Multi Directional Conductive Metal Detection Robot Control

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ABSTRACT
As technology is growing there is a considerable demand on machine interface to the controlling system. Robotics is an era where mechanical structures are powered by interfacing personal computers with the improved software tools. Hyperlink is a standalone program to interact with the devices remotely interfaced with the personal computers. Wireless communication is also a supporting mechanism to regulate the direction and movement of the robotic machines. This paper aims to direct the conductive metal finding robot in all eight directions. An IR sensor assembly is used to position the robot to move with defined angle. Concentric coil type metal detector is used to pinpoint the targeted metal. Offset Quadrature phase shift keyed modulation stream (OQPSK) with 2.4 G Hz is used for transmitting the information to the remote control section of the robot. The mechanical load calculations are estimated to design the robot. The developed model is best suited on uneven surfaces.

Keywords
IR Sensor, metal detector, Hyper link, OQPSK

1. INTRODUCTION
The rapid growth of technology is enabling the researchers to meet the challenges of the society. Considering the speed and Flexibility to the demands, especially the new innovation in the electronic era is totally dominating the requirements in association with the mechanical structures, the combination of mechanical structures and electronics is labeled as mechatronics. The mechanical components will be driven by the electronic circuits to fulfill the needs of the developer labeled as a robot which will be guided by an operator or independently i.e. Knowledge based.

Researchers proposed several methods to promote the metal detection robots (MDR) for identifying Strong and weak conductive metals. This paper discuss about the mechanical construction of the MDR and controlling through personal computer (PC). Five number of 100 rpm DC motors are used to traverse the MDR along the specified path. One DC motor is located at the center point to transmit the signals. An IR transmitter is equipped to the shaft of the center motor. Eight number of IR receivers are positioned based on the theoretical calculations of the angle finding mechanism. The IR Transmitter and IR receiver circuit will enable the direction and movement of the MDR. IR sensor is working based on IR Emitter and an IR receiver. When power is on, IR emitter emits the infrared rays continuously. The IR receiver will receive the emitted infrared rays. The IR transmitter and receiver are mounted side by side. The amount of IR signal hitting the receiver will be measured in terms of its output voltage of the receiver. The output voltage varies with the intensity of the signal outputted from emitter circuit. AT 89S52 microcontroller is used to read the output voltage of the IR receiver. The micro controller will enable the driving motors using L293D. Each receiver is positioned with a separation angle of 45 degrees. The IR Transmitter connected to the center motor will move with an angular velocity of 10.46 rad / sec. The angular velocity under no load is theoretically estimated. Receiver 1,2,3,4 is provided to move the MDR towards east, west, south, north directions. Receiver 9 is used to stop the MDR. North-east, south-east, south-west, and north-west direction movements of the MDR will be directed by using the receivers 5,6,7,8 respectively. The receivers will respond to the corresponding transmitted signal. If the emitter and any receiver will be in line of sight the corresponding receiver output signal will be fed as an input signal to the microcontroller. The microcontroller will enable the motor driving circuit to traverse the MDR accordingly.

a) Communication
The MDR was constructed in a square shape. Non corrosive rust free material is used to safe guard from hazardous and chemical environment. The four edges of the MDR is equipped with four 100 rpm DC motors. To fix the motion and its direction Heavy duty plastic gear assembly is used as shown in Fig.2.

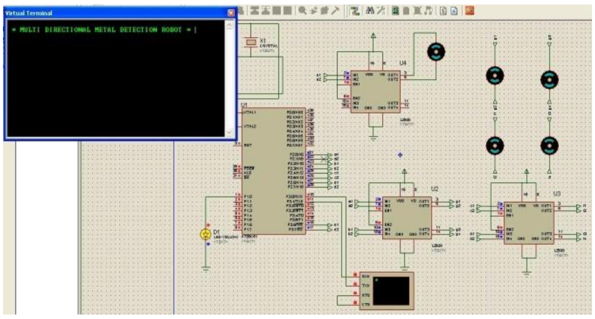

Fig . 1 Simulation Circuit diagram of the Receiver

The MDR is guided remotely using wireless communication. Between the metal detection robot control unit and the control room Low power short range communication is established.

