Development of Mine Detection Robot with 4 Degree of Freedom Robotic Arm

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Abstract - *Robots have gradually been going out on a limb occupations which have been too difficult for people to do. Our exertion in this paper is to plan and build up a bomb transfer and disposal robot for the identification of bombs. The primary focal point of this work is to configure, build up a bomb identification robot with an automated arm with upgraded control. The automated arm outlined has 4 degrees of flexibility development remembering that it could accomplish a couple of basic undertakings, for example, light material handling. This will be coordinated into a versatile base/stage which will enable it to move it crosswise over separations without coordinate human cooperation to help lift protests and perform arm developments, the automated arm is furnished with servo engines accomplishing around 11kgcm of torque. The activities of the arm will be controlled by programming an ATMEGA – 328 microcontroller utilizing an open-source stage called Arduino. The contributions for the arm can be given utilizing potentiometers and the course of task can be controlled utilizing a parallax joystick. This framework is straightforward and normal sensors, for example, flex sensors, ultrasonic sensors are actualized.*

Key Words: Arduino, bomb disposal, Servo Motors, 4 DOF Robotic Arm

1. INTRODUCTION

Recent breakthroughs and developments in sensor, motor and control technologies have paved the way for new robotic models with much more enhanced functionality and dexterity. Today in the 21st century, robots have found themselves in almost all industries from manufacturing to transportation to material handling and even in defence to protect our borders from attacks where it is too dangerous or expensive to be taken up by humans. Many explosive devices have been found and have been detonated in public places causing harm and death to many. Hence, a robotic arm with the dexterity and ease of use similar to a human arm is in much requirement. This design and the concept of robotic control is a high challenge research work and have applications where automation and industrial robotics are required.

The current design is a safe way for disposing the explosive all while minimizing the risk of damage to life and property since the priority is given to protection of human life over anything else, including collateral damage. Since, the parts are made from common materials; any on spot repair is also possible. The core concept is to emphasize on creating a barrier to protect the bomb disposal squad by providing a safe distance to neutralize the bomb which would have been done manually if not for the robot. Providing the operator to manipulate a 4DOF robotic arm in order to inspect or defuse the bomb using the preferred end effector. As the robotic arm is placed on a mobile base, it reduces the time taken for the technician to detect the mine or bomb on the battlefield or the target thereby reducing the risks involved. The mobile base can be programmed to cover a particular area of land automatically. This is done by creating waypoints using Global Positioning System (GPS) co-ordinates. If in case of an event, the bomb cannot be diffused, the robot could still be used to transmit key information and trigger the mine or the IED and sacrifice itself else it can also be used in moving the mine or bomb downrange [1].

2. MECHANICAL DESIGN

The robotic arm consists of servo controlled rotary joints and links made from 4mm thick acrylic sheets. These together form kinematic pair which acts similar to the motions of a human arm. The links together form a kinematic chain. One end of the kinematic chain is attached to the base which provides support while the other end houses the end effector. The design of the end effector is job specific although a simple gripper can be used to perform majority of the tasks. End effectors such as clippers or pliers can be used to probe the mine or bomb. Each joint servo has a rotary range of 360° however all of this cannot be used due to limitations in the arm itself as there is a possibility of other links coming in the way of its movement.

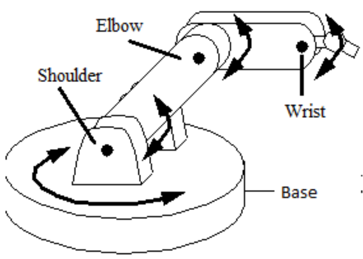

Fig – 1: Free body diagram of the robotic arm

The mechanical design for the robotic arm is based on the free body diagram of the robotic arm as shown in Figure 1. The gripper is not shown in this figure because the end effector is just a joint and therefore cannot be considered as a link. One of the features which classify a robot is its reach. A typical four degree of freedom (4 DOF) robotic arm workspace is shown in Figure 2. [3]. Four Degree of Freedom was specifically chosen it is enough to perform the necessary operations and movements all while keeping the costs and weight as minimal as possible.

