DEVELOPMENT OF ROBOTIC ARM AND GRIPPER FOR UNMANNED GROUND VEHICLE IN AUTOMOTIVE APPLICATION

AMIRUL HAFIZ BIN ZEXAFIZA

BACHELOR OF ENGINEERING TECHNOLOGY (ELECTRICAL) WITH HONS

UNIVERSITI MALAYSIA PAHANG

UNIVERSITI MALAYSIA PAHANG

DECLARATION OF THESIS AND COPYRIGHT

Author's Full Name	:	AMIRUL HAFIZ BIN ZEXAFIZA
Date of Birth	:	
Title	:	DEVELOPMENT OF ELECTRONIC SYSTEM FOR UNMANNED GROUND VEHICLE IN AUTOMOTIVE APPLICATION
Academic Session	:	SESSION 20/21

I declare that this thesis is classified as:

☐	CONFIDENTIAL	(Contains confidential information under the Official Secret Act 1997)*
☐	RESTRICTED	(Contains restricted information as specified by the organization where research was done)*
☒	OPEN ACCESS	I agree that my thesis to be published as online open access (Full Text)

I acknowledge that Universiti Malaysia Pahang reserves the following rights:

1. The Thesis is the Property of Universiti Malaysia Pahang
2. The Library of Universiti Malaysia Pahang has the right to make copies of the thesis for the purpose of research only.
3. The Library has the right to make copies of the thesis for academic exchange.

Certified by:

_________________________ (Student's Signature)

_________________________ (Supervisor's Signature)

_________________________ New IC/Passport Number
Date:

_________________________ Name of Supervisor
Date:

NOTE: * If the thesis is CONFIDENTIAL or RESTRICTED, please attach a thesis declaration letter.

THESIS DECLARATION LETTER (OPTIONAL)

Librarian,
Perpustakaan Universiti Malaysia Pahang,
Universiti Malaysia Pahang,
Lebuhraya Tun Razak,
26300, Gambang, Kuantan.

Dear Sir,

CLASSIFICATION OF THESIS AS RESTRICTED

Please be informed that the following thesis is classified as RESTRICTED for a period of three (3) years from the date of this letter. The reasons for this classification are as listed below.

Author's Name
Thesis Title

Reasons (i)

(ii)

(iii)

Thank you.

Yours faithfully,

____
(Supervisor's Signature)

Date:

Stamp:

Note: This letter should be written by the supervisor, addressed to the Librarian, *Perpustakaan Universiti Malaysia Pahang* with its copy attached to the thesis.

SUPERVISOR’S DECLARATION

I/We* hereby declare that I/We* have checked this thesis/project* and in my/our* opinion, this thesis/project* is adequate in terms of scope and quality for the award of the degree of *Doctor of Philosophy/ Master of Engineering/ Master of Science in ……………………………..

____

(Supervisor’s Signature)

Full Name :

Position :

Date :

____

(Co-supervisor’s Signature)

Full Name :

Position :

Date :

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

____

(Student's Signature)

Full Name : AMIRUL HAFIZ BIN ZEXAFIZA

ID Number : TB17048

Date :

DEVELOPMENT OF ROBOTIC ARM AND GRIPPER SYSTEM FOR UNMANNED GROUND VEHICLE IN AUTOMOTIVE APPLICATION

AMIRUL HAFIZ BIN ZEXAFIZA

Thesis submitted in fulfillment of the requirements
for the award of the degree of
Bachelor of Engineering Technology in Electrical with Hons

Faculty of Electrical & Electronics Engineering Technology

UNIVERSITI MALAYSIA PAHANG

FEBRUARY 2021

ACKNOWLEDGEMENTS

First of all, I want to say thanks Allah S.W, T for giving me strength, wisdom, patience and divine help to help me complete this advanced design Project (SDP) and this paper. If it weren't for his will and grace, this his research will not be completed.

I would like to express my high appreciation to my Dr. Roshahliza Binti M Ramli, the project supervisor. She guided the whole process after completing this project comments, stimulating suggestions, experience and encouragement, it helps me a lot the way.

My respective team members were also unable to complete the project. I want special thanks and gratitude to Mohamad Syazwan Bin Mohd Roni. The combination of these different trade disciplines is ideas, problem solving and creativity flourish. I hope we learned a lot from we completed this project together, thank you very much for your contribution.

I would also like to thank all parties involved in my final project, whether or not help me start this project directly or indirectly, and spent their precious time, guidance and advice. The support is small, but it means a lot to me in order to make this project successful.

Finally, I will prepare my mind and body to face everything that is coming how to complete the project. Thank you very much and may Allah S.W.T bless you all.

ABSTRAK

Rover keselamatan adalah aplikasi robot rover, yang dapat digunakan dalam keadaan berbahaya dan berbahaya untuk digunakan orang dalam situasi berbahaya. Dalam projek ini, bahagian mekanikal merangkumi lengan mekanikal, sendi dan pencengkam mekanikal, rangka dan pergerakan, sementara bahagian elektrik meliputi motor servo, pengawal servo, pemancar dan penerima, dan pengawal tanpa wayar melalui USB host sebagai sistem kawalan. Di samping itu, ia juga dilengkapi dengan lengan robot untuk menambahkan lebih banyak fungsi pada rover. Sebagai maklumat tambahan, alat pencengkam lengan robot mempunyai kebebasan enam darjah (DOF). Kesemua tahap kebebasan ini memainkan asas, bahu, siku, pinggang, pergelangan tangan dan efek akhir. Alat ini dapat digunakan untuk membantu agensi keselamatan dalam memilih objek dan meletakkannya di tempat yang diperlukan, dan melakukan operasi mencari dan menyelamat. Projek ini bertujuan untuk mengawal dan mencapai tujuan keselamatan. Di samping itu, matlamat utama projek ini adalah untuk menjadikan pembangunan dan pengeluaran robot mudah alih mudah dan menjimatkan kos. Dilengkapi dengan lengan robot yang diintegrasikan dengan kamera penglihatan masa nyata, menambah lebih banyak fungsi pada rover. Rover adalah kamera bersepadu ("pandangan orang pertama") yang dilengkapi dengan kamera FPV di rover, yang akan memberikan pandangan dan arah yang baik kepada pemandu rover. Cadangan itu akan menjelaskan perlunya teknologi dan langkah penyesuaian yang sesuai dan boleh dipercayai untuk rover robot untuk keadaan tempatan, yang dapat meningkatkan keselamatan pekerja. Oleh itu, dalam pelbagai tugas, termasuk mencari korban, mengidentifikasi bencana, mencari dan menyelamat, pengawasan dan pengintaian, dan penilaian risiko, teknologi rover yang dicadangkan juga dapat digunakan.

ABSTRACT

Safety rover is an application for a robotic rover to be deployed in hazardous and dangerous condition for human depends in risk situation. In this project, the mechanical components consist of robotic arm, joint and mechanical gripper, backbone chassis and locomotion while electrical components include servo motor, servo controller, a transmitter and a receiver for and wireless controller via USB host for the control system is proposed. Furthermore, it is fitted with a robotic arm to add more versatility to this rover. As the additional information, a robot arm gripper has six degree of freedom (DOF). All these degree of freedom play a fundamental base, shoulders, elbows, waist, wrist and end-effector. It can be used to assist safety authorities to pick object and place it in the desire place and to make search and rescue operations. The project aims to control and safety purpose. In addition, the main objective of this project is to make a simple robotic rover development and production are simple and cost-effective. Equipped with robotic arm integration with real-time vision cameras adds more functions to the rover. This wanderer is the integrated camera on the rover equipped with an FPV camera ("first-person view") will provide a good view and direction for the rover driver. The proposal will explain the need for suitable, reliable technology and adaptable robotic rover adjusting measures to local conditions can greatly improve worker safety. Therefore, in various tasks, including finding victims, identifying disasters, searching and rescue, surveillance and reconnaissance, and risk assessment, the proposed rover technology can also be used.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

g	Mass
kgm2	Moment of inertia
mm or ◦	The resolution of each axis movement
N	Thrust
Nm	Torque

LIST OF ABBREVIATIONS

CL	Closed Loop
CRASAR	Center for Robot-Assisted Search and Rescue
DOF	Degrees of freedom
EOD	Explosive Ordnance Disposal
FEMA	Federal Emergency Management Agency
FLIR	Forward-looking infrared
FPV	First Person View
HAZMAT	Hazardous Materials Management
HD	High dimension
ICARUS	Integrated Computer Application for Recognizing User Service
IGS	International GNSS Service
JPL	Jet Propulsion Laboratory
Kd	Derivative Gain
Ki	Integral Gain
Kp	Proportional Gain
LQR	Linear Quadratic Regulator
LUGV	Large Unmanned Ground Vehicle
OCU	Operator Control Unit
OL	Open Loop
PAEK	Polyaryletherketone
PID	Proportional Integral Derivative
PPM	Parts per million
RF	Radio Frequency
SUGV	Small Unmanned Ground Vehicle
UGV	Unmanned Ground Vehicle
WMR	Wheel Mobile Robot

CHAPTER 1

INTRODUCTION

1.1 Project Background

Unmanned Ground Vehicle (UGV) can be defined as a vehicle that remotely operated vehicles, without the absence of every person on-board.Whether in hazardous and dangerous condition in military operations, such as handling explosives, dispersing bombs and frontline reconnaissance, it also used as a human substitute.

This type of vehicle mainly uses sensors to observe the environment and automatically take decisions on its own in an unpredictable situation and with unknown information or pass this information to the operator who controls the UGV through various communication when it requires support. This UGV can send visual feedback to the operator at the ground station. An onboard sensor gives the complete environment of the vehicle as signals to the operator.

Therefore, this prototype of UGV that can move under difficult terrain conditions. Plus, the rover consists of a maneuverability device based on the function of the vehicle, integrated with sensors, processors, software and additional features. In the virtual world, robot component such as arm and gripper are attached to this rover and have wide applications. In risky and dangerous situations, it tends to decrease or eliminate hazards as well as to avoid threats to life or deaths for staff (Janai et al., 2017).

More interestingly, in order to prevent the rover from getting lost or accidentally hitting an unexpected obstacle, engineers have developed software to help the rover make its own safety choices and "think on its own." (W.John.2007). For equip the rover with a camera to realize visual real-time viewing, and applied the drone camera application, so this rover does not need specific software to monitor the situation. It only needs a simple way to monitor security, just help us watch the remote camera in a "first-person view" (with a slight delay) through streaming media, then start recording video or taking pictures, manage zooming or turn on and turn off the flash at any time , And most importantly, it allows us to know the relative position and try to obtain information (K.Konstantin.2015).

Today, from the research it has shown the use of robotic rover in robotic skills. It is clear that perception is the most important function of all complex and automated operations. In various academic and commercial research projects (T. Cristen and K. Sara. 2013), they are actively pursuing the vision of robots as assistants. Currently, real rover stations, especially those used for space exploration, use expensive and specific software, such as VERVE. VERVE is an integrated 3D view built on Ardor3D (C. Tamar and A. Mark B. 2014) to help them navigate.

In 1970, Stanford University developed a computer-controlled robotic arm with an electric drive motor, called the Stanford arm. In 1973, Cincinnati Milacron developed the first industrial robot equipped with a microcomputer-based control system. In 1977, a European company called ASEA also developed an electric industrial robot equipped with a microcomputer-based control system. In the same year, Stanford University's Stanford Research Institute (SRI) developed a robot vision system. In 1978, the Puma (Programmable Universal Assembly Machine) robot was developed based on the arm of Stanford University in the United States. The servo motor used by the robot is equipped with an advanced control system, which uses some microprocessors and advanced software. In 1079, Sankyo and IBM developed the famous SCARA (Selectively Compatible Articulated Robot Arm) at Yamanashi University in Japan (S. Yu, X. Yu, B. Shirinzadeh, and Z. Man, 2005).

1.2 Problem Statement

The robotic rover system is usually costly. The robotic rover is heavier, bulkier and needs a lot of storage space. Furthermore, standard rover components are designed and manufactured specifically for particular tasks, thus decreasing the range of flexibility and system adjustment.

Many researchers have confirmed that there are still several problems to solve for the UGV robot used for nuclear detection, which is too slow because it is heavy and large, making it difficult to move around, particularly stairs and uneven surfaces. It demonstrates that this type of rover must have a special design that can climb stairs at high speed as required by the authorities. Although, there are robots that have provided the solution to climb the stairs for dexterity, but they did not have a full surveillance system (De Luca & Book, 2016).

In addition, they are limited unmanned trucks that can handle explosive chemicals. They do need a specific UGV. It needs a flexible manipulator with less vibration and can lift explosive substances such as picric acid. The reason is that they are usually isolated between the mobile robot and the robotic arm during the isolation design, causing them to perform only a single task instead of multitasking. The rover has been used in most cases to perform basic tasks, such as navigation and imaging alone.

The complexity of robotic tasks is becoming more advanced, so to optimize and maximize the efficiency of industrial robots it is important to design and analyze an intelligent, stable, computer-simple and easy-to-implement controller.

Experiments on the actions and mechanisms of real robots will damage the robot and require a lot of funds, robot modeling and computer simulation to reduce the cost and time required to study robot systems.

1.3 Objectives

The purpose of this study is to model and develop a controller for an industrial robot. The industrial robot should be able to perform a pick and place task and simulate it include:

i. To design a low-cost arm and gripper rover based on material use
ii. To develop robot arm with gripper and assemble with locomotion of a rover
iii. To pick and place an object that less than 1.5 kg with correct position control

1.4 Scope of Project

The aim of this project will be to build a robotic rover that will allow users to freely select the maximum number of customizable features installed on the rover. An example is the installed functionality, such as remote control, wireless HD camera, thermal camera, gas sensor, and flashlight. In addition, there are a few conditions that allow the rover, such as before any accident occurs, to be deployed for the monitoring process and gas detection.

1.5 Organization of Thesis

Besides this chapter, the following chapters are included, as follows. Chapter 2 presents literature surveys on the rover's introduction on how the idea of constructing this type of robotic rover was generated. In addition, in terms of electrical and mechanical components, the similarities between the previous and the developed rover would demonstrate the research gap in the robotic rover. However, implementation in the real world will be unveiled at the end of the project to create this great project.

Chapter 3 explains the proposed methodologies for creating the specifics of the flowchart research on how to manufacture the robotic rover. Parameters also need to be examined because all calculations will influence the performance of the robotic rover.

The chapter will also briefly explain how the robotic rover control system integrates other characteristics.

In Chapter 4 will explain about the result of proposed design for robotic arm and gripper. Also included the controller of arm and gripper from the circuit diagram that has been construct. Furthermore, the comparison to lift the object with different weight are included.

Lastly for Chapter 5 will summarize all the method to develop the robot arm and gripper for unmanned ground vehicle in automotive application.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In different situations in contact with the surrounding world, humans are constantly trying to find alternative ways to imitate their actions. These alternative ways can be based on the process of centuries. Robotics has profound cultural roots and as a science as a science dealing with intelligent movement of various robot mechanisms which can be classified in the following four groups: robot manipulators, robot vehicles, man-robot systems and biologically inspired robots, (Matjaž Mihelj et al, 2019).

