easier every day, and these studies are concentrated in robotic arm studies. Robot arms work with an outside user or by performing predetermined commands. Nowadays, the most developed field of robot arms in every field is the industry (automobiles, product packaging, product testing and rejection, etc.) and medicine sector.

1.2 Relevance

The project is based on the controlling operation therefore it comes under the embedded systems. The bot is operated using arduino and is fully manually and remotely controlled using bluetooth which comes under the wireless communication part. Also the design of arms as well as various circuits designed for it come under Mechatronics.

1.3 Literature Survey

In this survey, we studied papers according to the different parameter of a robotic arm

A. Axis

Axes are used for movement indication, one use for a line, two for a plane and three for a point at anywhere in space. Roll pitch and yaw control are the main factors of a robotic arm axis, used for full control. Before 1987 robotic arms were working on [**6**] 2-axis and 3-axis, but now they are in **[7]** 4-axis, in [**8**] 5-axis, in **[9]** 6-axis and in [**10**] multi-axis robotic arms are available. Figure 1 shows a six axis- robotic arm. Mass of arm should be less for less force of inertia at different joints, lighter arm performs more dynamically than bulky arms at same stability level. Industrial robotic arms are using bulky tools and the weight of the arm is also very high, used for big construction. Robots may become flexible and less in weight by using multiple axis arms.

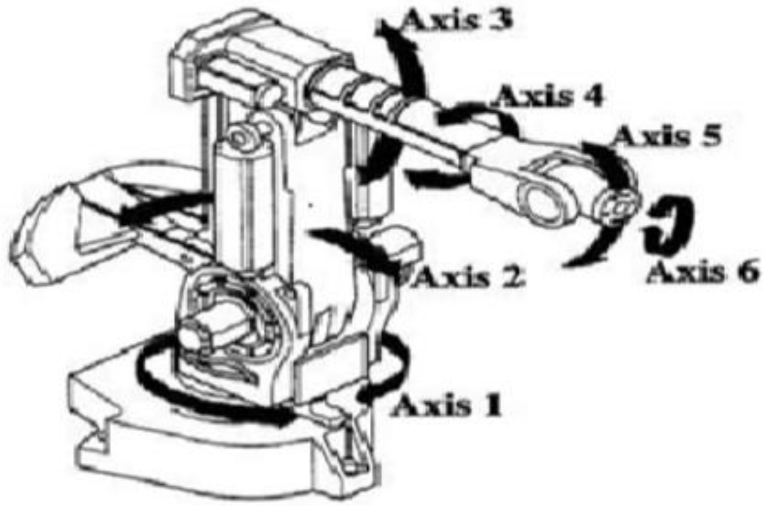


Figure 1.1. A six-axis-robotic arm **[16]**

B. Degrees of Freedom

Robotic arm controls all points (directionally) using their degrees of freedom. A human arm is controlled by seven degrees of freedom, articulated arms typically have up to six degrees of freedom. [**3**] A robotic arm is made by using different solid parts, joined by 'n' number of joints connected, each joint having one degree of freedom if there are 'n' number of the joints, then the arm has 'n' degree of freedom (DOFs). Figure 2 shows a seven joint robotic arm.

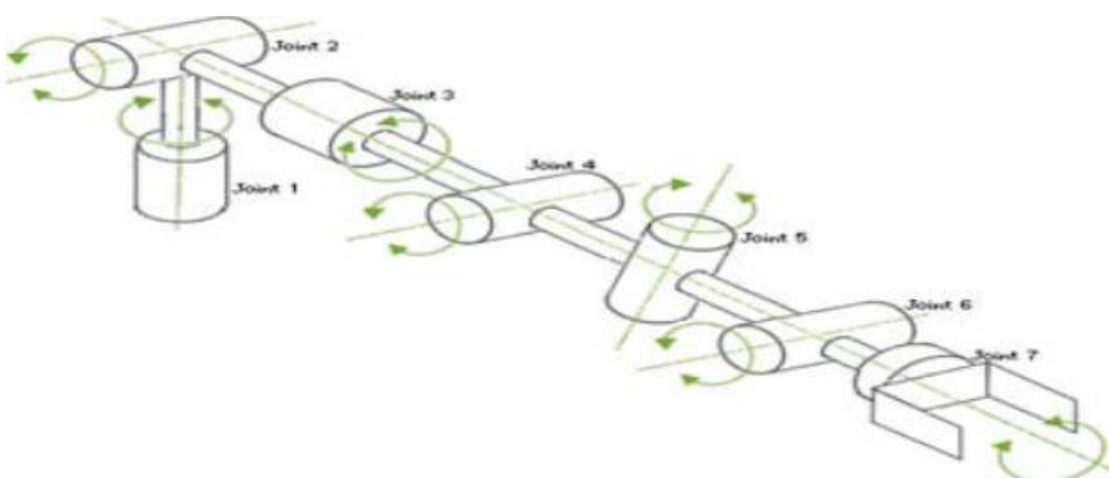


Figure 1.2. A seven joint robotic arm [**17**]

C. Working Envelope and Working Space

The robotic arm can cover a circle in space is a working envelope of a robotic arm. Envelope means the range can be covered by arm or range of movement. If we use the arm in different possible directions (forward and backward, up and down) then one 3D shape is an envelope, it depends on a robotic arm and number of axes, the axis can manipulate the range of motion. Figure 3 show Side dimension working envelope and top dimension working envelope. A robot can only work in their working envelope, but it's possible to design some flexible robotic arm they can change their envelope according to their requirement like a moving robot moving with track and covering a large envelope.

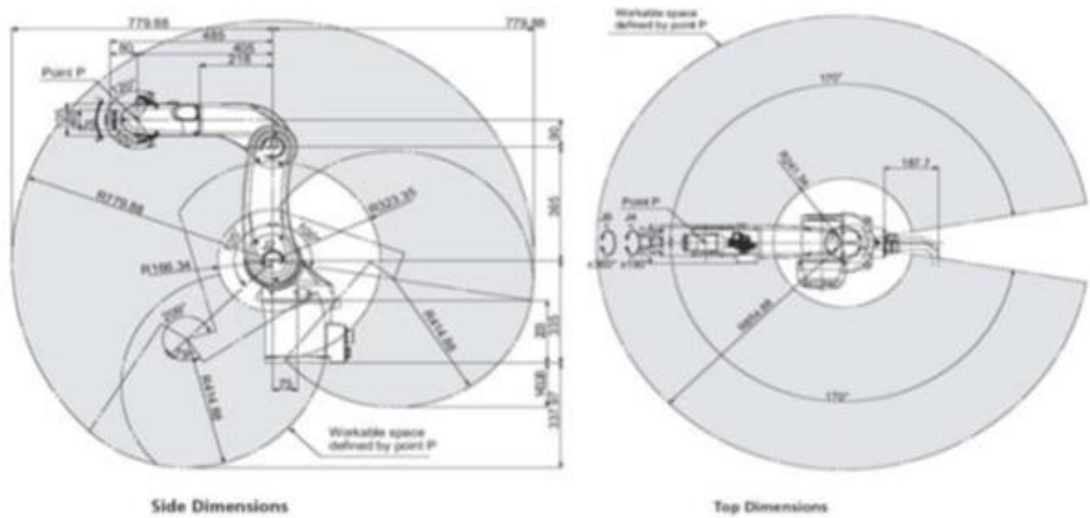


Figure 1.3.Side dimension working envelope and top dimension working envelope **[18]**