IEEE 802.15.4. Offset Quadrature phase shift keyed modulation stream (OQPSK) with 2.4 G Hz is used for transmitting the information to the remote control section of the MDR. This paper also focused on controlling the robot remotely. The receiver circuit is equipped with the robot as shown in Fig.3 and Fig.4. The transmitter is interfaced to the Personal computer using recommended standard (RS) 232-E serial communication device. The hyper terminal of the personal computer is linked to transmitter.

b) Hyper terminal
Hyper Terminal is a program that record the messages passed to and from computer to the receiving circuit. Hyper terminal executes a program for the device that connects via serial port. The Commands can be sent to the MDR directly via hyper terminal. The hyper terminal is configured with baud rate of

9600, character bits are '8' and stop bits are appended at the end of character bits are '1'. Terminal emulation is 'Ansi', Local Echo is turned to off state. The commands send to the MDR directly via hyper terminal. The receiver control receives each command and executes it. The status of the execution will be resend to the hyper terminal as a command 'X' for successful execution and a command 'E' for an error.

c) Metal detector

Round shaped concentric coil is used for metal detection. Electromagnetic Induction Principle is adopted by applying the pulsing current to the coil which induces an electromagnetic field. The magnetic field of the coil is used to detect the metal objects. When any metal object is in the field of the coil an electric current i.e. eddy current is influenced on the metal. This eddy current causes to develop its own magnetic field and generates an opposite current in the coil. The metal detector constitutes of a transmitter and a receiver coils. A transmitter coil i.e. labeled as search head. The operating frequency of the search head depends on the electric current flows in that coil is reversed several time every second. In contrast the current flows from clockwise to anti clockwise and back to clockwise again. Any metallic object is sensed the changing magnetic field will induce the current inside the metal. This induced current produces its own magnetic field with polarity opposite to the transmit field.

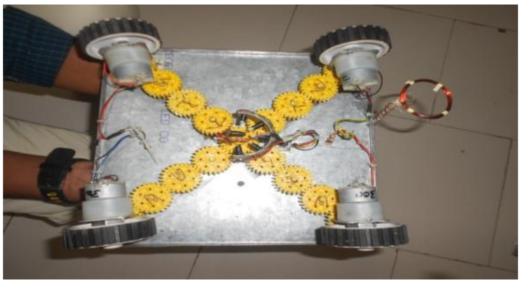

Fig.2 Gear assembly of MDR (Bottom View)

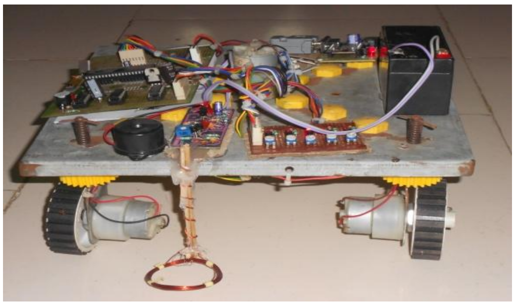

Fig.3 MDR Structural front view

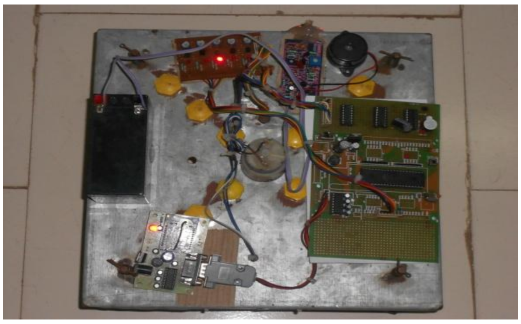

Fig.4 Top view of the MDR

In the Fig. 3, '1' represents concentric coil type metal detector. '2' represents controlling unit.

At the receiver coil the influenced current by the transmitter is cancelled. The currents flow in the receiver coil due to metal objects will be amplified and processed. The resulting signal at the receiver coil is having phase shift with the transmitted coil. The kind of metal is identified based on the phase shift. Gold, Silver and copper are excellent conductors. Large phase shift occur for such kind of metals. Small phase shift occur for less conductive and thinner objects. In this paper the metals used for testing are iron metals. Low frequency will have longer wavelength. Longer waves can lead to getting greater penetration depth.

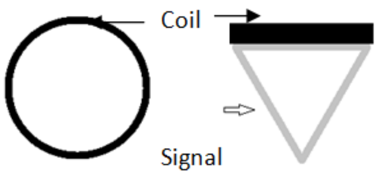

Fig.5 Concentric coil metal detector view

The concentric coils used in the MDR transmit a cone shaped signal. The signal is at the center of the coil hence pinpointing is easy. In this paper the swing of the signal is allowed to overlap in order to enhance the finding metal depth. Pinpointing is more difficult with double 'D' coil even with the elliptical coil.

d) Angle finding method

The Robot was designed to detect the metal objects. The motion of the robot is controlled by using the hyper terminal of the Personal computer. The robot was designed to traverse in eight directions. The angle of its motion is determined based on horizontal reference points i.e. control points. A control survey was carried out to position the control points. The direction of the signal between two points is labeled as bearing. The whole circle bearing of a line in clockwise direction is in the range of 0 to 360^0.