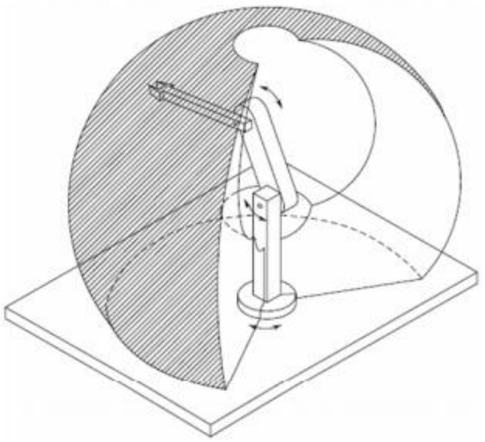

Fig -2: Work region of the robotic arm [3]

The robotic arm in this case is actuated using electric servo motors. The specifications of these motors were specially chosen to deliver maximum torque required for the structure which in the current case is made of acrylic to lift its own weight as well as the payload put together. Calculations for the maximum payload to be carried out were done considering the weight of the motor and the weight of the links together. Calculations were performed only for the links which undergo the largest loads keeping the weight of the motor to be about 55 grams. Figure 3 shows the force diagram used to calculate the torque acting on joint B.

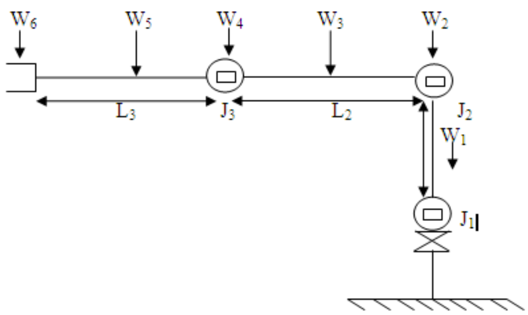

Fig – 3: Force Diagram of 4 DOF robotic arm

The values used for torque calculation are as follows:

W2 = W4 = 0.055 kg (weight of the motors)
W1 = 0.07 kg
W3 = 0.053 kg
W5 = 0.06 kg
W6 = payload
L1 = 200 mm
L2 = 150 mm
L3 = 50 mm

By performing the sum of forces in the Y axis, the loads can be calculated which then comes to around 12.224 kg-cm.

The obtained torque and keeping a small factor of safety, a maximum payload of around 600 grams was estimated to be manipulated by the robotic arm. Based on this value, Tower Pro MG-995 servo motor was selected. The servo motor has around 11 kg of torque and weighs around 55 grams which is shown in Figure 4. To completely handle the payload, two motors are used at J1 and J2. This is found to be much cheaper than using one servo to handle the entire torque.

Fig – 4: Tower Pro MG-995

Based on the dimensions of the servo motor shown in Figure 4, the basic dimensions of the arm were defined and design was carried out using CATIA. The design must take into consideration the thickness of acrylic sheet. The thickness of the acrylic sheet is 5 mm because it offers good strength as well as easy machinability. The acrylic sheets were cut using laser cutters because they offer good accuracy and least wastage. The resulting robotic arm is shown in Figure 5.

Fig – 5: 3-D Model of the robotic arm

2.1 Selection of the end-effector:

The end-effector is the most complex and important part of the robot. It is what defines the purpose and application of the robot. The end-effector might be complex or simple such as a gripper like in this case to manipulate objects. It can be hydraulic, pneumatic or electrically powered. The end effector used in this case is powered by a servo motor which drives a gripper with two fingers. Figure 6 shows the 3D model of the end effector used in the robotic arm.

Fig – 6: End effector powered by servo in the robotic arm

The end-effector is a basic two fingered gripper which is powered by a servo motor as shown in Figure 4. The servo motor is connected to one gripper which has a gear which is meshed with the gear present on the other gripper. Hence, moving one of the fingers will result in the equal movement of the other finger.

2.2 Design of the Mobile Base

There are many robots which have been built on locomotive base. Through recent developments in motor and control technologies, there have been a recent trend in making autonomous robots fixed on a mobile base. Such kind of robots can be used to transfers parts and finished goods from one part of the factory to another. They are also being used in industrial environments, military and security applications, handling of hazardous material, providing mobility to handicapped people and in planetary exploration [7]. In this case, it is being used to find and map areas to detect mines and Improvised Explosive Devices (IED's). It is also used to move the arm from the control center to the bomb site.

The mobile base used in this case is designed keeping the robotic arm in mind. The weight of the robot is considered in selecting the motor required to drive the mobile base. The design of the base should also consider the Centre of Gravity (C.G) of the arm and the mobile base. The entire arm should not collapse when it is extended with the payload hence the center of gravity of the base should be as low as possible in order to maintain stability. The rover is basically has a 4 wheel differential drive i.e. there are a motor on each wheel which are actuated differentially in order to control the direction of the movement. The motors used here are electric motors and must have enough torque to pull the base as well the robotic arm.