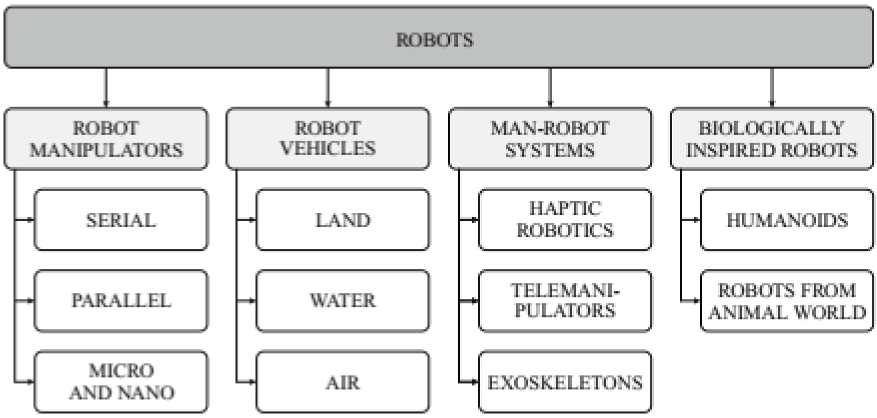


Figure 2.1 Classification of robots (Source; Matjaž Mihelj et al, 2019)

The serial robot mechanism is the most common robot manipulator. The industrial robot manipulator market is one of the interesting fields in manufacturing, education and medical applications. Research the power and motion control of industrial robots. According to Webster a robot is “An automatic device that performs functions normally ascribed to humans or a machine in the form of a human”.

In serial robots, the number of degrees of freedom is identical to the total number of degrees of freedom in joints. Thus, all joints must be actuated, and usually only simple one degree of freedom translational and rotational joints are used. Parallel robots are of considerable interest both in science and in industry. With these, the robot base and platform are connected to each other with parallel segments, called legs.

In parallel robots, the number of degrees of freedom is lower than the total number of degrees of freedom in joints so that many joints are passive. Passive joints can be more complex; typical representatives are the universal joint and the spherical joint. The universal joint consists of two perpendicular rotations while three perpendicular rotations compose the spherical join. Parallel robots are predominantly used for pick-and-place tasks. They are characterized by high accelerations, repeatability, and accuracy.

By contrast in the areas of biotechnology and new materials micro- and nano robots are used. Nano robots enable pushing, pulling, pick-and-place manipulations, orienting, bending, and grooving on the scale of molecules and particles. The most widespread Nano manipulator is based on the principle of atomic force microscope (Matjaž Mihelj et al, 2019).

The control method of this rover project is to use a microcontroller, which acts as the main brain to control the input and output hardware of this security and monitoring rover project. A microcontroller is a system with peripherals, processors and memory that can be used in embedded systems. In short, a microcontroller is a small computer on a single integrated circuit.

Advances in the technical field have led to the use of microcontroller settings instead of electrical and mechanical switching systems to solve control problems more effectively and reliably. Therefore, in our program, we insisted on the idea that basic knowledge of microcontrollers is essential for all types of engineering professions. (Parikh, 2015).

2.2 Unmanned Ground Vehicle

This section discusses some of the current UGV and the related studies will be discussed. Compared with the existing UGV, the advantages of the proposed UGV will also be described. In addition, related works will be compared.

2.2.1 Large Unmanned Ground Vehicle (LUGV)

Large Unmanned Ground Vehicle (LUGV) is a vehicle with chain transmission and initially designed as part of the Integrated Computer Application for Recognizing User Service (ICARUS) project, which conducts the use for search and rescue operation (Gert De Cubber et al., 2013). Commonly, it could assist in collecting data on hazardous locations and submit it straight to end safety personnel because it was equipped with several sensors such as camera and gyro sensor. Besides that, LUGV also has additional features like gripper to lift payload with high capacity (Armbrust, De Cubber, & Berns, 2014).

Design developments of robotic rover are usually based on the specify and requirements needed from the authorities. Table 2.1 shows several examples of LUGV with their general specifications in nuclear.

Table 2.1 Examples of LUGV in nuclear industry

Robot	Payload Capacity	Operating Area	Functions	Total weight	Year
AMOOTY	10 kg	Nuclear power plant	Dig in hole Climb stairs	360 kg	1985
Dry Ice Blast Decontamination Device	-	Reactor building	Decontaminate dry ice blast	730 kg	2014

Source: (Iqbal, Tahir, Islam, & Riaz un, 2012) and (Saito et al., 2016)

In 1985, scientists at the University of Tokyo created a robot called AMOOTY, which was named after six robotic researchers (Iqbal et al., 2012). Figure 2.1 shows the structure of the robot. It looks like the trunk of an elephant and can go upstairs. Robotic researchers studied the concept of nuclear reactor maintenance and created a robotic locomotive device and nine degrees of freedom (DOF). The paper was a huge success. At the time, there was still no robotic arm. The robot still faces some challenges. Because it is heavy and wide, the pace is too slow to rise and pass on rough surfaces (Wehe et al., 1989).

Figure 2.2 AMOOTY, Source: (Armbrust et al., 2014)

In addition, LUGV has also been used in search and rescue activities. Table 2.2 describes several examples of LUGV, which have general requirements in the Hazardous Materials Management (HAZMAT) search and rescue operations. In most cases, the robotic rover is bulky, heavy, and takes up a lot of storage space. For example, Hazardous Materials Management (HAZMAT) agencies face many dangerous obstacles when performing life-saving duties. The robot rover presents the most terrifying danger in the initial steps of entering and repairing where people are afraid to step on.

Table 2.2 Examples of LUGV in HAZMAT Department

Robot	**Operating Area**	**Year**
ANDROS	Nuclear power plant	1991
HAZBOT II	Hazardous condition	1992

Source: (Welch, 1994; R. V. Welch & G. O. Edmonds, 1994)

The first entry of HAZMAT personnel is particularly dangerous because the nature of the materials used may not be disclosed. The robot rover system can be used to evaluate, reduce or minimize the risk of solving this dangerous situation. In this way, any life-threatening or death threats to individuals lurking in any wrong actions can be avoided. Therefore, the main purpose of the Jet Propulsion Laboratory (JPL) emergency response robot project is to develop a remote-controlled mobile robot that the HAZMAT team can quickly deploy. In October 1991, the prototype was constructed and the robot was renamed Remote Andros Mark V-A (Welch, 1994).

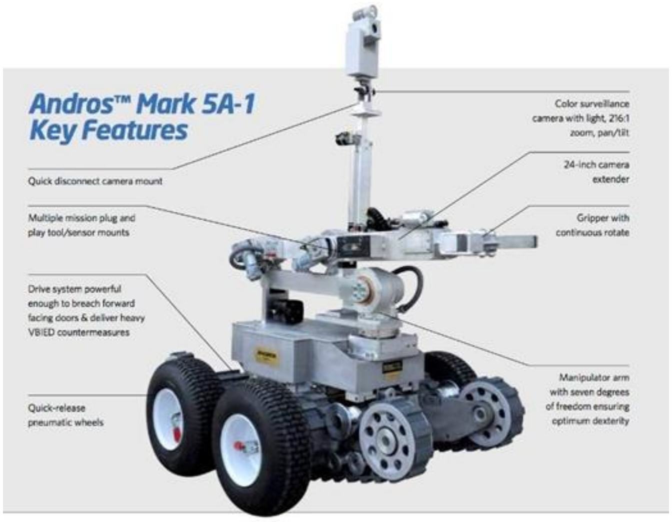


Figure 2.3 Remoted Andros Mark V-A, Source: (R. Welch & G. Edmonds, 1994)

In 1991, the Jet Propulsion Laboratory built another rover under the emergency response robot project. As shown in Figure 2.3, this rover is a remote mobile robot named Andros, used to deploy the HAZMAT team (R. Welch and G. Edmonds,1994). In order for the HAZMAT team to determine other requirements for the effective use of this robot, the team conducted various tests and training on the robot.

The Andros robot has been redesigned by incorporating other specifications such as track changes and advanced key instruments. The route was adjusted by articulating the front and back of the stair climbing robot. Then developed a special key instrument to open the door of the robot. When opening the door, a winch mechanism is also added to assist the robot.

Based on these modifications made by the HAZMAT team, the robot was renamed HAZBOT II (Stone & Edmonds, 1992). Figure 2.4 shows that HAZBOT is a type of UGV used only in emergency situations, also known as ground emergency vehicles.

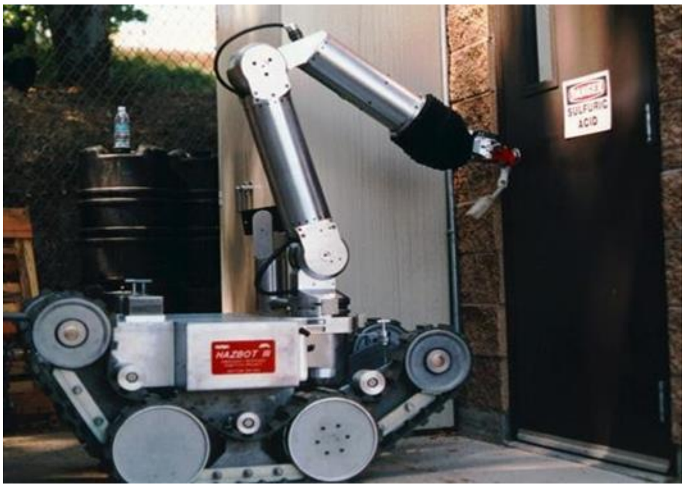


Figure 2.4 HAZBOT II, Source : (Matthies et al., 2002)

2.2.2 Small Unmanned Ground Vehicle (SUGV)

SUGV can be defined as UGV which can lift load less than 90 kg. This section discusses several examples of SUGV in search and rescue operations and they had been reviewed as shown in Table 2.2. Based on the table below, Federal Emergency Management Agency (FEMA) had discussed about robot requirements with Center for Robot Assisted Search and Rescue (CRASAR) and finally they decided to choose Inuktun micro-Tracs VGTV because the size is the smallest compared to among of them. However, sometimes they will also use Solem robot in certain condition which need time constraint. The reason is, dexterity of the Solem robot is three time faster than Inuktun and it has more capabilities to climb the more irregular ruble (R. R. Murphy, 2004).

Table 2.3 Examples of SUGV in search and rescue operation

Robot	**Year**
Inuktun micro-Tracs VGTV	1989
Micro-Tracs	1989
Foster-Miller Solem	2001
Talon	2001

Source: (Liu & Nejat,2013) & (R. R. Murphy, 2004)

a) MicroTracs (b) VGTV

Figure 2.5 Examples of SUGV (a) MicroTracs and (b) VGTV, Source: (Liu & Nejat, 2013)

Due to its small size and basic control unit, MicroTracs and VGTV were chosen instead of other robots. They all have the most versatile data and modern technology for search equipment. Also, due to their ability to provide video that can be controlled remotely, these two robots are called "cameras with wheels" as the most obvious feature. In contrast, the operator's time consumption is only 1.5 minutes. Usually, before starting the task on the rubber pile, professional rescuers choose the micro robot to be used.

Foster-Miller holds two robots. Sulem and Talon. Talon can travel on all terrains, and through the use of two-way radio frequency, the user can control (RF). By looking at the image transmission at 1.6 kilometers, the operator control unit (OCU) usually provides accurate feedback. In addition, due to its speed, the robot has high flexibility and can exceed 6.6 kni/h. In addition, although Talon is classified as SUGV, its ability to lift payloads is higher than 90 kg. In addition, special vision systems such as FLIR, night vision, microphones and zoom cameras are installed.

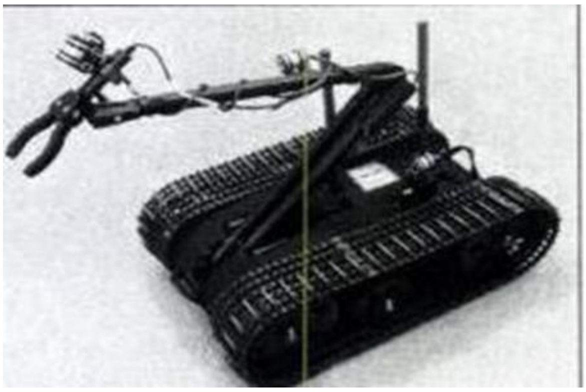


Figure 2.6 Talon robot, Source: (R. R. Murphy, 2004)

2.3 Axis

The axis is used for motion indication, one for a line, two for a line, for a plane and three for a point at anywhere in space. Roll pitch and yaw control are the main factors of the robotic arm shaft for full control. Before 1987, the robot arm was processing. In 1987, there has 2-axis and 3-axis (A.Shirkhodaie, S. Taban, & A. Soni, 1987). But now there in 4-axis (Y.Huang, L.Dong, X. Wang, F.Gao, Y.Liu, M.Minami & T.Asakura, 1997), in 5-axis (Z.Kuijung, C.Pei & M.Haixia, 2010) in 6-axis (A. Bejo, W. Pora & H.Kuneida, 2009) and in multi-axis robotic arms are available (M. Nakashima, K. Yano, Y. Maruyama, and H. Yakabe, 1995). Figure 2 shows a six axis- robotic arm. Freely movement is good for three-dimensional, rotating shaft arm active interaction must be maintained to maintain good stability. Arm mass it should be less to reduce the inertial force of different joints and be lighter. In the same situation, the arm's performance is more dynamic than the bulky arm stable level. Industrial robot arms are using heavy tools, the weight of the arm is also high and is used for large buildings. Robot can become flexible and lighter by using multiple axes arms.

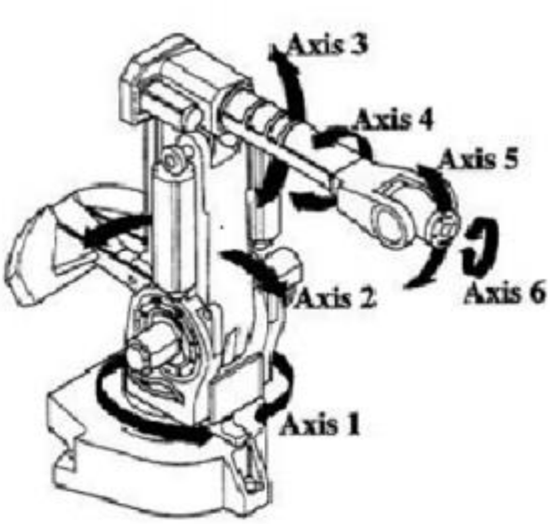


Figure 2.7 A six-axis-robotic arm

2.4 Degree of Freedom

Robotic arms use all their point (orientation) control Degree of freedom. The human arm can control seven angles free, articulated arms usually have up to six degrees free arms (V. Potkonjak, S. Tzafestas, D. Kostic, and G. Djordjevic, 2001). A robotic arm is made by using different solid part, join by n number of joint connected, each joint having one degree of freedom if their n number of the joint then arm have n degree of freedom (DOFs) (Virendra Patidar & Ritu Tiwari,2016). Figure 3 show a seven joint robotic arm.