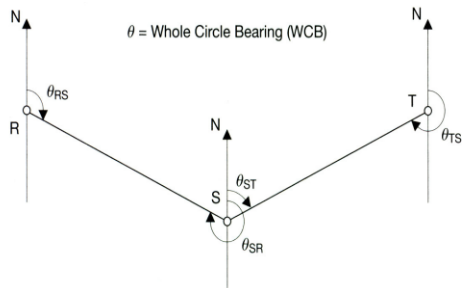

Fig.6 The whole circle bearing

The traverse directions are determined by considering the transmitter located at the center position of the robot. The receiver positions are determined using the whole circle bearing geometrical procedure.

If the line direction is between the points A and B then

The Horizontal distance between A and B (DAB)

$DAB = \sqrt{\Delta E^2 + \Delta N^2}$

ΔE = Easting difference between AB

ΔN = Northing difference between AB.

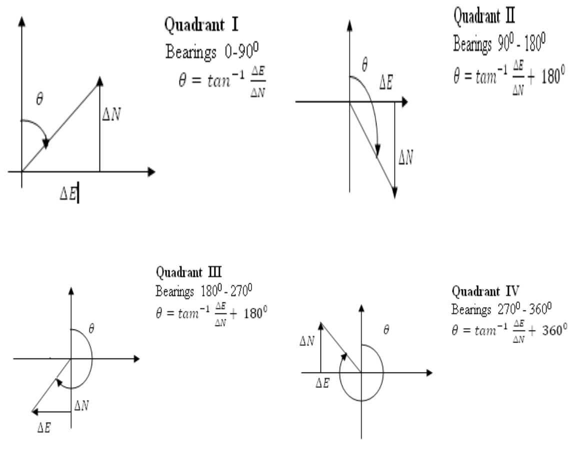

Fig .7 An approach to find the angle for diagonal traverse of the robot.

Quadrant '1', Quadrant '2', Quadrant '3' and Quadrant '4'is used to determine the angle of movement for north- east (NE), south – east (SE), south –west (SW) ,north – west (NW) direction respectively.

2. LITERATURE SURVEY

This paper describes designing and working of a system which is useful in areas concerning security, surveillance etc. This project uses AT89S52 MCU as a controller and an induction type metal detector is used in this robot. The system designed in this paper inputs hand gestures to the system through an electronic sensor glove and it identifies the gesture patterns via microcontroller network. Based on the movement of the hand the robot is positioned to move either forward, backward, left or right directions [1]. The paper [2] proposed a method to dynamically adjust the angle of the peripheral rollers to a large extent. In this paper dual tone multi frequency signaling (DTMF) is adopted. The cellular mobile phone is used as a handheld controlling device to monitor several physical parameters [3]. This paper evaluates the critical objective points and its validity from the on sight tests underwent by gryphon in Croatia and combodia in order to realize a practical humanitarian demining robot [4]. This paper proposes the design of a fuzzy logic based controller for mine detecting robot remotely. The designed controller has two loops with an Outer Fuzzy Speed Control Loop and an Inner Current Control Loop. The software for both the client system and the robot is developed using Data socket protocol in Lab VIEW [5].

An autonomous aria robot is designed to detect the barriers and landmines. Multiple sensors are used like digital compass, optical encoder, current sensor and range finding sensor, IR Sensor and Mine Detection sensor. Wireless communication is established between the robot control unit and the remote control unit. AVR microcontroller is used as local controller and Personal computer is used as a central controller [6]. The developed robot is intended for military application which is powered with Gigbee wireless communication. For front panel of robot the author used national instruments Lab View software. Pic16F877A microcontroller is used as a local controller to guide the robot movements. A software tool (VEX) used as a knowledge based guide for the robot to respond to the situations. Ultrasonic range finding sensor and metal detection robot is equipped with the robot. The obstacle detection and removing from the path is the prime responsibility of the developed robot [8]. A robot is designed to move on rough terrains with the support of four crawlers and hydraulic motors arranged to rotate in synchronously. 2-Link arm SCARA type horizontal and 6 degree freedom vertical multi joints are installed in the robot as robot sensor arm for mine detection [9]. Autonomous navigation of a robotic metal detector is designed by adopting the obstacle avoidance algorithm. An array of IR detectors is used to control the robot. 16F84A microcontroller is used as a local controller to the robot in order to determine the directions [10].