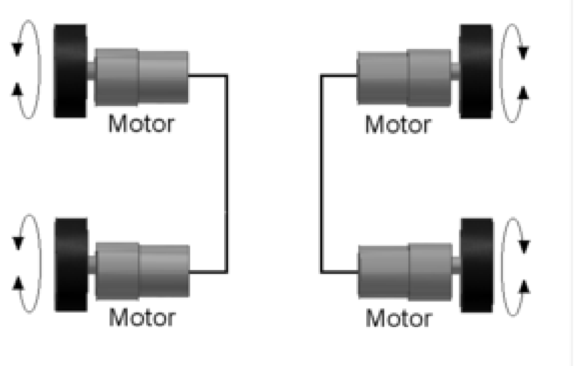

Fig – 7: Four wheel differential drive using electric motors

3 CONTROL SYSTEM DESIGN

Diagram showing the control scheme for the entire robotic arm and the mobile base is shown in figure 8.

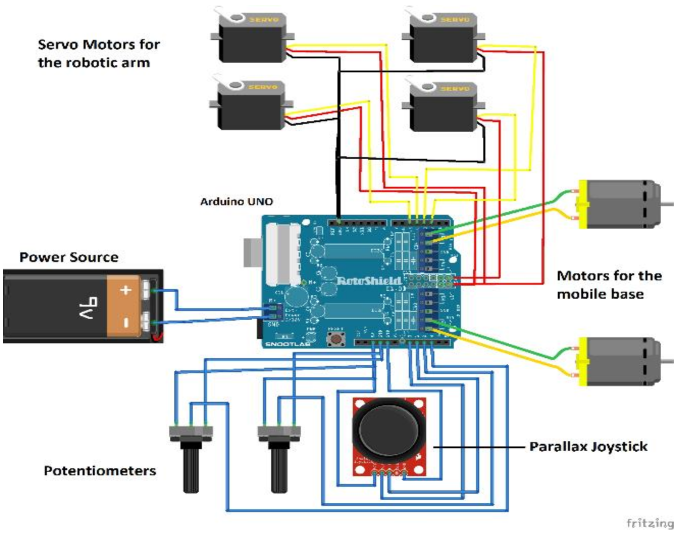

Fig – 8: Basic circuit diagram of the circuit with Arduino Uno and a motor shield

The main control unit consists of an Arduino Uno board which has an Atmega-328 microcontroller which receives the input from various sensors and input modules, processes them and provides the appropriate output. Arduino Uno was chosen for this robot because it is simple to use, easily available and an open source programming platform which is easily available. Mounted on top of the Arduino is a L293D motor shield which is used to differentially actuate each of the motors of the mobile base. The motor shield is driven by an external power supply of 9V and the motors are controlled by Pulse Width Modulation (PWM) ports present on the motor shield.

The Arduino receives its input through various input devices and sensors such as potentiometers, parallax joystick and flex sensors. The potentiometers are mounted on a jig which is then strapped to the user's arm. This enables the user to manipulate the robotic arm more naturally and with ease. The flex sensors is strapped to the finger which enables the user to control the end effector with high levels of dexterity. The various motions of the mobile platform is controlled by a single parallax joystick. Since, the mobile platform is based on the 4 wheel differential chassis it is able to quickly turnabout its axis with almost no radius of rotation. The mobile base along with the robotic arm is light enough to not trigger the mine when it runs over a personnel mine. This is important because at times, the mines are not easily detectable.

The robotic arm is mounted on top of the mobile platform. Due to the servos having 360° range of rotation, the arm can be placed compactly on top of the mobile platform. This reduces the overall size of the whole system enabling it to be extremely portable.

The mobile platform is attached with a mine detection system which consists of a tank circuit shown in Figure 9 which will trigger a piezoelectric buzzer upon any fluctuation in the induction coil. The induction coil is made of 22 gauge copper cable in a coil of 15cm diameter. It has the ability to detect any metal particles within a depth of 50 centimeters.

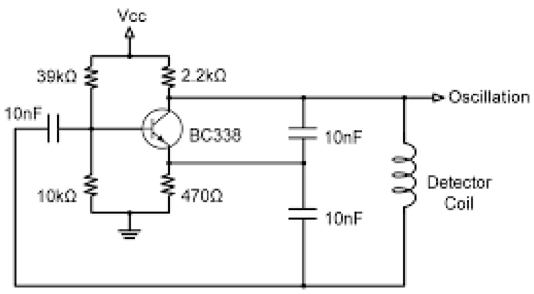

Fig – 9: Tank Circuit

3. CONCLUSIONS

In this paper, we present the design, development and implementation of various concepts such as mine detection, haptics, and manufacturing concepts. It can be shown how intelligent software and simple hardware can work in tandem in giving extraordinary results which can have various applications. However, this is not the end as new motor and sensor technologies are evolving everyday which will aid in further development of such machines which will aid in clearing up minefields. To further improve the robot, many additions can be made to it such as providing machine vision, artificial intelligence, stairs climbing capabilities, wireless video transmission etc.

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