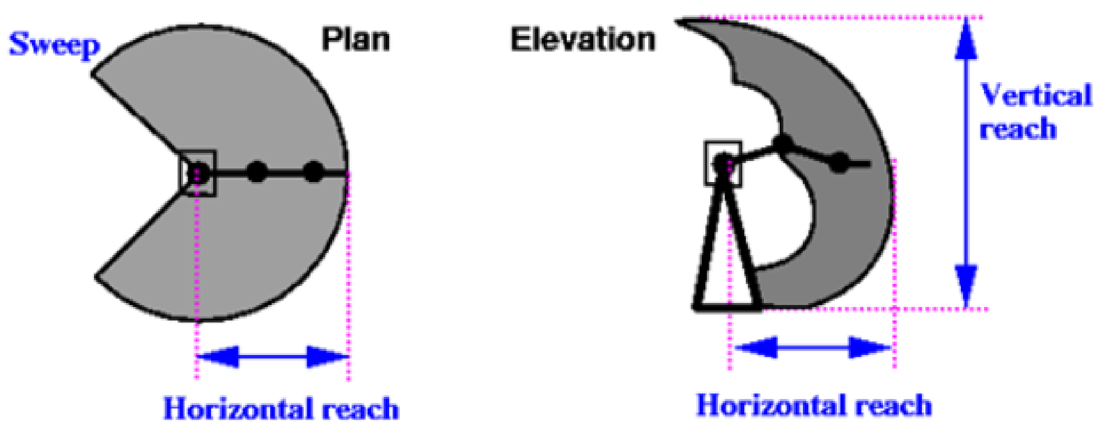


Figure 1.4. Workspace of a revolute robot [**22**]

The region where a robotic arm can fully work without any obstacles is a working space of that arm. Figure 4 show Workspace of a revolute robot it's same as the space required for all their efficient activities.

D. Kinematics

Robotic arm has a different joint of Cartesian, articulated, spherical and parallel etc., we arrange them for controlling the motion of a robotic arm. Robot kinematics is used for finding the movement of multi-axis and multi-degree of freedom. A chain of kinematics is used for making the structure of the robot; Figure 5 shows arm kinematics and motion planning. The priority of structure is different parts (rigid bodies) are properly connected at joint to provide excellent rotation, robotic kinematics is used to know about velocity, acceleration and position of all rigid body parts in the robotic system and decides all control movement. It also calculates exact force, torque, decides the role of motion, inertia and mass at every part of a robotic arm for making an efficient arm. [**5**] Non-Redundant robot configuration solved kinematics problems, but it's difficult to solve accuracy and dynamic effects, these problems are solved by redundancy. A redundant robot cannot work in a unique manner so it's difficult to define the next move of a redundant robot. This problem is solved by a real vision function monitor. [**3**] The distributed positioning is used for human arm motion; joint interfere measurement is called kinematic fatigue. This concept also known as integral kinematic involvement, in this work they discussed some support and results. In this paper, they gave some new models for solving problems and proposed some local new redundancy solutions to help to control the movement of a robotic arm and modeled and controlled joints.

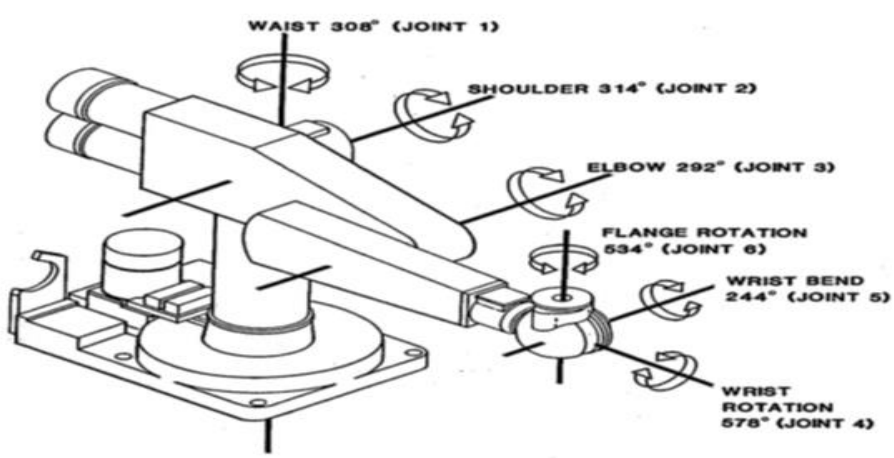


Figure 1.5. Arm kinematics and motion planning [**19**]

E. Payload

A payload is simply the weight that the arm will be able to carry and the movement will be possible with weight, Figure 6 shows weight lifting robotic arm. It is important to maintain payload at the time of implementation and it must be checked how much weight can be lifted. It also includes weight of the entire arm with tools and is also dependent on the use of an arm. In industries robotic arm is used for heavy work so payload should be high for industry arm and for normal use payload is in the 1 to 10 kg range. Specific tools are used for proper weight calculation. **[4]** The robotic arm has a maximum payload 500gm.

Figure 1.6. Weight lifting robotic arm **[20]**

F. Speed and Acceleration

It is defined by each part and total, linear and angular movement. **[11]** Robotic arm can reach speed movement with a max velocity of 8 m/s. [**12**] Robotic arm all joints can work at a very high joint speed of 360degree/s**.[11]** This arm can help in reactive movement using acceleration and velocity of 13m/s. [**1**] Robotic arms can change acceleration according to the situation with velocity 7m/s.

G. Accuracy and repeatability

Accuracy and repeatability are important factors and complete robotics performance depends on it. The accuracy of a task is needed for performing any task in exact time and a single attempt and repeatability is when we repeat the same task again and again and still got the same result, Figure 7 shows Accuracy and repeatability over 10 measurements.**[13]** In this robotic arm three laser sensors used for distance measuring, range of every laser between 80-180mm, it gives three accuracy value at three different times, 1ms with an accuracy of 1mm, 10ms with accuracy of 0.33mm and 100ms with an accuracy of 0.1mm. **[14]** Robot accuracy changes with velocity and measuring distance gives error between 3 to 10 percent so accuracy and repeatability are not good.