3. DRIVING MOTOR LOAD CALCULATIONS

For stable position of the MDR the required spinning force (Torque) of the motor is estimated. More torque is required for the MDR to move on uneven surfaces. Hence it exerts more force on the rotor body to enhance the acceleration. The torque required to drive the MDR is proportional to the weight. More torque is required to drive on inclined surfaces. The total weight of the MDR body is 41.1879 Newton. And the shaft length is 0.03 meters.

Torque required = Force * distance

= 41.187930120288 * 0.03

= **1.2356 Newton meter**

The Mechanical power is also the significant factor to consider. The power required for the MDR limits the speed of movement on the inclined surfaces. More power output may cause to drive the rotor smoothly. The power [watts] = Force [Newton] * Velocity [Meter / second]

Required power = 41.187930120288 * 0.125 =5.14849 watts

For MDR Body Linear motion

The power [watts] = Force [Newton] * velocity [Meter/ Second]

The estimated required power = 41.187930 * 0.125 = **5.1484 watts.**

For angular motion of the motor shaft

The angular velocity of motor under no load is 100 RPM.

The calculation of power is the product of torque and the rotational distance per unit time.

P_{rot} = M* W

Where

P_{rot} = Rotational mechanical power

M= Torque

W= Angular velocity

Angular velocity $W_{rad/sec}$ = 100 * [2*Π / 60] = **10.46 rad / sec**

Power required to drive a torque load of **1.2356** Newton / meter

= Torque Load* 100 rpm * conversion factor

= **1.2356** *100 * 0.1047= **12.9367 Watts**

Rotational mechanical power P rot =**12.9367 Watts**

Output shaft torque M = 1.2356

Motor current estimated (I) = M /K

Where K is torque constant = **1.22 NM/A**

The resistance (R) of the motor **= 3.3 Ohms**

Drive voltage U = R*I + K* W

Where w is Angular velocity

Motor current I = 0.57 A

Estimated Drive Voltage = 14.64 V dc

Rated voltage = 15 V dc

4. METHODOLOGY

A command outputted from the hyper terminal will be transmitted to the receiver at the robot. This signal will be processed using the Micro controller (AT 89S52) causes to drive the center motor in order to emit the infrared rays to the corresponding receiver. The output voltage of the receiver will be the input signal to the microcontroller. Then the micro controller will enable the motor driving circuit to transverse in the required direction. The metal detector keeps on emitting the electromagnetic waves to detect the conductive metal. If these waves hits any targeted metal the metal itself will induce their own electromagnetic field due to the induced eddy current and reflects back to the IR transmitter. The phase shift between the transmitted signal and the received signal will be processed to determine the type of metal it is.

5. ALGORITHM

Step1: Initialize ports '0_0', '0_1', '0_5' and '0_6' for MDR driving motors

Step2: Initialize port '0_7' for Buzzer

Step3: Initialize Port 3_0 for IR Transmitter

Step4: Initialize port 1_0 to Port 1_7 for IR receivers

Step5: Initialize port'1_0' for metal sensor

Step6: initialize the port 1_1 for Receiver

Step7: Read the receiver port

If a command is received from the transmitter

Then

Go to step 8

Else repeat the step 7

Step8: Evaluate the received command

If forward command

Then enable the IR receiver 1

Display the Direction Angle

Else

If backward command

Then enable the IR receiver 2

Display the Direction Angle

Else

If south Command

Then enable the IR sensor 3

Display the Direction Angle

Else

If North Command

Then enable the IR sensor 4

Display the Direction Angle

Else

If North-east command

Then Enable IR Sensor 5

Display the Direction Angle

Else

If South –East command

Then enable the IR Sensor 6

Display the Direction Angle

Else

If South-West command

Then enable the IR sensor 7

Display the Direction Angle

Else

If North-west Command

Then Enable the IR Sensor 8

Display the Direction Angle

Else

If Stop

Then enable the IR sensor 9

Else go to step 9

Step9: Enable the Motor driver assembly

Step10: Turn the motor shaft angle based on step 8

Step11: Release the driving load to the motors.

Step12: If No errors

Send a command 'X' to the hyper terminal

Else

Send a command 'E' to the hyper terminal

Step13: Read the port 1 of the metal detector

Step14: Evaluate the phase shift

Step15: If the phase shift is small

Then display the metal is weak conductive material.