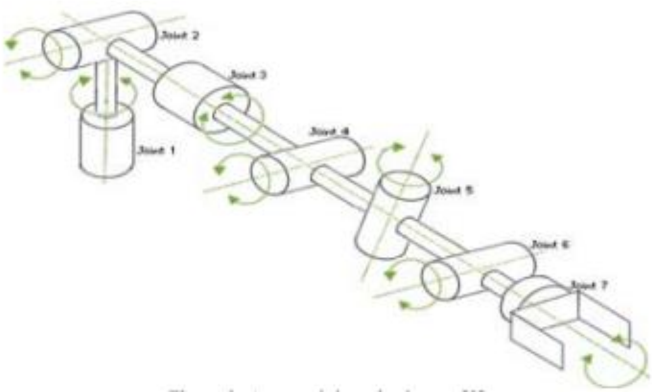


Figure 2.8 A seven joint robotic arm

A robotic arm that behave like a human analog motion, this arm was designed with 7 degrees of freedom for increasing interactivity with humans, force sensor was attached to wrist sensor work in six axis and used calculating force apply at the arm (C.-H. Kuo, Y.-W. Lai, K.-W. Chiu, and S.-T. Lee, 2008).

2.5 Mechanical Aspects in Development of Rovers

The main feature of a robot is its mechanical structure. In this section, the approach of embedded features on the rovers is discussed.

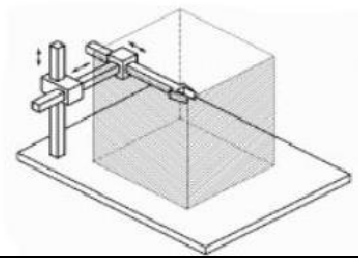
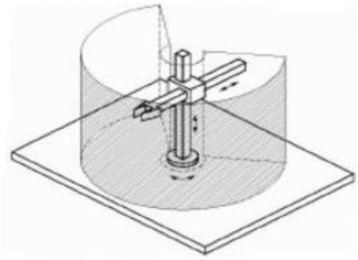
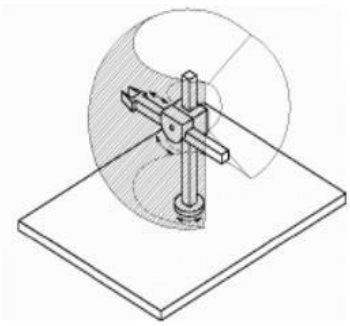
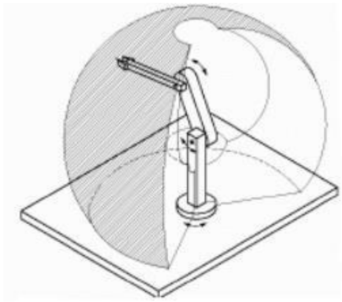
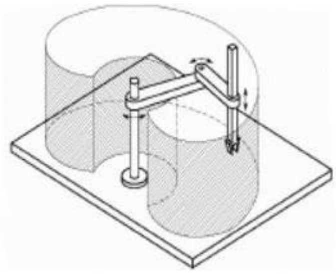
2.5.1 Robot Mechanical Structure

The robot manipulator classification is classified by types of coordination systems. Robot manipulators are typically categorized according to the configuration of their arm geometry or kinematics. In one of these five configurations, the majority of these manipulators break.

To have a sufficient number to perform a given task, the degrees of freedom (DOF) should be correctly distributed along with the mechanical structure. Six DOFs are required in the most general case of a task consisting of arbitrarily placing and orienting an object in three-dimensional (3D) space, three for positioning a point on the object. Concerning a reference coordinate frame, and three for orienting the target. The manipulator is said to be redundant from a kinematic point of view if more DOFs are available than task variables (Bruno Siciliano et al, 2010).

Until considering the industrial robot's efficiency and requirements manipulator. The basic typical mechanical structure must define the degree of freedom of the coordinate frame-dependent robot manipulator to be understood.

Table 2.4 Classification of robot manipulators, Source: (Bruno Siciliano et al, 2010 and Matjaž Mihelj et al, 2019)

Type	Workspace	Types of Joint	Symbol	Application
Cartesian		• Three prismatic joints • A cartesian degree of freedom	PPP	• Assembly • Pick and place
Cylinder		• One revolute joint and two prismatic joints • Cylinder configuration	RPP	• Machine tool • Spot welding
Spherical		• Two revolute joints and one prismatic joint • Spherical configuration	RRP	• Gas and arc welding
Articulated		• Three revolute joints • Most hand structure	RRR	• Welding • Spray painting
SCARA		• Two revolute joints and one prismatic joint • Selective Compliance Assembly Robot Arm	RRP	• Assembly

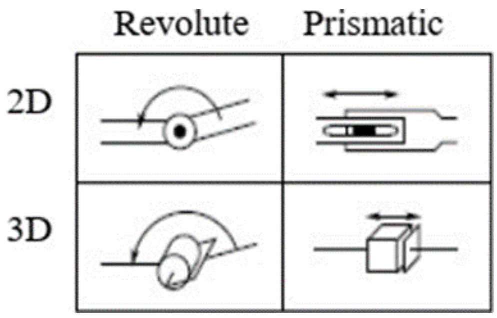


Figure 2.9 Representation of robot joints, Source: (Mark W. Spong et al 2005)

The robot data must be accompanied by the characteristic loading parameters, such as mass (kg), torque (Nm), the moment of inertia (kgm2), and thrust (N). The maximal velocity must be given at a constant rate when there is no acceleration or deceleration. The maximal velocities for particular robot axes must be given with the load applied to the end-effector. The resolution of each axis movement (mm or ◦), description of the control system, and the programming methods must also be presented (Matjaž Mihelj et al, 2019).

2.5.2 Component of a robotic system

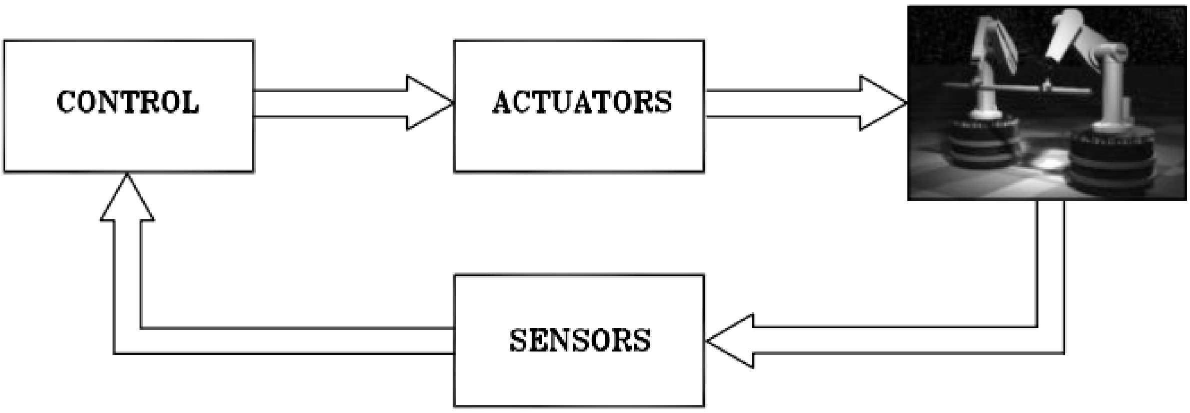


Figure 2.10 Components of a robotic system, (Bruno Siciliano et al, 2010)

With reference to this definition, a robotic system is in reality a complex system, functionally represented by multiple subsystems.

The essential component of a robot is the mechanical system endowed, in general, with a locomotion apparatus (wheels, crawlers, mechanical legs) and a manipulation apparatus (mechanical arms, end-effectors, artificial hands). (locomotion apparatus). The realization of such a system refers to the context of design of articulated mechanical systems and choice of materials. The capability to exert an action, both locomotion and manipulation, is provided by an actuation system which animates the mechanical components of the robot. The concept of such a system refers to the context of motion control, dealing with servomotors, drives and transmissions. The capability for perception is entrusted to a sensory system which can acquire data on the internal status of the mechanical system (proprioceptive sensors, such as position transducers) as well as on the external status of the environment (exteroceptive sensors, such as force sensors and cameras). The realization of such a system refers to the context of materials properties, signal conditioning, data processing, and information retrieval. (Bruno Siciliano et al, 2010)

2.5.3 Locomotion

Locomotion is a very crucial aspect to be studied in mechanical because it will complement the maneuverability of UGV effectively. In addition, it also considered kinematic and dynamic elements which are in terms of stability, traits of the contact surface and type of condition the robot needs to be deployed. There are four types of locomotion applied in mobile robots which are by using the leg, wheel, track, and hybrid locomotion (Siegwart, Nourbakhsh, & Scaramuzza, 2011).

Main activities regarding the categories of vehicles are the design of active suspension, whereas control aspects are the main problem. There exists now an interest for a new type of vehicle which inherits both advantages of wheeled and legged vehicles, namely the high velocity and payload and the high adaptive capabilities. These systems offer rough terrain adaptation capabilities based on the system reconfigurability and are able to perform hybrid locomotion like peristalsic mode.

First type is legged locomotion. It is defined by how many multiple points of contact surfaces link between the robot and the ground. Legged locomotion can be categorized in one leg, biped leg, quadruped leg, and hexapod leg. Each of them has their own special characteristics and the researchers just need to select according to their robot applications. For example, the single -legged robot needed a series of one contact only to enable it to move on the uneven terrain. However, the drawback from this design is, it will affect stability so the robot needs either altering their core of gravity or by transmitting pressures correctly to maintain the stability. (Larin, 2004).

Second type is wheeled locomotion. Various areas and applications such as medical, Industrial have been utilized Wheel Mobile Robot (WMR) (A. E.-S. B. J. J. Ibrahim, 2016). By using this type of locomotion, all wheels will automatically be suspended especially when more than three wheels had been used in order to keep ground contact when the robot move on irregular terrain. Thus, this type of locomotion will tend to concentrate on traction force, ability to move and control system rather than issue of stability. Moreover, the advantage by using wheeled locomotion is the possibility of the robot to slip can be avoided (Hamid, Nazih, Ashraf, Abdulbaky, & Khamis, 2016).

Third type is tracked locomotion. This concept used different concept compared to wheeled locomotion because the design implements dual-tread mechanism, which are the mobile robots are controllable when using differential drive condition. Commonly, this locomotion was used in safety authorities like Explosive Ordnance Disposal (EOD) reconnaissance, military and surveillance exploration (Schempf, 2003).

Last type is hybrid locomotion. This concept implements the advantages of both previous locomotion which are legged and wheeled locomotion. It means, hybrid can encounter obstacles and move on the rough terrain by using legged locomotion concept and at the same time it can also move on hard surfaces with high speeds by using wheeled locomotion concept (Siegwart et al., 2011).

2.6 Integration of Additional Features

2.6.1 Robotic Arm

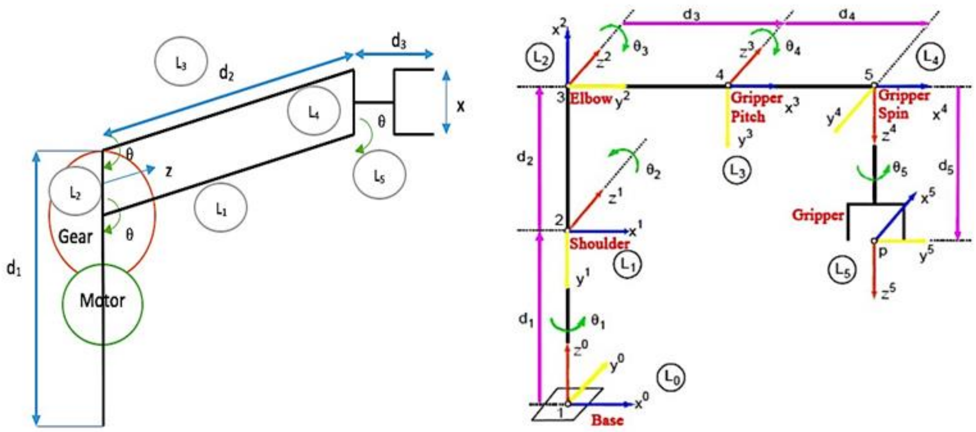
A robotic arm is required to perform two separate tasks, “Object Repositioning” and “Disc Loading”. It is a type of mechanical arm with same purposes to a human arm which can be program. The arm has the entirety total of the mechanism or may be part of a more multifaceted robot. The links of such an exploiter are connected by joints allowing either rotational motion such as in an uttered robot or translational which is in linear displacement. The links of the exploiter can be considered to form a kinematic chain. The end of the line of the kinematic chain of the exploiter is called the end effector and it is analogous to the human hand.

A robotic hand, can be designed to perform any desired task depending on the application such as gripping and spinning. For example, robot arms in automotive assembly lines perform a variety of tasks such as parts rotation and placement during assembly. In some cases, close imitation of the human hand is desired, as in robots designed to deportment bomb deactivation and discarding.

In robotics arm design, modelling stage supports design parameterization task by generating mathematical models that describe geometric structure, kinetic, and dynamic behaviours of the robot. Hence, geometric parameters and the structural design problem can be derived from the modelling stage. Only proper design parameterization will yield a good optimum design, since the optimization algorithm will search within a design space that is defined for the optimal design problem. (Leonard Felicetti, 2015)

Each robot design involves mathematical modelling of the kinematics, structure design, electronic design and software design. The robotic arm has a total of five axes. Three major axis which correspond to the base, shoulder and elbow are needed to move the arm to the desired spot, and two minor axis which correspond to the gripper pitch and gripper spin. The design has six rotary joint and with consideration of the number of joints as five because two joints that move the shoulder, rotate in the same direction with the same speed. Therefore, they are counted as one joint. Figure 2.1 (a) shows the precise link coordinate diagram of axes and joints. (Faravar, 2014)

While for our robot arm rover, the arm haves four link (L1, L2, L3, L4), three distances (d1, d2, d3), three angles of rotation (θ), and two axes of joint (z and x). For the $L1$ and $L2$ they are connected with gear and motor to move the arm. For the $L4$ is connected with a gripper. The distance of $L1$ and $L3$ is the same and $L3$ is parallel to the link L1. Only one axis which is x-axis at the gripper (open and close) and at the elbow of the arm only have z-axis (up and down) which they can move as shown in Figure 2.1 (b).