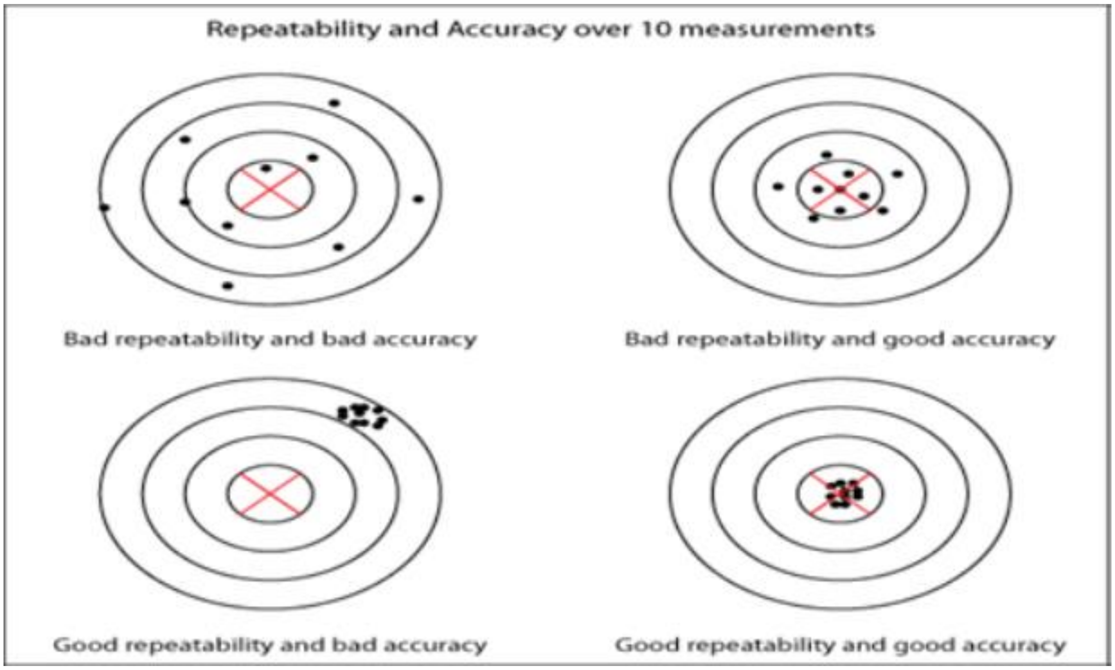


Figure 1.7. Accuracy and repeatability over 10 measurements [**21**]

H. Motion Control and drive

For any specific work arm may at any point in working space then this is not possible with a single movement, if all joints are working together then only we can reach all points. **[4]** Robotic arms have six joints and hands for controlling them; they design multi-motion control functions.

Robots are driven by a different type of motors, according to the use of the joint, the motor is chosen for the joint. They are connected by two types of connections, first is direct when motor directly connected at joint and second is indirect when motor connected with single or multiple gears. **[2]** This robotic arm is testing in a laboratory all flexible joints connected with

DC motors so that arm can work in different loads. [**5**] Robotic arm all joint connected by DC motor and wrist driven by high-speed DC motor. [**12**] Robotic arm consisting brushless DC motors driven with the help of tooth belts and harmonic drive gears.

1.4 Motivation

As we had already done a project on the pick and place arm but this project had quite a few problems and was primitive in a lot of sense including its non-mobility, low picking capacity, small working envelope, unstable motion due to less power being supplied to the servos, the inability of being remotely controlled, etc. So, we decided to improve on all these problems and improve the overall performance of the arm by trying a complete redesign of the arm and designing a mobile base which houses a powerful battery, wireless communication enabled to be able to remotely control the arm.

1.5 Aim of the Project

To achieve stability of the robotic arm on the mobile platform and to remotely control the arm and its base mobile platform.

1.6 Scope and Objectives

The project is expected to reach completion within the time limit of 4 months and with the budget of 1000 Rs. To achieve the aim of the project we have following objectives is mind:

- Lighter material
- Improved working envelope
- Optimized axes of rotations
- Reduction of unwanted vibrations
- Smoother operation on Mobile platform
- Manual wireless control

CHAPTER 2

Proposed System

2.1 Technical specifications of the project, resources required

Component	**Specifications/Description**	**Quantity**
Bluetooth Module	HC-05 Bluetooth module	1
Wheel	65mm diameter	2
DC motor assembly	100RPM	2
Servo motors	MG90s, stall torque=1.8kg/cm	3
Aluminum Sheet	2mm x length x breadth for arm linkages	1
Acrylic Sheet	5mm thickness for arm linkages, base and claw	1
M3 nut	Assembly of arms	10
M3x6 screw	Assembly of arms	9
M3x8 screw	Assembly of arms	10
M3x10 screw	Assembly of arms	5
M3x12 screw	Assembly of arms	7
M3x20 screw	Assembly of arms	4
LM2596	Simple switcher 5.0V fixed version	1
Arduino Uno	Control center	1
Caster Wheel	motion	1
Female header	40x1	3
Jumper wires	Male to Male, Male to Female	25
Barrel Jack	5mm, aux power	1
Battery	11.1V, 2200mAh	1
Battery connector	XT60 connector pair	1
General Purpose PCB	6”x4”	2
Other Components and equipment required	Capacitors, Inductors, Soldering equipment, DMM, Spacers, Epoxy resin, Double tape, Drill machine, files, hand drill, electrical tape, etc.	

2.2 Block Diagram

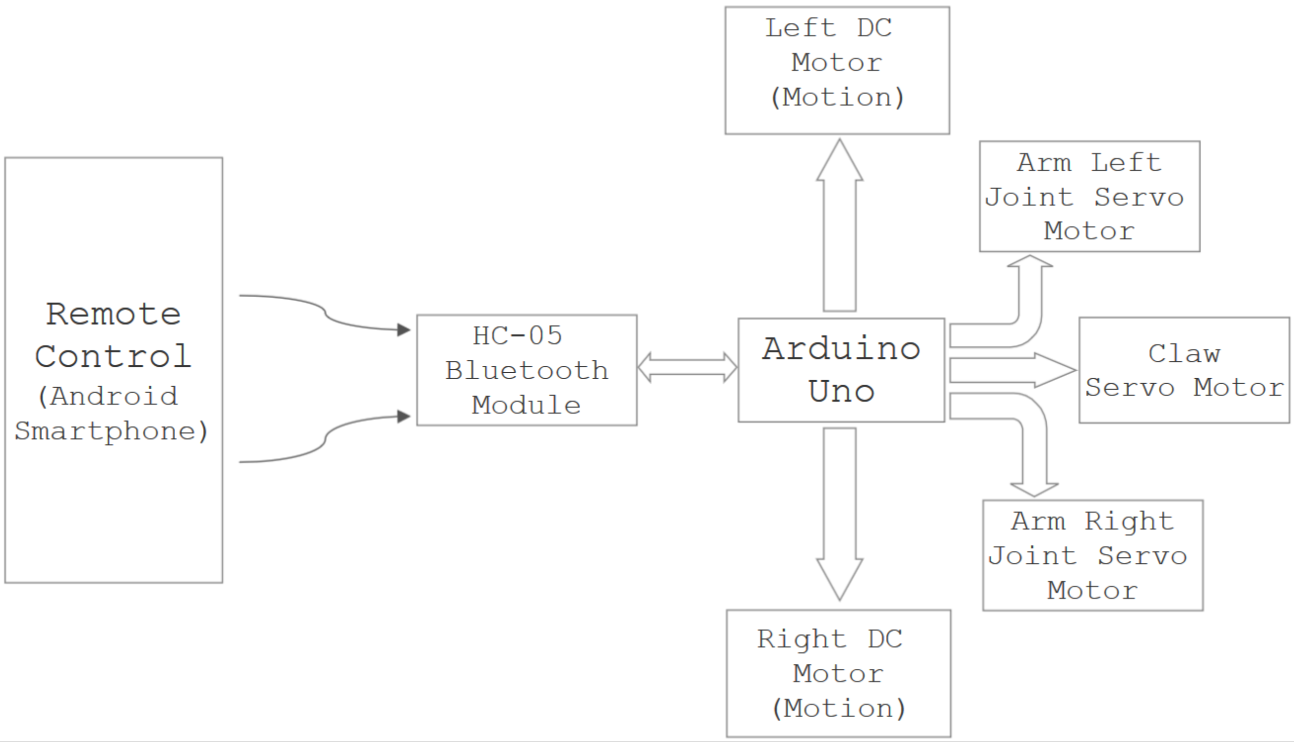


Fig: 2.1. Block Diagram of the Proposed System.

2.3 Block wise design

2.3.1 Remote Control

The Remote control which is the Android smartphone transmits a character corresponding to the button tapped by the user in android application. The Android was chosen so as to avoid unnecessary use of other Bluetooth module and controller and also to cut costs. The android application can be customized by the user to set key bindings according to his or her choice.

2.3.2 HC-05 Bluetooth Module

HC-05 Bluetooth module is used to receive the command signal from the Android which is then provided to Arduino Uno for further processing. The HC-05 has a range of 10m which is ideal for this kind of operation and to test the feasibility of the Project. Thus, it was preferred over other wireless communication modules.

2.3.3 Arduino Uno

According to the received character from the Bluetooth module Arduino decides which action to take whether to move the mobile platform using the Left and Right DC motors or to actuate the Arm using the Arm Left and Right joint Servo motors or to open or close the end claw using the claw Servo motor.

2.3.4 DC motors

The DC motors are inside a gear assembly which has output shaft RPM of about 100 RPM. These are mounted onto the mobile base platform the wheels are attached to the shaft of this assembly for motion control.

2.3.5 Servo motors

There are 3 Servo motors used, the placement of each servo depends on the arm design used. As the MeArm based design is actually mounted onto the mobile base platform the arrangement of servos is shown according to that in the block diagram.

The right joint servo is used to extend and contract the arm in horizontal direction for simplicity we have referred to this as forward and backward motion of arm. The left joint servo is used to extend and contract the arm in vertical direction for simplicity we have referred to this as upward and downward motion of arm. And finally, the Claw Servo is used to grip and ungrip the object which is referred as open and close motion of the claw.

CHAPTER 3

Implementation and Working Principle

3.1 Implementation

We first looked at various existing arm designs, studied their strengths and weaknesses and ultimately tried to come up with a design which would combine various strengths in order to achieve our objectives.

While designing the base mobile platform we tried to make it as compact as possible we designed in such a way that it had just the right amount of mass and also located its centre of gravity a little behind to avoid the bot from flipping under loaded conditions.

For wireless communication we have used Bluetooth module as it has just enough range for us and also it costs less while having a good amount of online support including various android apps that are customizable.

As for power we have used a 11.1V 2200mAh Lipo battery and the power division is done using the prior circuitry. For the stepping down of voltage and current boosting we have designed a buck converter which performs without any power loss (Buck converter using LM2596 input=12V and output 5V,3A).