(a) Robot arm rover (b) Robot arm for real industry

Figure 2.11 Link coordinates of axes and joint of the developed robot

Where:

d	: Distances between the joint	θ	: Angle of rotation
x, y, z	: Axes of joint	L	: Link

2.6.2 Gripper

A gripper or end-effector is a key component of a robot enabling it to pick up and manipulate workpieces (Pham & Heginbotham, 1986). The gripper selection program described in this paper is a hybrid expert system which employs both the rule-based and object-oriented programming approaches. The main objective is to assist the user in choosing suitable grippers for industrial tasks varying from a simple pick and place operation to more sophisticated processes such as mechanical assembly. The system consists of two parts dealing with preliminary and detailed choices, Figure 2.2. In the preliminary choice section, suitable gripper types are suggested according to the general requirements of the user. The exact gripper or grippers corresponding to the user's detailed needs are retrieved from an external data file and displayed to the user in the detailed choice section. (D. T. Pham And E. Tacgin,1992)

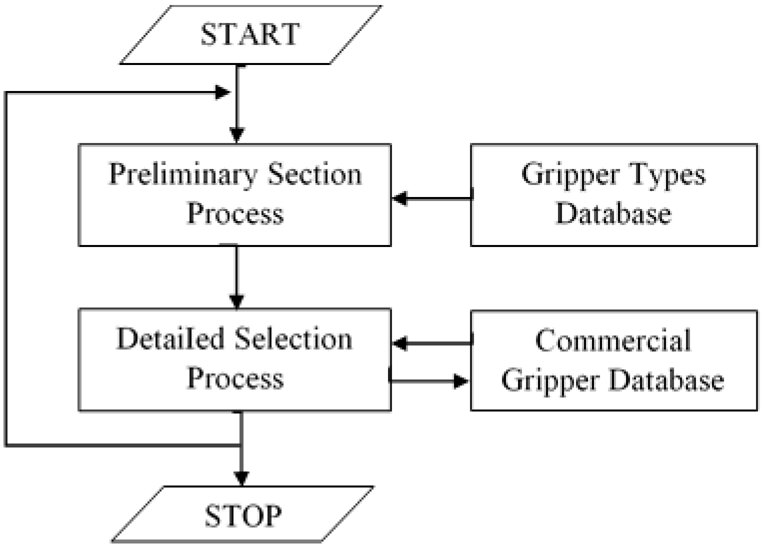


Figure 2.12 Structure of the expert system.

Although the gripping problem in robots is a subdivision of the general handling problem, grippers perform an important task in grasping and handling hot or gaseous loads from a distance. They permit the safe handling of objects into and out of pickling tubs, as in the chemical and steel making industries. In atomic power plants they permit remote handling of radioactive materials. They make it possible to transport and store materials, parts, assemblies, subassemblies, equipment, etc. In addition to insuring safety, their use, especially in the case of more specific types, increases speed of operation in practically all cases and vastly reduces labor cost.

In general, grippers can be classified according to the following:

1. Mechanical finger type

   According to the number of fingers in a gripper, we have 2-finger type and 3-finger type grippers. The majority of grippers are of the 2-finger type.

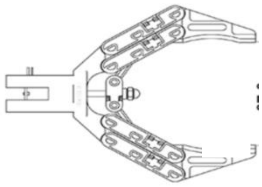
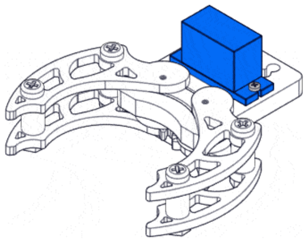
2. Vacuum and magnetic type

   This class includes those fitted with suction cups or electromagnets as force-exerting elements.

3. Universal grippers

   This class consists of inflatable fingers, soft fingers, 3-fingered grippers and grippers that are made of mouldable materials. Many grippers in this category have resulted from new developments.

Table 2.5 Differences between Robot Gripper and Mini gripper

Types of gripper	**Robot gripper** 	**Mini gripper** 
Design	• Simple and durable robotics that is great for "getting a grip". • Anti-slippery material (rubber) added on the inner side of two fingers. • Self-Protection Design that can protects the screw motor from short-circuits and over-current, ensuring long-time use of the gripper.	• Small-volume, simple gripper perfect for "getting a grip" in lightweight projects.
Material	The gripper itself is made of light-weight PVC material.	Made of light-weight acrylic material.
Function	• The self-locking function of fingers. • Protect objects it grips from falling off.	• It is perfect to grab with the diameter between 22mm and 60mm, and carry small items with weight under 60 grams, for examples, a ping pong ball, a plastic bottle, and a paper cup.

Specialties	• Heavy-duty to grip items up to 1.5kg. • Large Open-Width capable of opening an impressive 3" (67mm) wide. • The inner N20 screw motor of the gripper will automatically stop running when the gripper is fully open or closed because of the built-in fuse.	• Grip an item by using the phalanx of the gripper instead of the fingertip since using the phalanx can grip items firmly. • This gripper also equipped with a 9g servo which ensures fast gripping speed.

2.7 Electrical & Electronic Aspects in UGV Developments

The type of control system and vision system traditionally used in rovers are reviewed in this section. By indicating the common form of communication used and the type of vision system commonly used in the rover, it will elaborate further on how to monitor the rover's motion.

2.7.1 Control System

The control system is a mechanism for regulating all subsystem behaviors**.** It allows the movement and functions of different parts of the robot, and at the same time enables them to perform a specific set of movements and forces. Generally, the control system is divided into two methods: open loop system and closed loop system. An open loop system is a system in which all activities are controlled in the system and will not be affected by the result of the restoration. In contrast, the closed-loop system is a well-known system with feedback, so it can reduce the errors contained in the system (A. Ibrahim et al., 2016). However, there are many types of control systems commonly used to control robots, such as proportional integral derivative controller (PID) control, linear quadratic regulator (LQR) and international GNSS service (IGS).

The PID regulator enables the controller to achieve stability, tracking and parameter robustness. Moreover, this control system is such an important regulator or controller that in almost every industry, almost all controllers implement PID regulators under the hood. Equation 2.1 gives the PID control formula. We only need to know three knobs. The first is Kp, which is the proportional gain. The others are Ki (the integral gain), and then Kd (the differential gain). The effect of these gains is that p in the equation contributes to stability. In a sense, it makes the system not guaranteed. But this helps to make the system more stable. In addition, it makes the system develop in the direction of value, because in practical applications, the speed of the system is not super fast, and is called medium rate responsiveness. In fact, the response speed depends on the function of the size of Kp. Unfortunately, this type of system is usually insufficient for tracking. However, i is very suitable for tracking. In fact, if the system is stable, having the i component is enough to ensure that it can be tracked in almost all situations.

$$u = Kp^{e} + K_i \int_0^t \quad edt + Kd\frac{d}{dt}e \qquad (2.1)$$

One of the limitations of using PID control techniques is that due to the nonlinearity of the robot manipulator due to unpredictable conditions, they are not enough to obtain the desired tracking control output. A great deal of time is therefore needed to change PID parameters (G.U.V.Ravi Kumar and Mr.Ch.V.N.Raja et al 2014).

PID controller transfer function takes one of the two formats the first format is given such as;

$$G_{PID}(s) = K_p + K_I/s + K_D s \qquad (2.2)$$

With , KI , and KD are the proportional, integral, and derivative gains respectively. The second format is

$$G_{PID}(s) = K_P(1 + {}^{1}/_{T_I s} + T_D s) \qquad (2.3)$$

With $TI = KP/KI$ and $TD = KD/KP$ are known as integral and derivative time constant respectively.

If the input is positive large, the proportional gain KP must be large, the integral term KI small 'and the derivative term KD small; thus speeding the performance of the device and if the input is very small, the PID parameters KP should be smaller, KI larger, 19 and KD larger; thus, the output would have reduced overshoot and faster response (G.U.V. Ravi Kumar and Mr.Ch.V.N.Raja et al 2014).

2.7.2 Communication system

Many standard types can be used to describe a communication system as information and data, and it can also be transferred from one computer system to another through a geographic area. For this information, different methods are used, such as electric waves and electromagnetic fields transmitted through conductors, and finally light waves through optical fibers. Many standard types can be used to describe a communication system as information and data, and it can also be transferred from one computer system to another through a geographic area. For this information, different methods are used, such as electric waves and electromagnetic fields transmitted through conductors, and finally light waves through optical fibers.

A wireless network is a collection of networks that use radio signal frequencies to communicate between computers and other network devices. Therefore, the topology is the configuration of a geometric network. A typical topology is composed of a star topology, a bus topology and a ring topology. However, many computer networks used for data transmission and resource transfer often require data. There are two types of wireless networks, Local-Area Networks (LANs) and Wide Area Network (WANs) (Rossi, Wang, & Zuo, 1997), but Low Power Wide Area Networks (LPWANs) have also been used today as a form of network (Jebril, Sali, Ismail, & Rasid, 2018).

CHAPTER 3

METHODOLOGY

3.1 Introduction

The rover development phase starts when the issue found is that the existing robotic rover is very big and requires more space and is unable to deploy in limited space. The aim of deploying a robotic rover is to help safety authorities conduct dangerous search and rescue operations. The literature review was then carried out to examine the use of UGV and the methodology used to build robotic rovers.

Next, the concept design suggested the use of rover as a locomotion mechanism and the selection at the same time of the best material that can achieve its practical requirements that can travel under different terrains. In addition, both indoor and outdoor tests must also be carried out by the rover to allow it to be used in actual, dangerous conditions. The rover's outcome and review will be collected and the enhancement will still proceed and the process will stop when it can provide users with high efficiency.

The flow chart of our integrated concept project process is shown in Figure 3.1. According to the flowchart, the firstly that we need to do is to identify the problem according to the given title. After studying the design and development of the robotic rover under dangerous conditions. The proposed design after studying the title, the design to be continued is selected according to the screening principle, which wants to display the score of each design according to the selection criteria. In order to get some suggestions and comments, the proposed concept has been submitted to the supervisor.

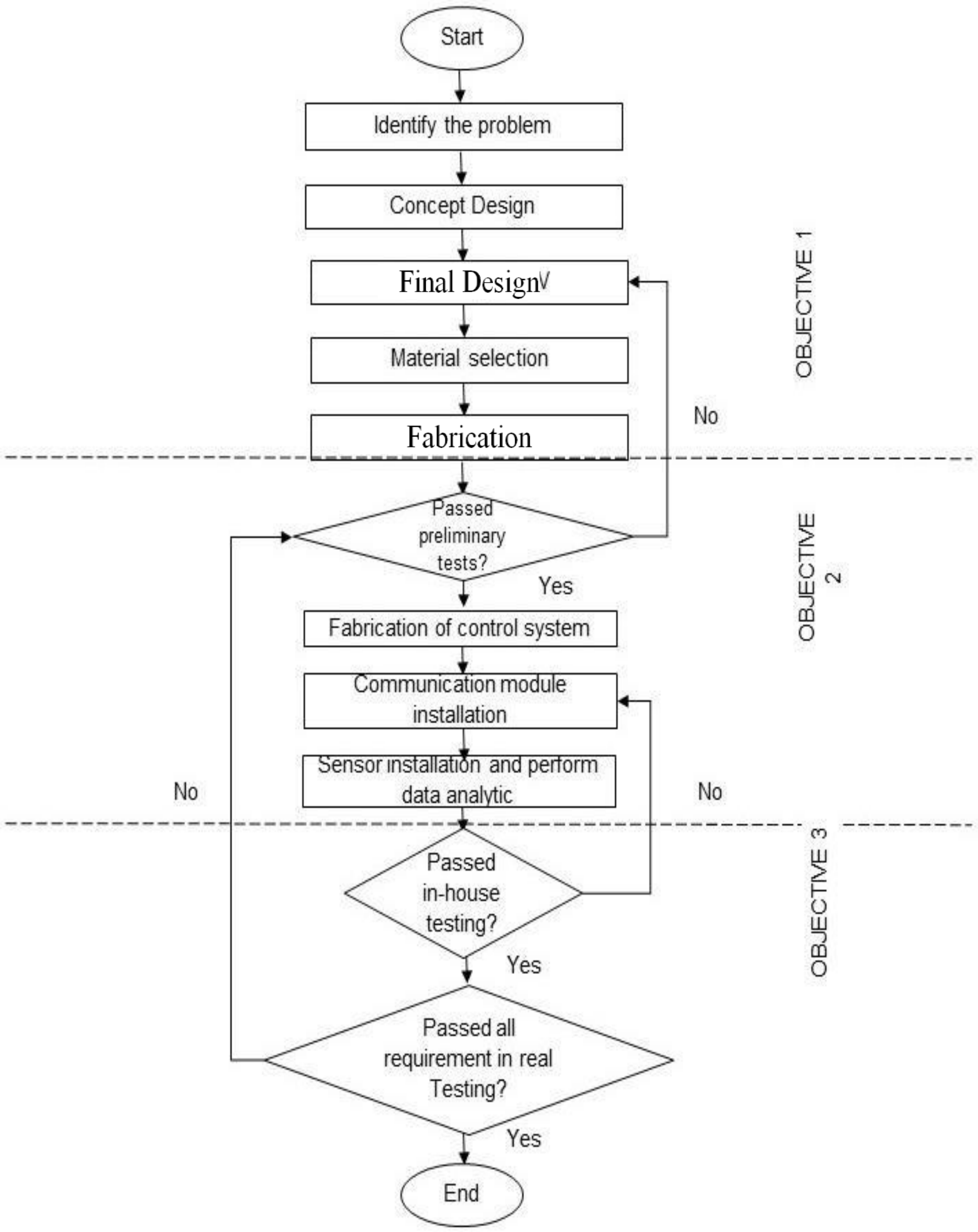


Figure 3.1 Fabrication Flowchart

3.2 Design of rover and features

It is suggested to build the proposed UGV with rocker boogie as its locomotion. In addition, UGV also includes robotic arms, grippers, crawlers, chassis, vision systems and controllers. Mechanical design involves selecting the appropriate motor for the rover application, and deciding on the materials used for the chassis and robotic arm, and the appropriate location for the motor to be placed inside the UGV as shown on the Figure3.2.