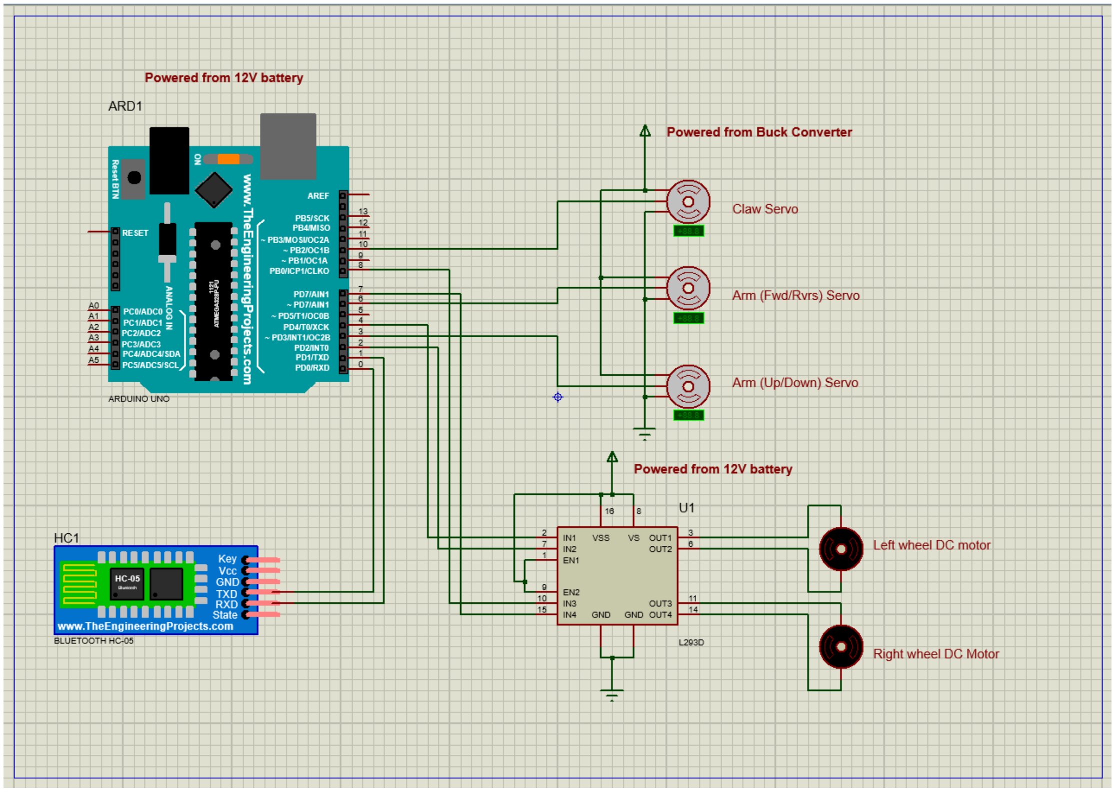


Fig.3.1.Proteus Simulation of Proposed System**[24]**

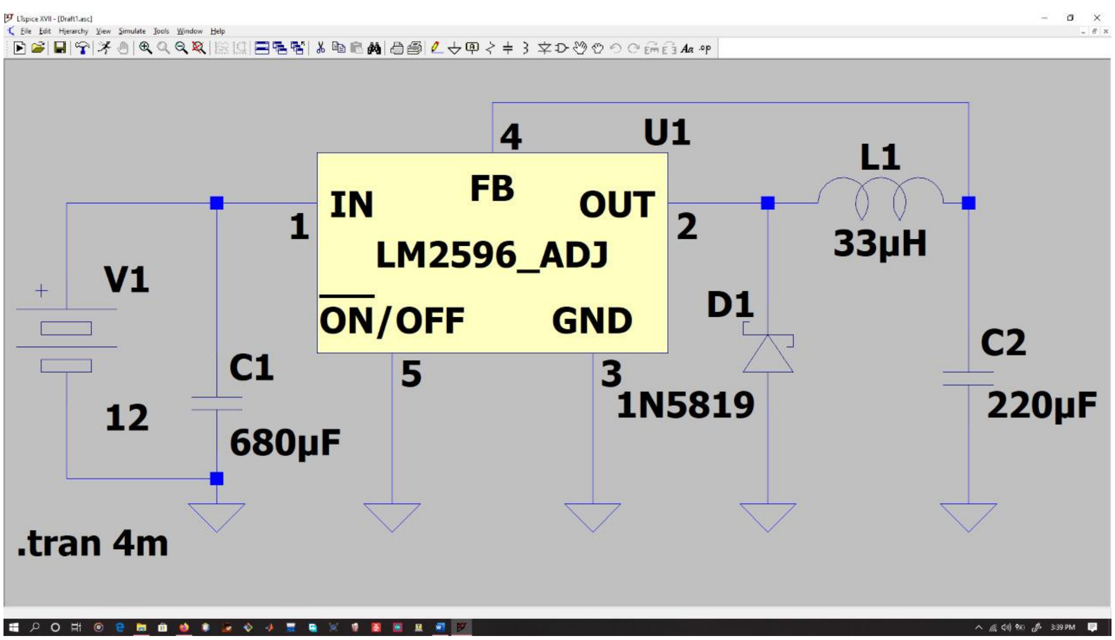


Fig.3.2.Buck Converter based on IC LM2596 LTspice simulation.

For the three arm designs that we came up with we used Acrylic sheet for one and aluminum sheet for the other two designs. The base is also made up of acrylic. For controlling arm motion, we have used 3 servos in each design (MG90s metal geared servos with stall torque=1.8kg/cm)

Fig.3.3.First Design prototype.

The first design was based on use of multiple links in conjunction to achieve flexibility and rigidity at the same time, which might have solved the problem of vibrations and would have given extra stability to the bot while further increasing the working envelope. The links were supposed to drive each other using the pulleys, but we failed to estimate the relative pulley motion with the shaft that made the motion of individual links dependent on motion of every other link which led us to the failure of this design.

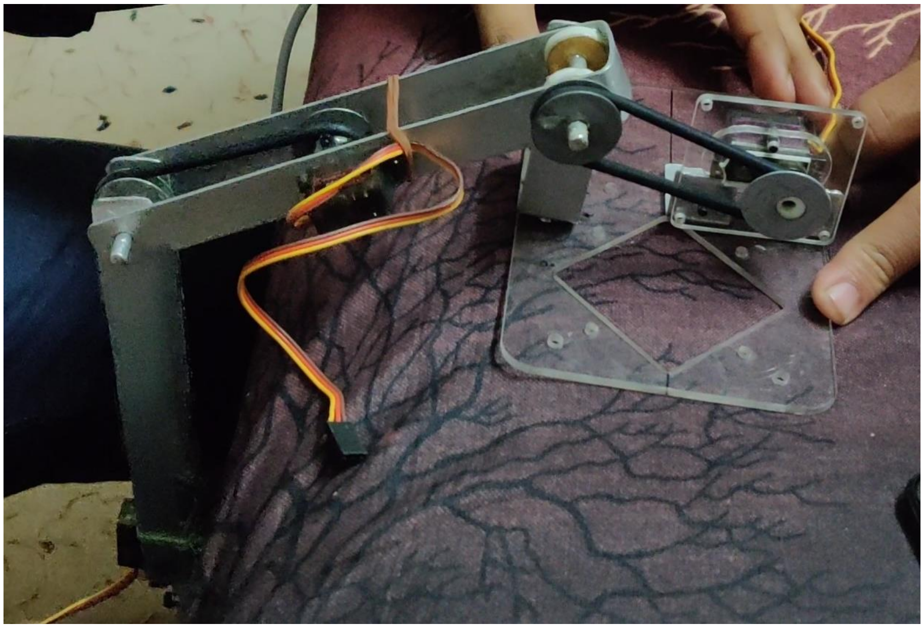


Fig.3.4.Second Design prototype.

To overcome the failure, we designed another arm with similar approach but which had a smaller number of links. This design was working satisfactorily but the whole structure was too heavy to move using a single belt which led to slipping of the belt.

We are thinking of replacing the belt of the main motor with the gear which will stop slipping and will give the exact rotation that we need.

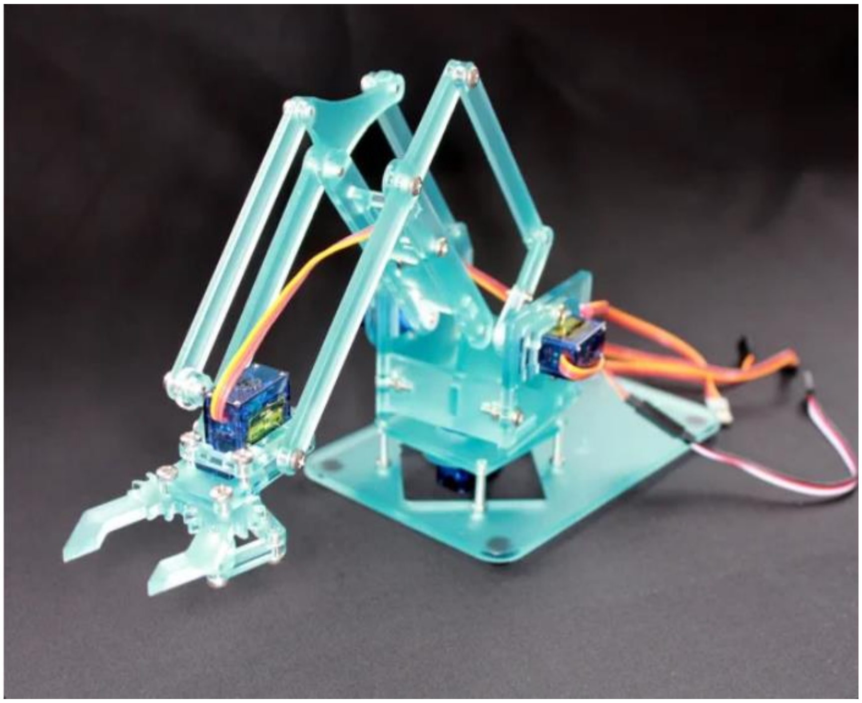


Fig.3.5.Third Design Reference MeArm V0.4 [23]

The third design is based on the mearm which contains acrylic parts to make it lightweight. This design is completely working and is currently implemented on the bot.

We have used Arduino Uno as the brain of our bot as it is quite easy to interface and has all sorts of peripherals required for our application.

3.2 Working Principle

The arm is based on the principle of Kinematic Chains. In mechanical engineering, a kinematic chain is an assembly of rigid bodies (links) connected by joints to provide constrained (or desired) motion that is the mathematical model for a mechanical system.A kinematic chain has the following parameters 'n' which gives the number of links and 'j' which gives the number of joints in the Kinematic Chain.

In our case we have three designs all are made up of varying number of links and joints which leads us to have different Degrees of Freedom in each case. The degrees of freedom, or mobility, of a kinematic chain is the number of parameters that define the configuration of the chains. We actuate these arms by placing Servo motors at joints.

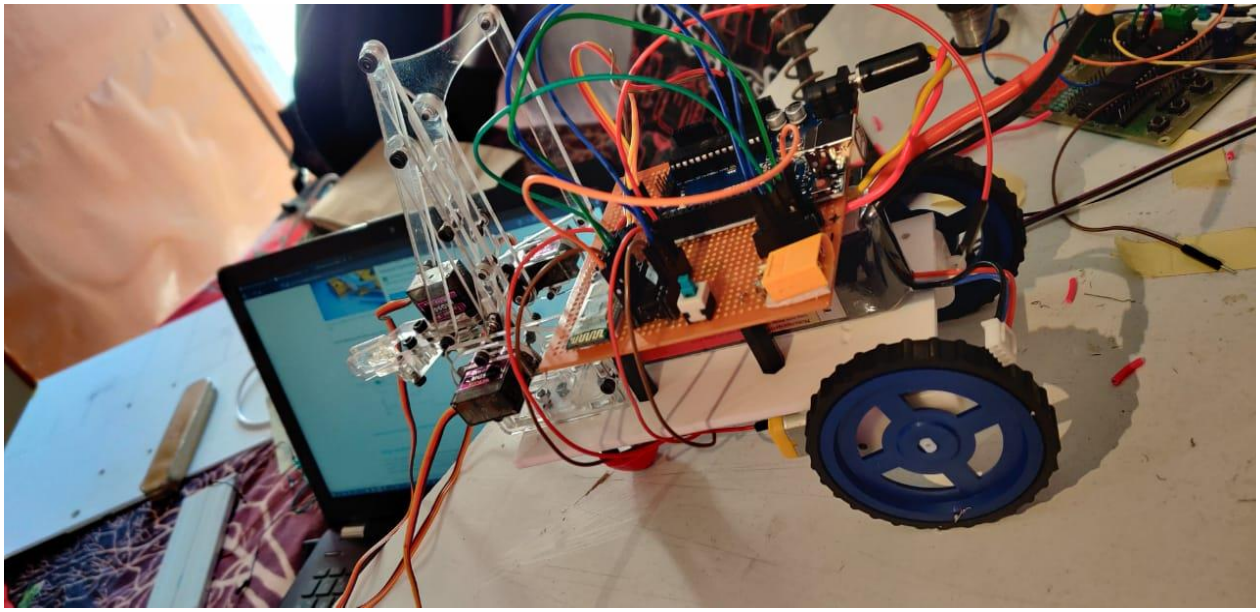


Fig.3.6.First Prototype of Mobile base platform with third design solution mounted.

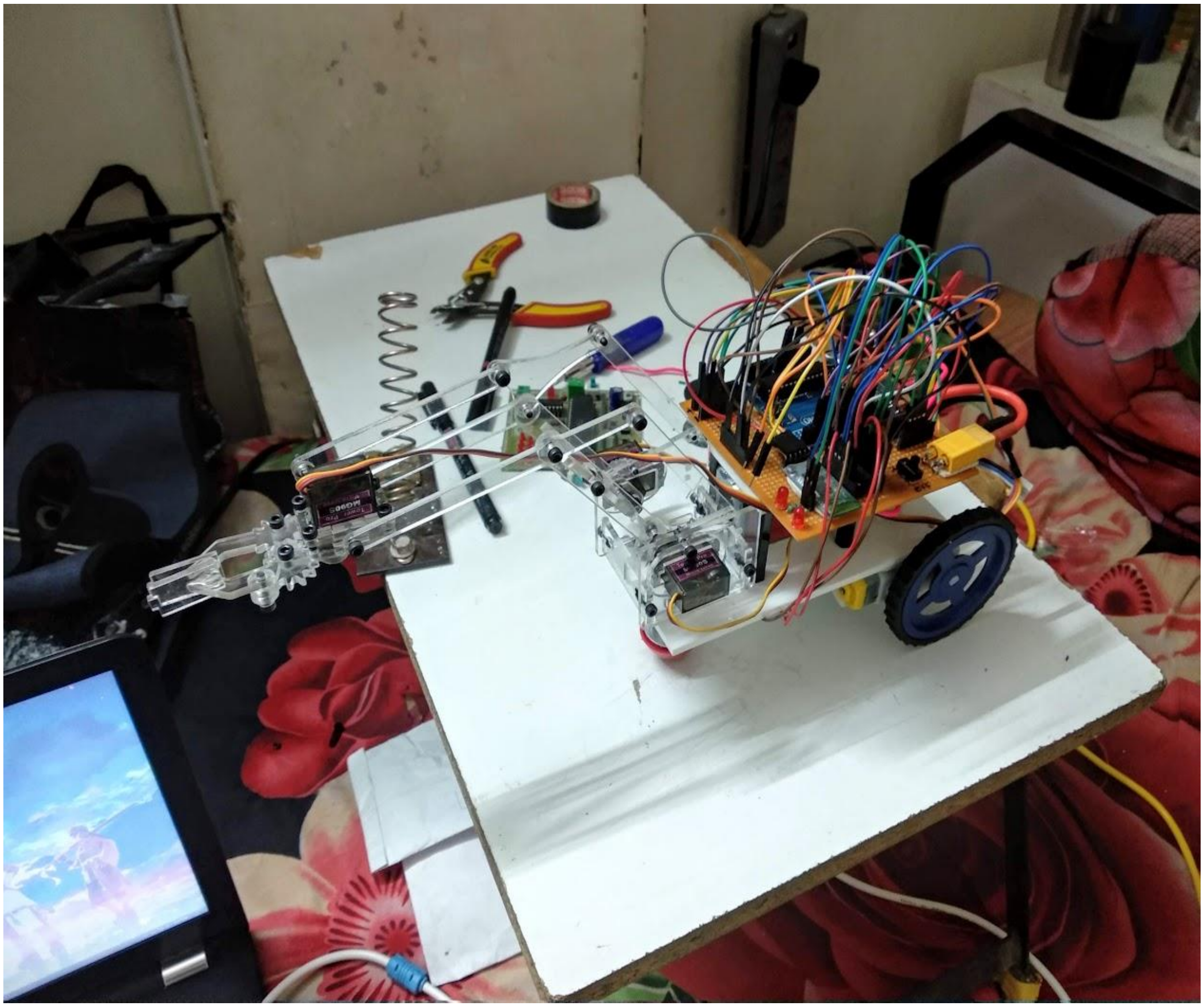


Fig.3.7.First Prototype of Mobile base platform with third design solution mounted arm extended UP.