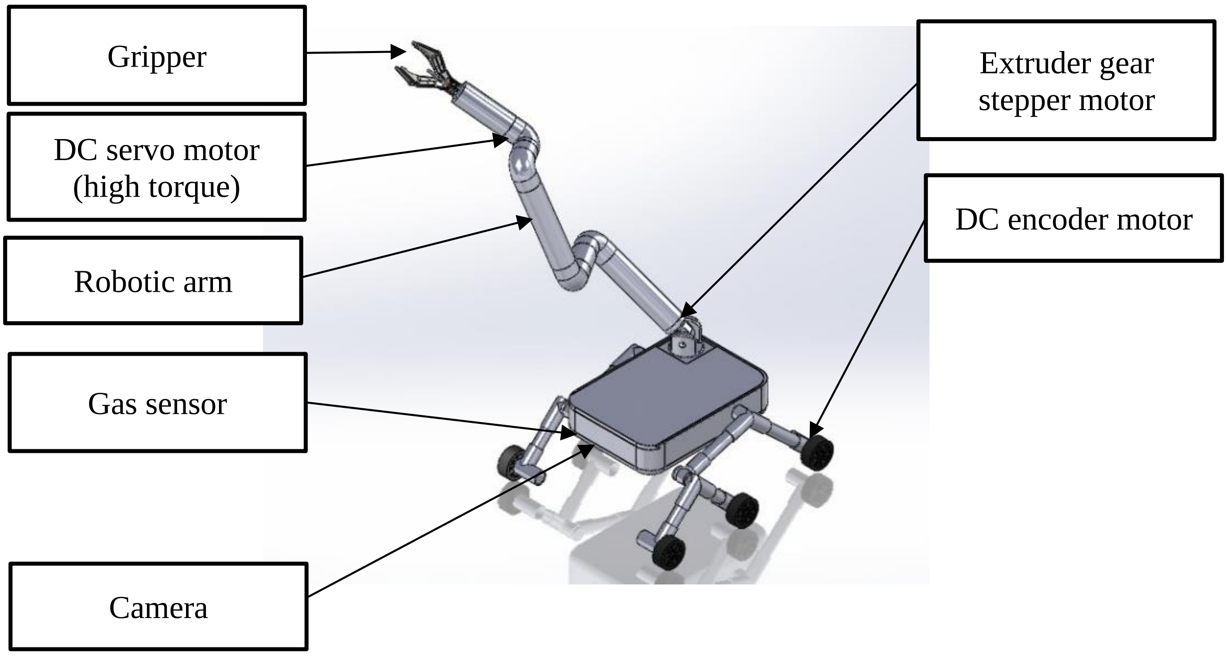


Figure 3.2 Proposed UGV

Due to the passivation phenomenon, the low density of the metal and its corrosion resistance are important factors for aluminum. Structural components made of aluminum and its alloys are vital to the aerospace industry, as well as to other transportation and structural materials industries. At least by weight, oxides and sulfates are the most useful aluminum compounds.

For conclusion, aluminum is almost always alloyed, significantly improving its mechanical properties, especially when tempered. For example, alloys with an aluminum content of 92% to 99% are common aluminum films and beverage cans. Copper, zinc, magnesium, manganese, and silicone are the main alloying agents (such as duralumin) and the weight level of other metals differs by several percentage points.

3.3 Locomotions

A multifunctional track for robotic rover is proposed to reduce its mobility on all surfaces. In addition, the developed chassis robotic rover needs to climb stairs to assist the authorities. For this reason, the design was changed to a specially designed rocker boogie design based on the research results of the overall size of the stairs in the building. In addition, due to shaking the wheels, the rocker boogie will use six DC motors.

Figure 3.3 shows the locomotion using the rocker boogie mechanism. This design is really suitable for rovers, especially due to its suspension mechanism, when conducting exploration activities. In addition, users can change the rocker boogie configuration by modifying the suspension links and joints. Therefore, it enables the rover to adjust the center of mass and improve its stability when moving. In addition, the purpose of this design is to ensure that the rover does not skid when crossing rough terrain (Tarokh, 2016).

The concept of movement is to use a rocker boogie system, all aluminum structures of the system follow the size of ordinary stairs to enable them to climb stairs. In addition, all connectors are made of Polyaryletherketone (PAEK) because it can withstand high temperatures.

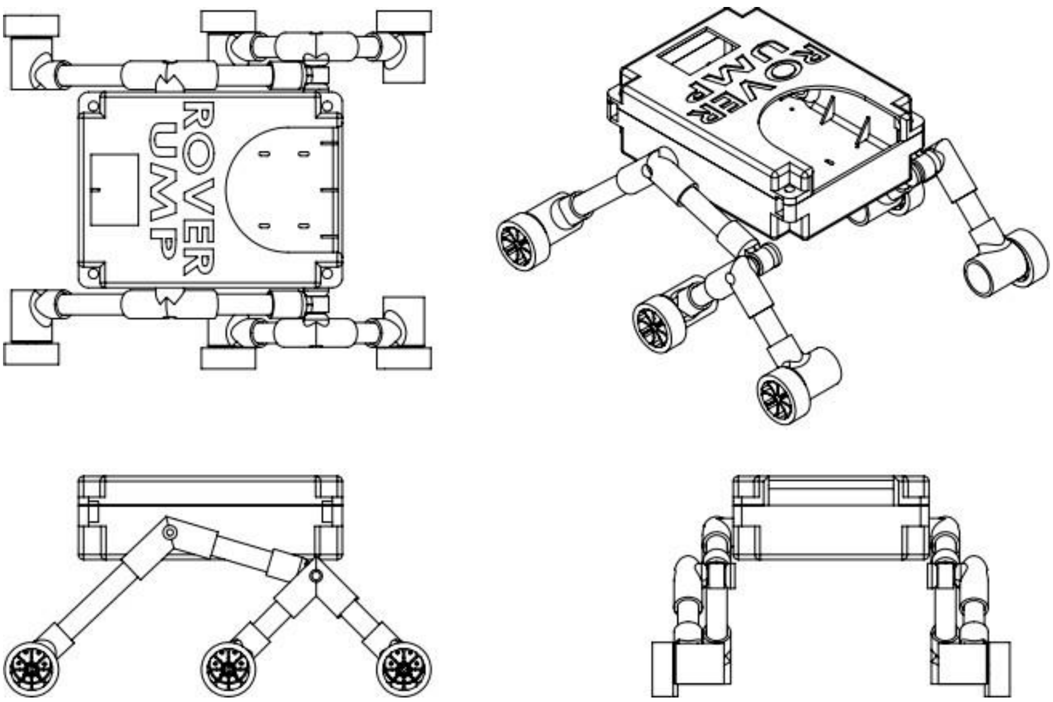


Figure 3.3 Mechanical Drawing of Rover

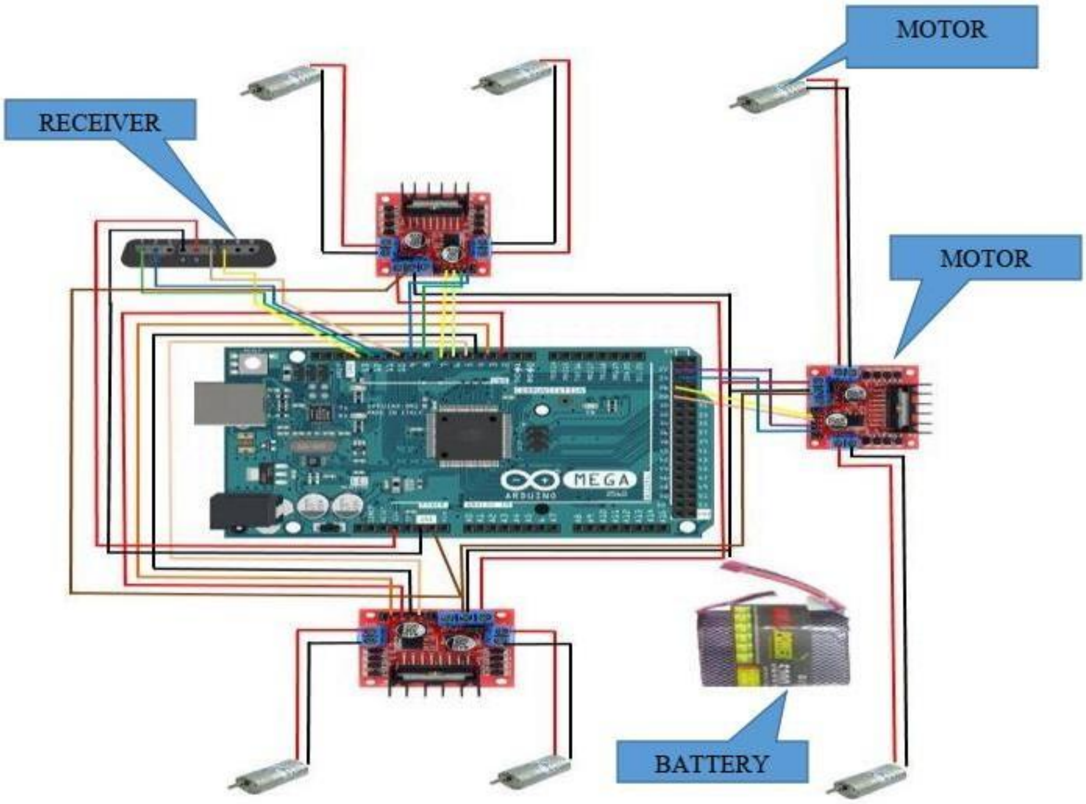


Figure 3.4 Electrical diagram in developed robotic rover chassis

There are several electrical components in the chassis of the rover in the Figure 3.4. In order to support the movement of the rover, all these components are necessary. For example, the rover will use Arduino Mega 2560 as the microcontroller. Finally, the rover uses lithium polymer lithium batteries so that the rover can work for a long time. In the current robotic rover, the power supply unit provides 12V DC power to the processing unit. Independent steering motors are installed on the front and rear sides of the two wheels so that the vehicle can be switched to the appropriate position. Each of the six wheels on the rover car has its own Arduino Mega integrated independent DC motor, powered by a lithium polymer battery.

This UGV will also be controlled by using a control loop. Whether the UGV needs to turn left or right, the control loop system will control the wheel movement. The motor will also be coded at right angles. This means that it is not only the opposite of a motor drive, but also a feedback system with sensors to achieve functions. Therefore, after the encoder is installed, the speed motor value can be defined.

3.4 Arm

The rover has much higher capabilities to move than the previous robot because it has 6 degrees of freedom that has shown in Figure 3.5. In addition, current robotic rover tends to have higher impact of strength in terms of material because the developed robotic rover made from Aluminum which is very strong, light and resistant to corrosion. Furthermore, the developed robotic rover used an extruder gear stepper motor gear ratio 3:7:1 as the main motor to move the robotic arm. Besides that, it used another 6 high torque servo motors to load payload. Finally, the controller plays the most important role to control the robotic arm. The robotic rover can safely control by the authorities because the developed UGV can be control to 500 m.

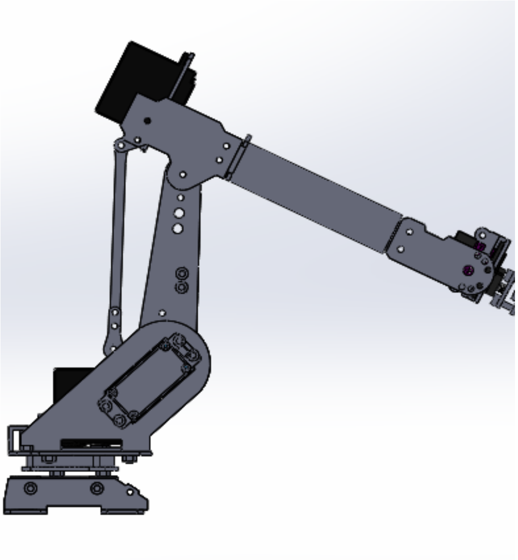


Figure 3.5 Side view of robotic arm

3.5 Gripper

Gripper model is the important part and critical part in designing the robotic arm. Nowadays, the most important is gripper part in robotic arm because of its function to pick or hold an item. Thus, gripper basically used to choose up and place objects to specific places controlled by remote or computer. The performances of robot to get handle on the object are depending on the weight of the object, friction between the object and the gripper, movement speed of the robot, and relation between the direction of movement and the gripper position that has shown in Figure 3.6.

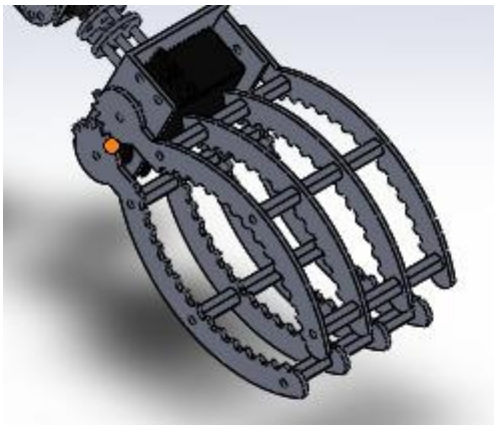


Figure 3.6 Gripper

3.6 Assemble Robotic Arm Gripper and Rover

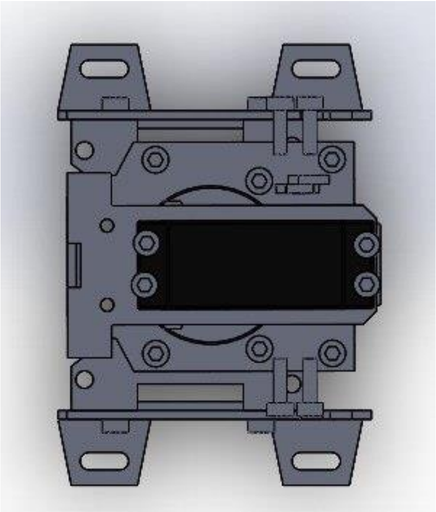


Figure 3.7 Combination of Rocker Boogie Mechanism with Arm and Gripper

Figure 3.7 show that the combination of rocker boogie with arm and gripper. The bracket is from the base of arm gripper that are attached with the body of the rocker boogie. This part include four screw that combine the part of arm gripper with rover so that the arm and gripper being stable.

3.7 Variety of Components Robotic Arm and Gripper

3.7.1 Robotic arm and gripper design

For electrical components such as controllers, the DC motor and the Lippo battery were used as a power supply to drive the arm and grip. Arduino-Mega is performed as a coding controller and executes the requested command in the device. The encoding is performed in combination with a Wi-Fi camera and a gas sensor to perform a multi-functional robotic process. The workflow for the design and development of robotics is shown in Figure 3.8.

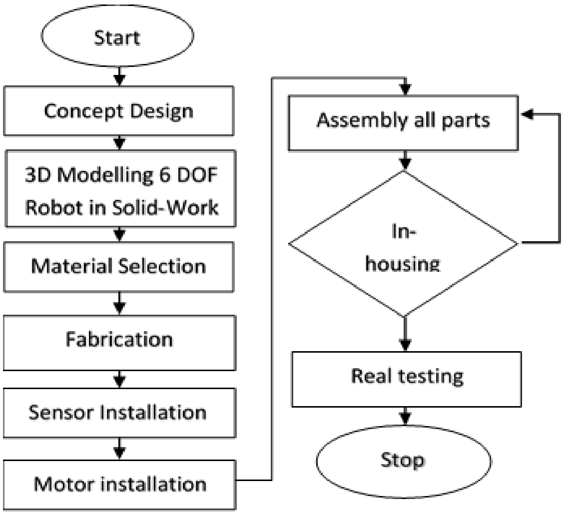


Figure 3.8 The workflow of the robotic arm and gripper development process.