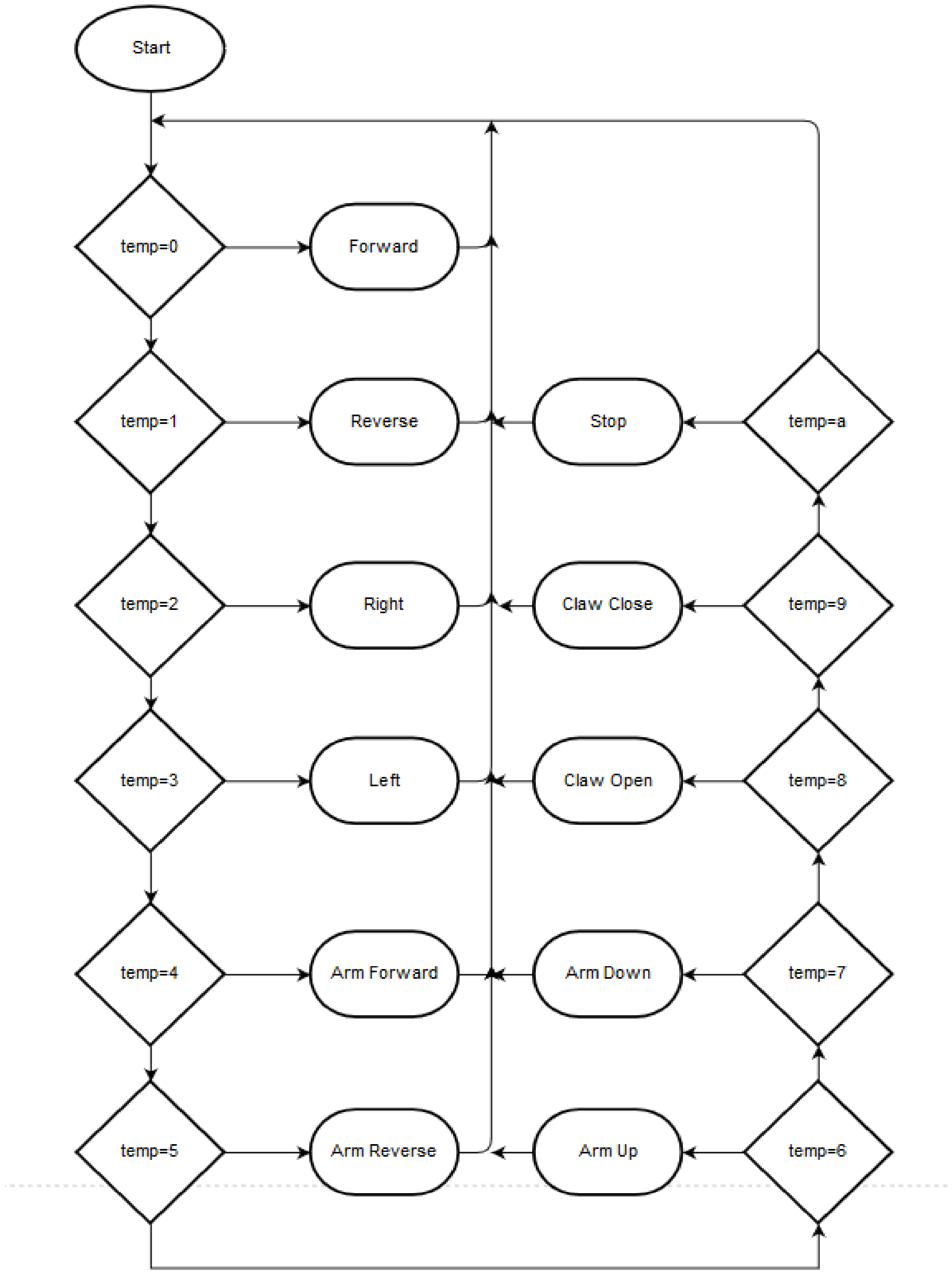
CHAPTER 4

Algorithm and Flowchart

4.1 Algorithm

1. Start
2. Using USART interrupt scan for the character data ‘c’ that is received from the HC-05 Bluetooth module.
3. Using a switch case compare the received character data ‘c’ with the 11 cases and take the action accordingly.
4. If c=’0’ : Move the base mobile platform FORWARD by rotating both the DC motors in forward direction.
5. If c=’1’ : Move the base mobile platform REVERSE by rotating both the DC motors in reverse direction.
6. If c=’2’ : Turn the base mobile platform towards RIGHT by rotating the right DC motor in reverse direction and left DC motor in forward direction.
7. If c=’3’ : Turn the base mobile platform towards LEFT by rotating the left DC motor in reverse direction and right DC motor in forward direction.
8. If c=’4’ : Move the ARM FORWARD by rotating the right Servo through the required angle.
9. If c=’5’ : Move the ARM REVERSE by rotating the right Servo through the required angle.
10. If c=’6’ : Move the ARM UP by rotating the left Servo through the required angle.
11. If c=’7’ : Move the ARM DOWN by rotating the left Servo through the required angle.
12. If c=’8’ : OPEN the CLAW by rotating the claw Servo through the required angle.
13. If c=’9’ : CLOSE the CLAW by rotating the claw Servo through the required angle.
14. If c=’a’ : STOP all the motors.
15. Keep on repeating steps 1 through 13.
16. End.

4.2 Flowchart



CHAPTER 5

Conclusions

Here we have come up with three arm designs as a solution to the given problem with the third and final design which is based on the Me arm being actually mounted on the mobile platform and used to demonstrate the project. The first two solutions were made of lightweight aluminum plates and third is made of laser cut acrylic sheet components.

While the first solution which had multiple links and joints, was able to give us a large working envelope and smooth operation we were unable to precisely control its motion and it also loaded all the servos to a great extent because of the extra material used for the joints and pulleys. The second design solution that we came up with had fewer links and joints as compared to the first design which helped us make the appropriate compromise between working envelope and smoothness of operation but still this design loaded the servos to a great extent as the servos could barely rotate due to the load. While one of our group members came up with the idea of replacing the pulley mechanism with gears which may help in unloading the main motor and avoid the unnecessary motion of the arm, but we were not able to implement it due to various reasons.

The third and final design solution which gave satisfactory results was based on the Me arm we modified so as to mount it on the mobile platform. The power to the servo motors was provided using a highly efficient buck converter based on IC LM2596 which made the servo motors work at their full load bearing capacity making the arm highly responsive. The whole structure is powered using a 11.1V 2200mAh Lipo battery and all the power division is made so that there is least power losses and battery will last longer.

The system is controlled using Arduino. Arduino has a very good response time and later the same system can be upgraded to more efficient controller for example raspberry pi in the future for more advanced and automatic control.