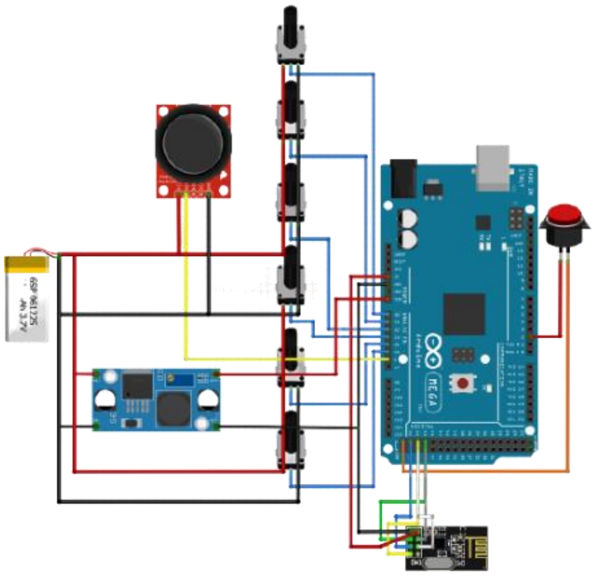


Figure 1.9 Electric circuit of Transmitter Robotic Arm and Gripper.

Figure 3.9 show the potentiometer are connect to Arduino Mega for control the servo motor. NRF 24L01 are used to transmit the data to the receiver.

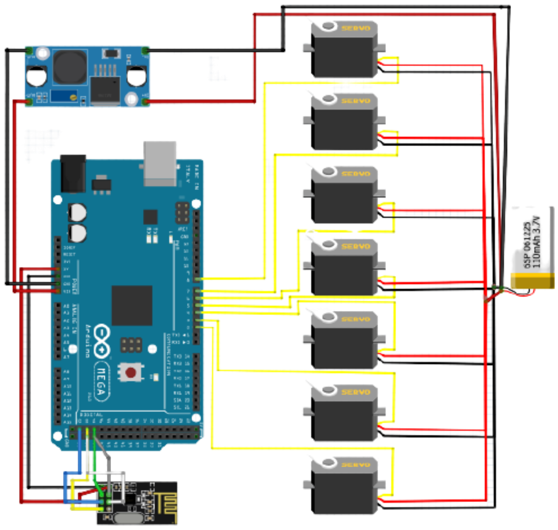


Figure 3.10 Electric Circuit of Receiver Robotic Arm and Gripper

In this present robotic arm, the power supply unit provides a 7V DC supply to the processing unit. The potentiometer is equipped with joystick individual steering motors which allow the arm to turn into desired positions. Each of the six servo motors on the rover has its own independent DC motor integrated with Arduino Mega and powered up by a LiPo battery shown in Figure 3.10.

3.7.2 Control technique

The robot system and its mathematical modeling are very complex, computer machine simulation is the simplest way to model a real robot without writing a code/programming and deriving a mathematical equation. A realistic and mathematical model of an industrial robot involved a lot of equations and spent a lot of time developing and experimenting with a real model. It has been shown that the benefits of designing an industrial model in computer simulation have decreased the cost and time of designing and simulating an industrial robot (Z.-Y. Zhao, M. Tomizuka and S. Isaka, 1993). Kinematics and mathematical modeling, Robot manipulator consists of a collection of n-links connected by joints. Each one of these joints has a motor allowing the motion to the commanded link. The motors have feedback sensors to measure the output (e.g., position, velocity, and torque) at each instant. Links and joints form a kinematic chain connected to the ground from one side, and the other is free. At the end of the open side, the end-effectors (e.g., gripper, welding tool, or another tool) are used to do some tasks as welding or handle materials (J Angeles,2003).

Kinematics is the motion geometry of the robot manipulator from the reference location to the target position, regardless of the forces or other factors that affect the motion of the robot (JJ Crage,2005). In other words, kinematics deals with the movement of a robot manipulator concerning a fixed frame as a function of time.

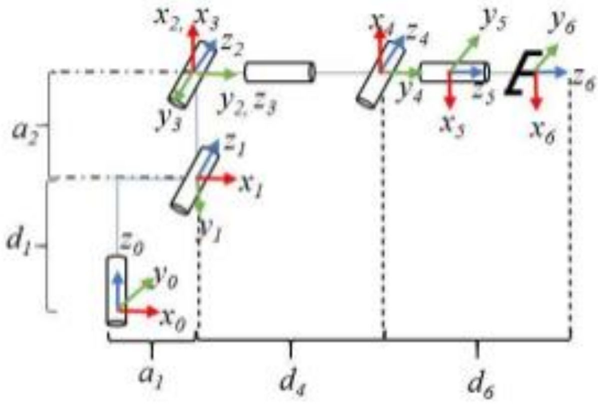


Figure 3.11 Kinematic diagram of Robotic Arm

Forward Kinematic requires the Homogenous Transformation Matrix to get the End Result. This is due to the capacity of the transformation matrix to define the position and orientation of the matrix. The Homogenous Transformation Matrix, a mixture of pure rotation and pure translation of a robotic manipulator (Maram, S. V., Kuruganti, Y. S., Chittawadigi, R. G., & Saha, S. K.,2019). To get the Homogenous Transformation Matrix, use Denavit-Hartenberg to record all displacement and rotation relationships with all manipulator frames (Cashbaugh, J. & Kitts C,2018). Figure 3.11 displays the kinematic diagram of the robot manipulator.

Table 3.1 below shows the 4 main parameters used in the D-H parameter which are defined as follows:

a) ***di*** (Joint off)
b) ***θi*** (Joint angle)
c) ***ai*** (Link length)
d) **αi** (Twist angle)

Table 3.1 DH Parameter of The Manipulator Link

Joint No	**D-H Parameters**			
	di(mm)	ai(mm)	αi(°)	θi(°)
1.	0.065	0.025	-90	0
2.	0	0.135	0	-90
3.	0	0	-90	0
4.	0.8	0	90	0
5.	0	0	90	180
6.	0.045	0	0	0

Multiplication of all joint matrixes as in equation 1 (Misra A., & Singh, G.,2019) will give the final transformation matrix value.

$$T_6^0 = T_1^0\, T_2^1\, T_3^2\, T_4^3\, T_5^4\, T_6^5 \tag{1}$$

$$T_6^0 = \begin{bmatrix} R_6^0(q) & P_6^0(q) \\ 0 & 1 \end{bmatrix} \tag{2}$$

$$T_6^0 = T_1^0\, T_2^1\, T_3^2\, T_4^3\, T_5^4\, T_6^5 = \begin{bmatrix} r_{11} & r_{12} & r_{13} & p_x \\ r_{21} & r_{22} & r_{23} & p_y \\ r_{31} & r_{32} & r_{33} & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{3}$$

The product of all multiplication matrixes shall be as follows in the form of the resulting matrix (Dong, S., Yuan, Z., & Zhang, F. ,2019). In equation 2, $R_6^0(q)$represents the direction of the end-effector, while $P_6^0(q)$ represents the value for the position of the end-effector. Typically, in a matrix, the 3x3 matrix on the upper left shows the orientation as shown in equation 3 and the 1x1 matrix on the upper right shows the position of x, y, and z. Based on equation 1, the multiplication value of the transformation matrix of link 0 respected for link 6 must be inserted into the matrix in equation 3 (Spiliotopoulos, J., Michalos, G., & Makris, S, 2018).

A dynamic torque and robot-induced forces (Misra, A., & Singh, G, 2019) is considered to be the dynamical robot equation. This part played a significant part in the selection of the best motor to power the manipulator by the builder or manufacturer. Equation 4 (Dong, S., Yuan, Z., & Zhang, F, 2019) reveals the equation used to calculate the manipulator's dynamics.

$$M(q)\ddot{q} + \mathrm{C}(\mathrm{q}, \dot{q})\dot{q} + \mathrm{G}(\mathrm{q}) = \tau \qquad (4)$$

$M(q)$ It represents the matrix of inertia. While $\mathrm{C}(\mathrm{q}, \dot{q})$ Is a centrifugal matrix known as Coriolis and $\mathrm{G}(\mathrm{q})$ This is the matrix of gravity. Generally, the equation in equation 4 can be used to determine the dynamics of Newton Euler and Euler Langrage using two methods. This measurement method can be used by both methods to describe dynamics.

In Inverse Dynamic, a combination of two inputs is required to generate joint torque, which is the kinematic parameter and the initial parameters (Liu, J., & Liu, R.,2016). The kinematic parameters consist of joint value, speed of joint, and acceleration of the joint (Camomilla, V., Cereatti, A., Cutti, A. G., Fantozzi, S., Stagni, R., & Vannozzi, G, 2017). Therefore, the Center of Gravity (COG), including volume, mass, and inertia must be coupled with initial parameters to easily find the couple values (Wind, H., Renner, A., Schaut, S., Albrecht, S., & Sawodny. O, 2019).

Servo refers to an error sensing feedback control that is used to correct the performance of the system that had shown in Figure 3.9. Servo or RC Servo Motors are DC motors that are equipped with a servo mechanism for precise angular position control. The rotation limit of the RC servo motors is usually between 90° and 180°. But the servos do not rotate continuously. Their rotation between fixed angles is limited. The Servos are used for precision positioning. They are used in robotic arms and legs, in RC toys such as RC helicopters, aircraft, and cars, and sensor scanners.

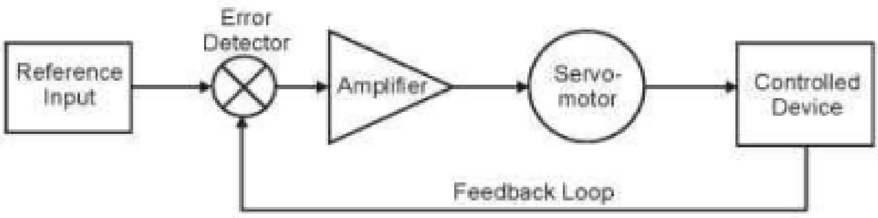


Figure 3.12 Block diagram of a servo motor

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

From the previous chapter has told about the proposed design of rover. So for this chapter will show the finalized design that has been prepared. The rover that using mechanical parts consists of joints and mechanical grip for picking and place the object in the desire place. This project is designed for control and security purpose.

4.2 Rover characteristics

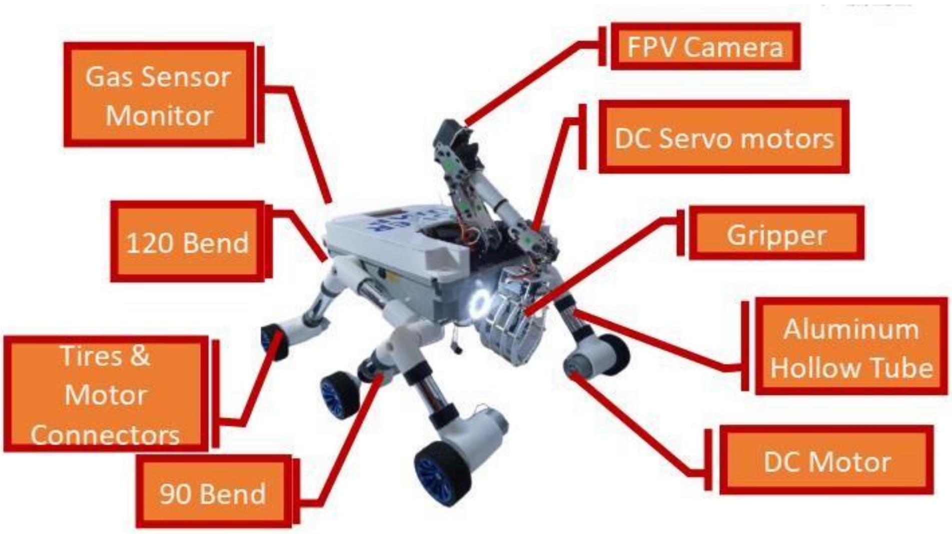


Figure 4.1 Component used in the robotic rover

In this review, this is the finalize prototype of smart robotic rover's. The rover mainly focuses on three tasks. The condition of the hazardous region is controlled, the obstacle surface is controlled and the hazardous gas is detected at the place exposed. For Figure 4.1 are shown the part of component in robotic rover. The electrical components and controls of the rover system are fixed on the body parts. A frame was developed using hollow aluminum tubes to control the power of the rover. The electrical components and controls of the rover system hold all in the body part.

4.3 Controller of robotic arm and gripper

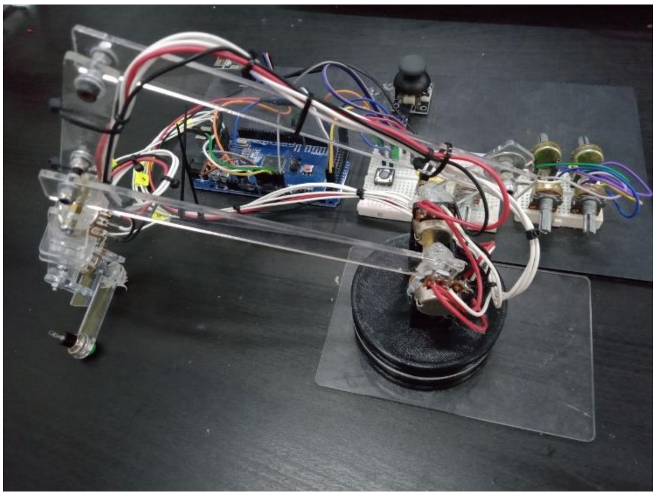


Figure 4.2 The controller of robotic arm and gripper

The potentiometer is an electrical resistor that is manually adjustable and uses three terminals. Potentiometers set the output levels for a variety of electrical devices. Servos are tiny but powerful engines that can be used for a variety of purposes, from robots to toy helicopters. There are three basic components of the servo: an electric motor, a feedback potentiometer connecting to the output shaft, and a joystick. This allows the servo to rotate to specific angles by keeping track of its current angular position. To guide a robot arm to pick up or move something, it is necessary to take several actions in a specific order; move the arm, rotate the "wrist" and open/close the "hand" or "fingers." In contrast to humans, robots pick up items without thinking about the steps that need to be taken. Pulse-Wide Modulation activates the servo (PWM). Depending on the service cycle of the received signal, the motor aligns the shaft to a given angle.

4.4 Arm

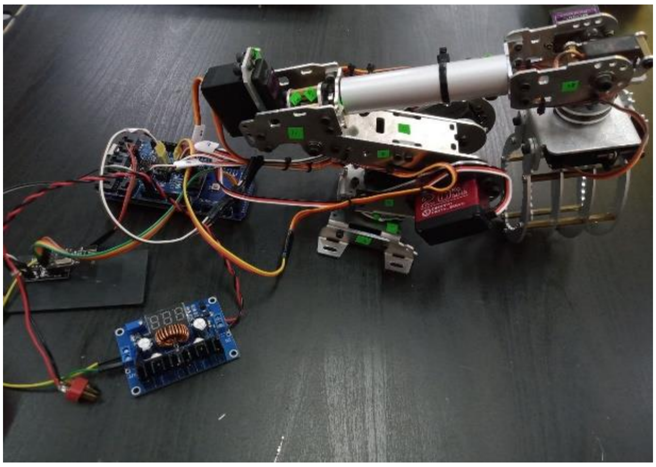


Figure 4.3 Real view of the robotic arm

For robotic arm, we must to concern about mechanical parts and electrical components that affect or influenced to sensor technology, computer programming system and overall robotic arm performance. For robotic arm design has two parts which are electrical components and mechanical design. For mechanical design, the design of gripper are included and body part of the robotic arm whereas the electrical components include the microcontroller, sensing system, circuit system to monitor and control the arm of robot that has shown in Figure 4.3. The mechanical design must be designed as exact as possible to avoid from any problem or error during its movement and the electrical components also must be appropriate and dependable to be attach at the mechanical part.

The design of robotic arm consists of the gripper and the body part. For the gripper must be of light weight and the body of the robot must be able to support the weight of the object to be lifted. For mechanical parts, the material used must be considered because the factor of weight is important to guarantee that the robot can give the best performance. Due to this reason, the whole mechanical parts are designed by choosing aluminum. The main reasons why we using aluminum because the strength is better and light weight as compared to the other type of material. Furthermore, aluminum is hard to break due to its quality.

4.5 Gripper

Figure 4.4 Real view of the gripper

Figure 4.4 shown the real view of the gripper after we design.Gripper model is the important part and critical part in designing the robotic arm. Nowadays ,the most important is gripper part in robotic arm because of its function to pick or hold an item .Thus, gripper basically used to choose up and place objects to specific places controlled by remote or computer. The performances of robot to get handle on the object are depending on the weight of the object, friction between the object and the gripper, movement speed of the robot, and relation between the direction of movement and the gripper position.

4.6 Performance of robotic arm and gripper

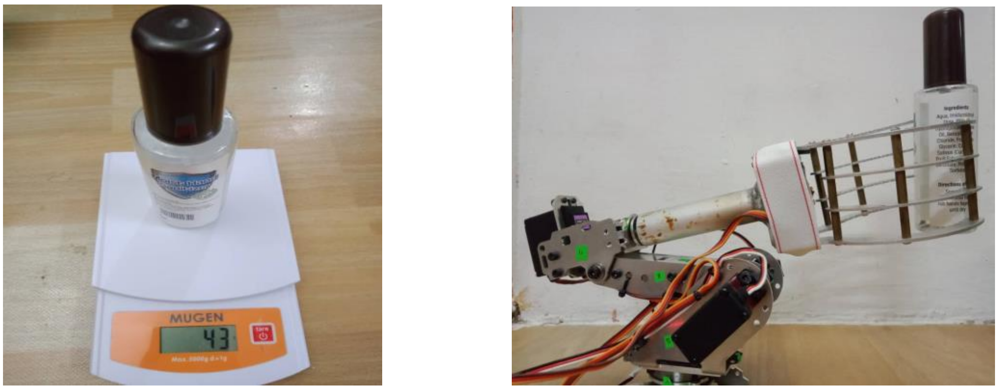


Figure 4.5 Lifting object with weight 43g

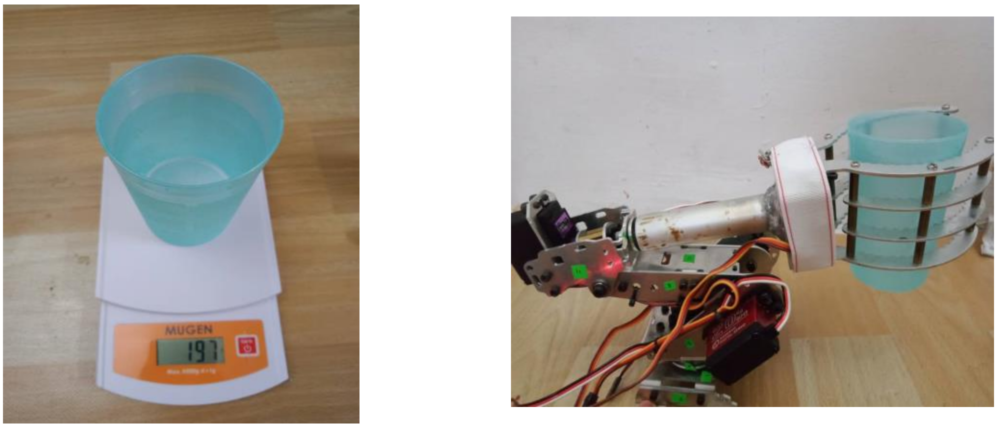


Figure 4.6 Lifting object with weight 197g

The performance of robot to pick the object and place it in the desire place are depending on the weight of the object, friction between the object and the gripper, movement speed of the robot and the relation between the direction of movement and the gripper position. The different of object weight are shown to test the robot arm and gripper. For the figure 4.5 shown that the robot pick the bottle of moist hand sanitizer contain 43 gram. Also that, figure 4.6 shown the robot pick a cup containing water for weight 197 gram**.**

CHAPTER 5

CONCLUSION

5.1 Introduction

For this chapter will explain about overall project, the recommendation is suggested to give an idea to other researcher who refer this thesis and also future work for concerns deeper analysis of particular mechanisms, new proposals to try different methods, or simply curiosity.

5.2 Conclusion

As for the conclusion, the goal of the project was achieved. The project successfully designed a low-cost arm and gripper according to the material usage. Therefore, aluminum is one of the most important materials that everyone uses. It is very strong, light, corrosion resistant and affordable. Likewise, aluminum has a higher strength-to-weight ratio. This means that for a certain amount of aluminum and steel of the same quality, aluminum will be stronger. In addition, a robot arm with a gripper was successfully developed and assembled in conjunction with the movement of the rover. For electrical components such as controllers, DC motors and Lippo batteries are used as power sources for driving arms and grippers. Arduino-Mega executes as an encoding controller and executes the requested commands in the device. In this robotic arm, the power supply unit provides 7V DC power to the processing unit. The potentiometer is equipped with a steering motor independent of the joystick, which can turn the arm to the desired position. Each of the six servo motors on the rover car has its own independent DC motor, which is integrated with the Arduino Mega and is powered by a lithium battery. In order to lift the object with the robotic arm and gripper, the 6 degrees of freedom (DOF) of this project is used to obtain the desired position of the robotic arm.

5.3 Recommendation

In future for recommended the robotic arm is that add a forklift concept to the robotic arm, because the gripper is not strong enough to lift heavy objects. Besides that, to make a gripper with less vibration to carry explosive substances like picric acid.

5.4 Future work

For future work in robot arm, servo characteristic will be selected and powerful to give the robot arm and gripper to pick the heavy object. Besides that, the use of gripper will be more appropriate based on the project.

REFERENCES

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.

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.

Bruno Siciliano, Lorenzo Sciavicco, Luigi Villani, Giuseppe Oriolo (2010) Robotics, Modelling, Planning and Control.

Camomilla, V., Cereatti, A., Cutti, A. G., Fantozzi, S., Stagni, R., & Vannozzi, G. (2017). Methodological factors affecting joint moments estimation in clinical gait analysis: a systematic review. Biomedical engineering online, 16(1), 1-27.

Cashbaugh, J., & Kitts, C. (2018). Automatic calculation of a transformation matrix between two frames. IEEE Access, 6, 9614-9622

C.-H. Kuo, Y.-W. Lai, K.-W. Chiu, and S.-T. Lee, “Motion planning and control of interactive humanoid robotic arms,” in Advanced robotics and Its Social Impacts, 2008. ARSO 2008. IEEE Workshop on. IEEE, 2008, pp. 1–6.

Dong, S., Yuan, Z., & Zhang, F. (2019, November). A Simplified Method for Dynamic Equation of Robot in Generalized Coordinate System. In Journal of Physics: Conference Series (Vol. 1345, No. 4, p. 042077). IOP Publishing.

Fofilos, P., Xanthopoulo, K., Romanos, E., Zikid, K. J. J. o. C., & Modelling. (2014). KERVEROS I. An Unmanned Ground Vehicle for Remote-Controlled Surveillance. 4(1), 223-236

J Angeles. Fundamentals of Robotic Mechanical Systems: Theory, Methods, and Algorithms, 2nd Edition, Springer. 2003.

JJ Crage. Introduction to Robotics Mechanics and Control, 3rd Edition, Prentice-Hall. 2005

Liu, Y., & Nejat, G. (2013). Robotic Urban Search and Rescue: A Survey from the Control Perspective. Journal of Intelligent Robot System, 72(2), 147-165. doi:10.1007/s10846- 013-9822-x

Liu, J., & Liu, R. (2016). Simple method to the dynamic modeling of industrial robots subject to constraint. Advances in Mechanical Engineering, 8(4), 1-9

Martial Hebert, Charles E. Thorpe, Anthony Stentz (1997): Intelligent Unmanned Ground Vehicles Autonomous Navigation Research at Carnegie Mellon.

Maram, S. V., Kuruganti, Y. S., Chittawadigi, R. G., & Saha, S. K. (2019). Effective

Teaching and Learning of Homogenous Transformation Matrix using RoboAnalyzer Software. In Proceedings of the Advances in Robotics 2019 (pp. 1-5)

Matjaž Mihelj · Tadej Bajd, Aleš Ude · Jadran Lenarčič, Aleš Stanovnik · Marko Munih, Jure Rejc · Sebastjan Šlajpah, 2019, Second Edition, Robotics

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.

Micire, M., & Murphy, R. (2002). Analysis of the robotic-assisted search and rescue response to the World Trade Center disaster.

Misra, A., & Singh, G. (2019, October). Kinematic and Dynamic Analysis of an Industrial Six-Axis Robotic Manipulator. In International Conference on Robotics, Automation and Non-Destructive evaluation.

Parikh, C.2015. An Intellectual Way of Infusing Microcontroller Fundamentalsinto Sophomore Students. Autonomous Robot, 1-4.

S. Yu, X. Yu, B. Shirinzadeh, and Z. Man, "Continuous finite-time control for robotic manipulators with terminal sliding mode," Automatica, vol. 41, pp. 1957-1964, 2005.

Spiliotopoulos, J., Michalos, G., & Makris, S. (2018). A reconfigurable gripper for dexterous manipulation in flexible assembly. Inventions, 3(1), 4

V. Potkonjak, S. Tzafestas, D. Kostic, and G. Djordjevic, "Human-like behavior of robot arms: general considerations and the handwriting taskpart 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.

Wind, H., Renner, A., Schaut, S., Albrecht, S., & Sawodny, O. (2019). Comparison of joint angle, velocity, and acceleration estimators for hydraulically actuated manipulators to a novel dynamical approach. Control Engineering Practice, 91, 10411.

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.

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.

Z.-Y. Zhao, M. Tomizuka and S. Isaka, "Fuzzy Gain Scheduling PID Controller," IEEE Transactions on Systems, Man., Cybernetics Society, Vol. 23, No. 5, pp. 1392–1398, Sep/Oct. 1993.

APPENDICES

Appendix A: Material selection

A1 The Physical Constant of Materials.

Material	Modulus of Elasticity E Mpsi	Modulus of Elasticity E GPa	Modulus of Rigidity G Mpsi	Modulus of Rigidity G GPa	Poisson's Ratio ν	Unit Weight w lbf/in^3	Unit Weight w lbf/ft^3	Unit Weight w kN/m^3
Aluminum (all alloys)	10.4	71.7	3.9	26.9	0.333	0.098	169	26.6
Beryllium copper	18.0	124.0	7.0	48.3	0.285	0.297	513	80.6
Brass	15.4	106.0	5.82	40.1	0.324	0.309	534	83.8
Carbon steel	30.0	207.0	11.5	79.3	0.292	0.282	487	76.5
Cast iron (gray)	14.5	100.0	6.0	41.4	0.211	0.260	450	70.6
Copper	17.2	119.0	6.49	44.7	0.326	0.322	556	87.3
Douglas fir	1.6	11.0	0.6	4.1	0.33	0.016	28	4.3
Glass	6.7	46.2	2.7	18.6	0.245	0.094	162	25.4
Inconel	31.0	214.0	11.0	75.8	0.290	0.307	530	83.3
Lead	5.3	36.5	1.9	13.1	0.425	0.411	710	111.5
Magnesium	6.5	44.8	2.4	16.5	0.350	0.065	112	17.6
Molybdenum	48.0	331.0	17.0	117.0	0.307	0.368	636	100.0
Monel metal	26.0	179.0	9.5	65.5	0.320	0.319	551	86.6
Nickel silver	18.5	127.0	7.0	48.3	0.322	0.316	546	85.8
Nickel steel	30.0	207.0	11.5	79.3	0.291	0.280	484	76.0
Phosphor bronze	16.1	111.0	6.0	41.4	0.349	0.295	510	80.1
Stainless steel (18-8)	27.6	190.0	10.6	73.1	0.305	0.280	484	76.0
Titanium alloys	16.5	114.0	6.2	42.4	0.340	0.160	276	43.4

A2 Selection of Material (Aluminium)

Material properties	Tool steel	Mild steel	Aluminium
Tensile strength (N/mm)	205 - 540	360 -490	90 - 450
Corrosion Resistance	Low	Medium	High
Density	7861	7850	2700
Hardness	High	Medium	Soft
Modulus Elasticity (N/mm)	207	206	72

Appendix B: Budget and Cost Analysis

Bil	Items	Quantity	Price (RM)
1	IOT Liolinn NODEMCU ESP8266 WiFi Controller Board ESP-12	2	40.00
2	Arduino Nano 3.0	2	46.00
3	2.4G Transceiver Nr f24L01 Module	2	17.00
4	Td-8120Mg Waterproof Metal Gear Digital Servo With 20Kg High Torque 180Angle For Rc Remote Control Car Model Vehicle 20Kg Servo	6	173.34
5	Rotary Potentiometer Single-Turn, 3-Pin [1K - 1M]	6	6.00
6	Male-to-Male Breadboard 20cm Jumper Wire | 40 pcs	1	5.50
7	Female-to-Female Breadboard 20cm Jumper Wire | 40 pcs	1	5.50
8	Mega 2560 (Arduino-Compatible) - bersama B-type USB Cable | Arduino Malaysia	2	115
9	Stainless steel tube	1	25.27
10	SZDOIT G8 Metal Mechanical Gripper Industrial Robot Arm Claw / Clamp With Digital High Torque Servo RC Robotic Part For Arduino May 2020	1	19.00
11	Lipo 3-cell (11.1V)	2	316
	TOTAL (RM)		768.61