CHAPTER 6
Future Scope

The system proposed that is the mobile pick and place bot will have a great impact on the current performance of industries. Most of the tasks in the industries are done by the robots especially the pick and place robots. Therefore, the improvements in the current designs helps to boost the performance of industries.

Few of the limitations of the current design are that it has low weight bearing capacity, objects of only a certain shape can be picked due to claw design, smaller range of control as Bluetooth has small range, limited mobility as it can only be controlled on a plain terrain, it is not automated yet so requires a manual control at all times, the working envelope can be improved further, improvements in structural design to mechanically protect onboard electronic components from environmental factors like rain, dust, etc.

In the future the design can be modified with the higher torque motors which will be able to take the weight of the metallic arm and the claw design can also be modified to grip any kind of object. Also, the wheels can be modified to perform on any kind of terrain.

The major area of application that we are looking at is the agricultural field especially the Harvestation part of it which can be automated to a great extent where a fleet of such mobile pick and place bots is deployed which decide if an object is harvest ready and pick it like various fruits, vegetables, flowers, etc. improving harvest times storage and valuable labour.

Another area of application is in the electronic and automobile industries where components are to be moved from one location to other frequently and the target location is different most of the time. Both the industries have different loads to be carried, accordingly the bot design will have higher and efficient components. Thus, making a modular arm with swappable modules like the arm module, claw module, etc. which can be swapped according to application is one of our main future objectives.

References

[1] J. Kober and J. Peters, “Movement templates for learning of hitting and batting,” in *Learning Motor Skills*. Springer, 2014, pp. 69–82.

[2] H. Malki, D. Misir, D. Feigenspan, G. Chen *et al.*, “Fuzzy pid control of a flexible-joint robot arm with uncertainties from time-varying loads,” *Control Systems Technology, IEEE Transactions on*, vol. 5, no. 3, pp. 371–378, 1997.

[3] V. Potkonjak, S. Tzafestas, D. Kostic, and G. Djordjevic, “Human-like behavior of robot arms: general considerations and the handwriting task part i: mathematical description of human-like motion: distributed positioning and virtual fatigue,” *Robotics and Computer-Integrated Manufacturing*, vol. 17, no. 4, pp. 305–315, 2001.

[4] W.-K. Song, H. Lee, and Z. Bien, “Kares: Intelligent wheelchair mounted robotic arm system using vision and force sensor,” *Robotics and Autonomous Systems*, vol. 28, no. 1, pp. 83–94, 1999.

[5] V. Potkonjak, D. Kostic, S. Tzafestas, M. Popovic, M. Lazarevic, and G. Djordjevic, “Human-like behavior of robot arms: general considerations and the handwriting task part ii: the robot arm in handwriting,” *Robotics and Computer-Integrated Manufacturing*, vol. 17, no. 4, pp. 317–327, 2001.

[6] A. Shirkhodaie, S. Taban, and A. Soni, “Ai assisted multi-arm robotics,” in *Robotics and Automation. Proceedings. 1987 IEEE International Conference on*, vol. 4, Mar 1987, pp. 1672–1676.

[7] Y. Huang, L. Dong, X. Wang, F. Gao, Y. Liu, M. Minami, and T. Asakura, “Development of a new type of machining robot-a new type of driving mechanism,” in *Intelligent Processing Systems, 1997. ICIPS’97. 1997 IEEE International Conference on*, vol. 2. IEEE, 1997, pp. 1256–1259.

[8] Z. Kuijing, C. Pei, and M. Haixia, “Basic pose control algorithm of 5- dof hybrid robotic arm suitable for table tennis robot,” in *Control Conference (CCC), 2010 29th Chinese*. IEEE, 2010, pp. 3728–3733.

[9] A. Bejo, W. Pora, and H. Kunieda, “Development of a 6-axis robotic arm controller implemented on a low-cost microcontroller,” in *Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology, 2009. ECTI-CON 2009. 6th International Conference on*, vol. 1. IEEE, 2009, pp. 328–331.

[10] M. Nakashima, K. Yano, Y. Maruyama, and H. Yakabe, “The hot line work robot system phase ii and its human-robot interface mos,” in *Intelligent Robots and Systems 95.'Human Robot Interaction and Cooperative Robots', Proceedings. 1995 IEEE/RSJ International Conference on*, vol. 2. IEEE, 1995, pp. 116–123.

[11] T. Senoo, A. Namiki, and M. Ishikawa, “Ball control in high-speed batting motion using hybrid trajectory generator,” in *Robotics and Automation, 2006. ICRA 2006. Proceedings 2006 IEEE International Conference on*. IEEE, 2006, pp. 1762–1767.

[12] S. Bitzer and P. van der Smagt, “Learning emg control of a robotic hand: towards active prostheses,” in *Robotics and Automation, 2006. ICRA 2006. Proceedings 2006 IEEE International Conference on*. IEEE, 2006, pp. 2819–2823.

[13] T. Fischer, “Sensor system for controlling a multifingered gripper on a robot arm,” in *Intelligent Robots and Systems, 1998. Proceedings. 1998 IEEE/RSJ International Conference on*, vol. 3. IEEE, 1998, pp. 1509– 1514.

[14] T. Tsumugiwa, R. Yokogawa, and K. Hara, “Variable impedance control based on estimation of human arm stiffness for human-robot cooperative calligraphic task,” in *Robotics and Automation, 2002. Proceedings. ICRA'02. IEEE International Conference on*, vol. 1. IEEE, 2002, pp. 644–650.

[15] Patidar, Virendra & Tiwari, Ritu. (2016). Survey of Robotic Arm and Parameters. 10.1109/ICCCI.2016.7479938.

[16] “a six axis robotic arm ,”

http://robotics.stackexchange.com/questions/284/which-type-ofactuator- will-be-suitable-for-a-very-strong-robotarm.

[17] “a seven joint robotic arm ,”

http://opensourceecology.org/wiki/File:Degreesofreedom.gif.
[18] “Side dimension working envelope and top dimension working envelope,” http://www.adept.com/products/robots/6- axis/vipers850/downloads.
[19] “ Arm kinematics and motion planning,” https://benegoodman.wordpress.com/mechatronicsembeddedsystems/pu ma-light-painting/.

[20] “ Weight lifting robotic arm ,” http://blog.robotiq.com/bid/69524/Robotic-End-Effectors-PayloadvsGrip- Force.

[21] “ Accuracy and repeatability over 10 measurements ,” http://blog.robotiq.com/bid/72766/What-are- Accuracy-andRepeatability-in-Industrial-Robots.
[22] “Workspace of revolute robot,” http://www.citr.auckland.ac.nz/georgy/teaching/1999/99773ST/slide12.html.

[23] “Me arm V0.4- Pocket Sized Robotic Arm,” https://www.thingiverse.com/thing:360108

[24] “Pick and Place bot motion Simulation Proteus L8_2” https://www.youtube.com/watch?v=Ibqg6qXzuEo&feature=youtu.be

[25] https://mearm.com/

[26] https://amazon.in/