Appendix C : Programming

C1 Transmitter coding

```
#include <SPI.h>       //masukkan library SPI, nRF menggunakan komunikasi SPI
#include <nRF24L01.h>  //masukkan library nRF24L01
#include <RF24.h>      //masukkan library RF24L

const uint64_t pipeOut = 0x8888F6F6E1LL; //address/alamat unik ditentukan oleh
pengguna

RF24 radio(48, 49); //pin CE(9) & CSN(10)
//MOSI(11) , SCK(13) , MISO(12)

//Struktur Data-Array yang akan di transmit setiap cycle
//data dinamakan MyData
struct MyData {
 byte but1;     //BUTTON 1 STATUS
 byte potA;
 byte potB;
 byte potC;
 byte potD;
 byte potE;
 byte potF;
 byte potG;
};               // boleh hantar sehingga 32 byte data dalam satu cycle
penghnataran data

MyData data; //prefix "data" diletakkan kepada setiap individu-array dalam
MyData

//PROGRAM/SEQUENCE VARIABLES
bool B1Cond;
byte B1Count;

//CONSTRAINT TUNING
int constA = -40;
int constB = 30;
int constC = 0;
int constD = 0;
int constE = 0;
int constF = 0;
int constG = 0;

void setup(){ //PERMULAAN VOID SETUP
 pinMode(49, OUTPUT); //SS PIN DECLARATION
 pinMode(2, INPUT_PULLUP); //BUTTON PIN 2

 pinMode(22, OUTPUT); //STATUS LED

 //ANALOG INPUTS
 pinMode(A0, INPUT);pinMode(A1, INPUT);
 pinMode(A2, INPUT);pinMode(A3, INPUT);
 pinMode(A4, INPUT);pinMode(A5, INPUT);
 pinMode(A6, INPUT);

 delay(100);

 Serial.begin(9600);  //Serial untuk debug/check coding output

 delay(100);

 radio.begin();                    //memulakan radio nRF
 radio.openWritingPipe(pipeOut);
 radio.setPALevel(RF24_PA_MAX );
 radio.setDataRate(RF24_250KBPS);
 radio.setChannel(115);
```

```
    radio.setAutoAck(false);

    delay(100);
    radio.stopListening();

    data.but1 = 0;                    //nilai permulaan variable untuk butang
bersamaan 0

    delay(300);
   } //PENUTUP VOID SETUP

   //PROGRAM UTAMA
   void loop(){ //permulaan void loop
    //INPUT CONTROLS
    InputControls();

    /***SEND RADIO DATA***/
    radio.write(&data, sizeof(MyData)); //send semua data set array MyData kepada
penerima
    /***SEND RADIO DATA COMPLETE***/

    checkserial();  //check data pada serial monitor adakah butang berfungsi
   }//END VOID LOOP

   //
   void checkserial(){ //seria print untuk debug
    Serial.print("B1: ");  //serial print nilai butang
    Serial.print(data.but1);   //serial print nilai butang
    Serial.print(" A0: ");
    Serial.print(data.potA);
    Serial.print(" A1: ");
    Serial.print(data.potB);
    Serial.print(" A2: ");
    Serial.print(data.potC);
    Serial.print(" A3: ");
    Serial.print(data.potD);
    Serial.print(" A4: ");
    Serial.print(data.potE);
    Serial.print(" A5: ");
    Serial.print(data.potF);
    Serial.print(" A6: ");
    Serial.print(data.potG);

    Serial.println();
   }//END CEHCK SERIAL

   void InputControls(){
    //PUSH BUTTON
    if(digitalRead(2) == LOW && B1Cond == false){  //jika butang ditekan, send
nilai 255 pada radio
      B1Count = B1Count + 1;
      B1Cond = true;
    }
    if(digitalRead(2) == HIGH && B1Cond == true){ //jika butang dilepas, send nilai
0 pada radio
      B1Cond = false;
    }
    if(B1Count > 1){
      B1Count = 0;
    }
    if(B1Count == 1){
      digitalWrite(22, HIGH);
      data.but1 = 99;
    }
    if(B1Count == 0){
      digitalWrite(22, LOW);
      data.but1 = 0;
    }
```

```
  //ANALOG POTENTIOMETER
  data.potA = map(analogRead(A0), 1023,0,(0+constA),(180+constA)); //BASE ARM1
  data.potB = map(analogRead(A1), 0,1023,0,180);
  data.potC = map(analogRead(A2), 0,1023,(0+constB),(180+constB)); //BASE ARM2
  data.potD = map(analogRead(A3), 0,1023,0,180);
  data.potE = map(analogRead(A4), 0,1023,0,180);
  data.potF = map(analogRead(A5), 0,1023,0,180);
  data.potG = map(analogRead(A6), 0,1023,0,180);

  ControlLimits();

}//END INPUT CONTROLS
```

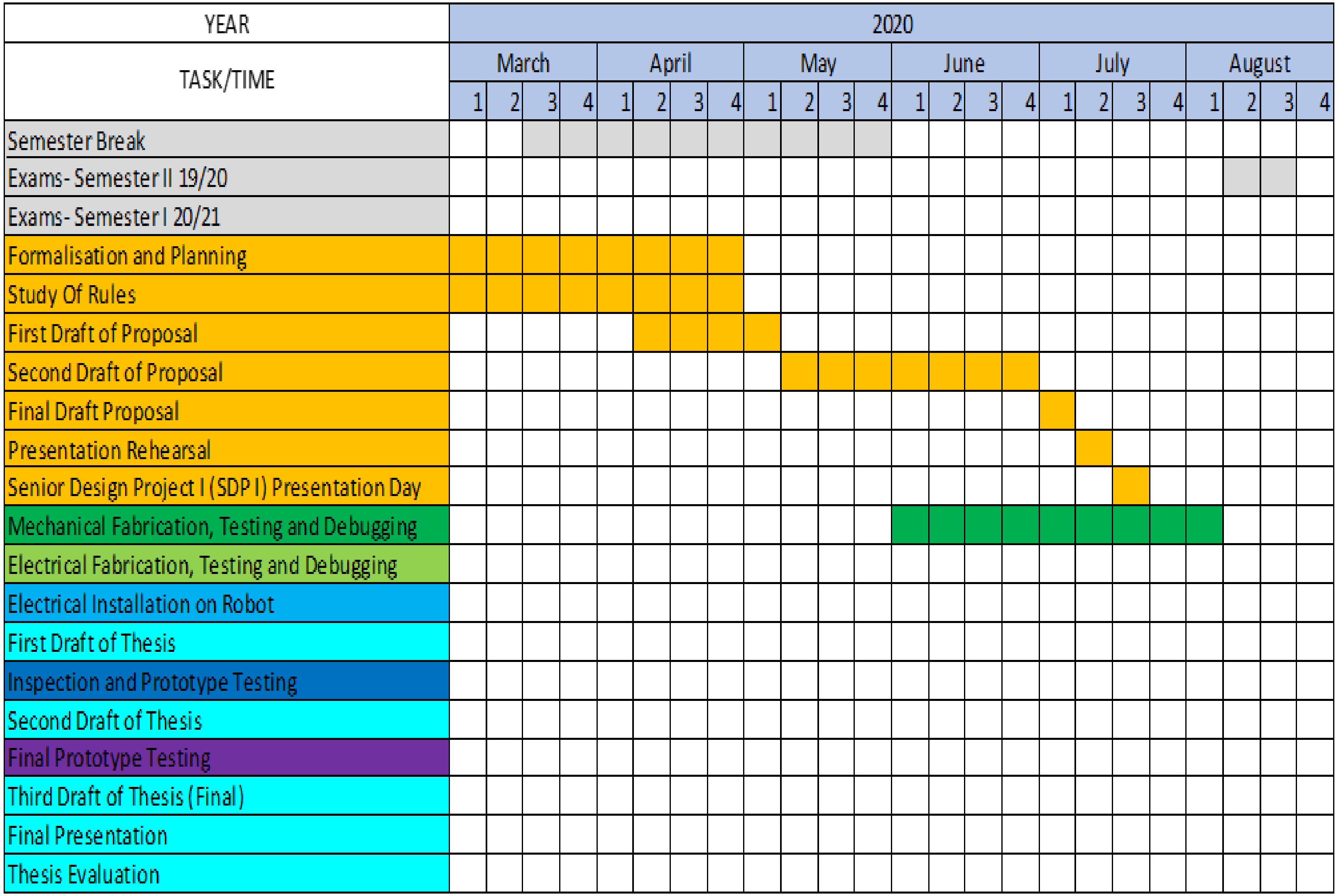
C2 Receiver coding

```
#include <SPI.h>       //masukkan library SPI, nRF menggunakan komunikasi SPI
#include <nRF24L01.h>  //masukkan library nRF24L01
#include <RF24.h>      //masukkan library RF24L
#include <Servo.h>

const uint64_t pipeIn  = 0x8888F6F6E1LL; //address/alamat unik ditentukan oleh
pengguna

RF24 radio(48, 49); //pin CE(9) & CSN(10)
//MOSI(11) , SCK(13) , MISO(12)

//Struktur Data-Array yang akan di transmit setiap cycle
//data dinamakan MyData
struct MyData {
 byte but1;     //BUTTON 1 STATUS
 byte potA;
 byte potB;
 byte potC;
 byte potD;
 byte potE;
 byte potF;
 byte potG;
};               // boleh hantar sehingga 32 byte data dalam satu cycle
penghnataran data

MyData data; //prefix "data" diletakkan kepada setiap individu-array dalam
MyData

//ROBOT SERVO
Servo servoA,servoB,servoC,servoD,servoE,servoF,servoG;

//CODING VARIABLES
byte But1;
byte srvA,srvB,srvC,srvD,srvE,srvF,srvG;

bool RobotEnable;

byte gripPos = 90;

void setup(){ //PERMULAAN VOID SETUP
 pinMode(49, OUTPUT); //SS PIN DECLARATION
 delay(100);

 //SERVO PINS
 servoA.attach(5); servoB.attach(7);
 servoC.attach(6); servoD.attach(3);
 servoE.attach(2); servoF.attach(4);
 servoG.attach(8);
```

```
    delay(100);

    //SERVO INITIAL POSITIONS
    servoA.write(90); servoB.write(90);
    servoC.write(90); servoD.write(130);
    servoE.write(80); servoF.write(90);
    servoG.write(90);

    delay(100);

    Serial.begin(9600);  //Serial untuk debug/check coding output

    delay(100);

    radio.begin();                   //memulakan radio nRF
    radio.openReadingPipe(1,pipeIn);
    radio.setPALevel(RF24_PA_HIGH );
    radio.setDataRate(RF24_250KBPS);
    radio.setChannel(115);
    radio.setAutoAck(false);

    delay(100);
    radio.startListening();
    //radio.openWritingPipe(pipeOut);  //set module nRF sebagai
transmitter(pipeOut)

    data.but1 = 0;                   //nilai permulaan variable untuk butang
bersamaan 0
    data.potA = 90;
    data.potB = 90;
    data.potC = 90;
    data.potD = 130;
    data.potE = 80;
    data.potF = 90;
    data.potG = 90;

    delay(300);
   } //PENUTUP VOID SETUP

   unsigned long lastRecvTime = 0; //declare variable  untuk check cycle time

   //PROGRAM UTAMA
   void loop(){ //permulaan void loop
    //RADIO RECEIVING ROUTINE
    RadioReceiving();

    //ROBOT CONTROL ROUTINE
    RobotControls();

    //DEBUG SERIAL
    checkserial();  //check data pada serial monitor adakah butang berfungsi
   }//END VOID LOOP

   void RobotControls(){
     //ENGAGE/ENABLE CONTROLS
     if(But1 == 99){
       RobotEnable = true;
     }
     if(But1 == 0){
       RobotEnable = false;
     }

     //ROBOT MANUAL CONTROL
     if(RobotEnable == true){
       servoA.write(srvA); servoB.write(srvB);
       servoC.write(srvC); servoD.write(srvD);
       servoE.write(srvE); servoF.write(srvF);
       servoG.write(srvG);
```

```
      //GRIPPER CONTROL
      if(srvG > 100){
        gripPos = gripPos + 1;
      }
      if(srvG < 80){
        gripPos = gripPos - 1;
      }
      gripPos = constrain(gripPos,80,142);
      servoG.write(gripPos);

    }


  }//END ROBOT CONTROLS

  void checkserial(){ //seria print untuk debug
   Serial.print("B1: ");  //serial print nilai butang
   Serial.print(But1);   //serial print nilai butang
   Serial.print(" A0: ");
   Serial.print(srvA);
   Serial.print(" A1: ");
   Serial.print(srvB);
   Serial.print(" A2: ");
   Serial.print(srvC);
   Serial.print(" A3: ");
   Serial.print(srvD);
   Serial.print(" A4: ");
   Serial.print(srvE);
   Serial.print(" A5: ");
   Serial.print(srvF);
   Serial.print(" A6: ");
   Serial.print(srvG);

   Serial.println();
  }//END CHECKSERIAL

  void RadioReceiving(){
    /***READ RADIO DATA***/
   while ( radio.available() ) {        //check jika ada sebarang input dari
Transmitter
     radio.read(&data, sizeof(MyData)); //read data dan susun dalam array MyData
     lastRecvTime = millis();           //declare permulaan masa data di-check
   }
  /***READ RADIO DATA COMPLETE***/

  /***FAIL-SAFE IF LOST TRANSMISSION***/
   unsigned long now = millis();        //masa selepas input diterima
   if ( now - lastRecvTime > 1000 ) {   //FAIL-SAFE jika masa melebihi 1 saat
     data.but1 = 0;                   //FAIL-SAFE data jika RF module tidak terima
data
     //data.potA = 90;
     //data.potB = 90;
     //data.potC = 90;
     //data.potD = 130;
     //data.potE = 60;
     //data.potF = 90;
   }                                    //data akan beri default value 0
  /***FAIL-SAFE IF LOST TRANSMISSION END***/

  //TRANSFER DATA TO VARIABLES
   But1 = data.but1;
   srvA = data.potA; srvB = data.potB;
   srvC = data.potC; srvD = data.potD;
   srvE = data.potE; srvF = data.potF;
   srvG = data.potG;

  }//END RADIO RECEIVING
```

Appendix D: Gantt Chart I



Appendix E: Gantt Chart II

YEAR	2020																2021							
TASK/TIME	September				October				November				December				January				February			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Semester Break																								
Exams- Semester II 19/20																								
Exams- Semester I 20/21																				■	■	■		
Formalisation and Planning																								
Study Of Rules																								
First Draft of Proposal																								
Second Draft of Proposal																								
Final Draft Proposal																								
Presentation Rehearsal																								
Senior Design Project I (SDP I) Presentation Day																								
Mechanical Fabrication, Testing and Debugging	■	■	■	■	■																			
Electrical Fabrication, Testing and Debugging	■	■	■	■	■	■	■	■	■															
Electrical Installation on Robot						■	■	■	■	■	■	■												
First Draft of Thesis	■	■	■	■	■	■	■	■	■	■	■	■												
Inspection and Prototype Testing													■	■	■									
Second Draft of Thesis													■	■	■	■								
Final Prototype Testing																	■							
Third Draft of Thesis (Final)																	■	■						
Final Presentation																			■					
Thesis Evaluation																				■				