Else

Strong conductive material

Step 16: Stop

6. RESULTS AND DISCUSSION

The experiments were conducted with the developed metal detection robot. The MDR is tested in all the possible directions to move. The velocity of the MDR is tabulated in table.1. We achieved constant velocity in diagonal movement of the MDR. Considering four 100rpm D.C motors is favorable to maintain the stable velocity. Fig.12, Fig.13, fig.14 Shows the traversing direction of the MDR. The black arrow represents the east, west, south and north direction. The pink arrow represents diagonal movement such as north – east etc. The metal detector is tested with Iron and Gold. Fig 10 and Fig. 11.represensts the 180^0 and 120^0 phase shifts. Large phase shift observed for extremely good conductor t and small phase shift for poor conductor. Hence the results show considerable readings to identify the conductive metals with MDR. The state of direction of the MDR is to be monitored on hyper terminal as shown in fig.8 and fig.9. Considering the results the developed MDR is more suitable for detecting the conductive metals at no man lands.

Table.1 Comparison metrics Mean values

Environ ment	East (Sec)	West (Sec)	NE (Sec)	NW (Sec)	Velocit y M/Sec
Smooth surface	8	8	8	8	0.125

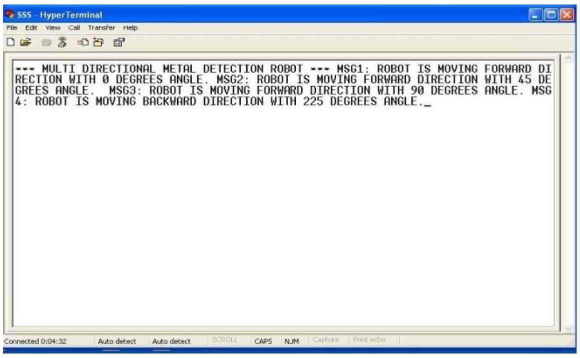

Fig. 8 Messeges at the Hyper terminal

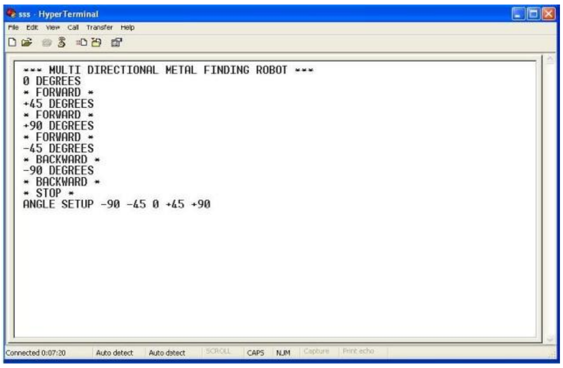

Fig. 9 Messages at hyper terminal

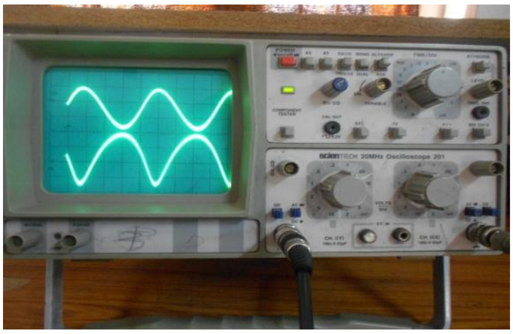

Fig. 10 180^0 phase shift between emitter and receiver of the metal detection sensor

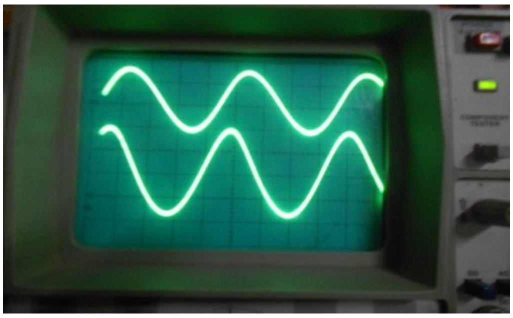

Fig.11 120^0 phase shift between emitter and receiver of the metal detection sensor

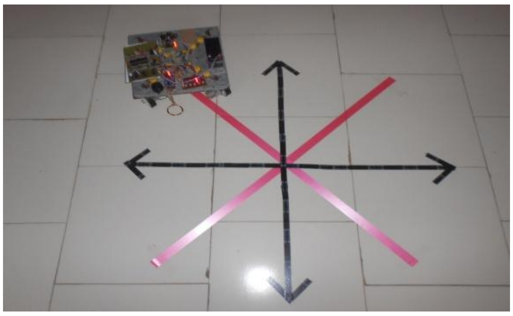

Fig. 12 MDR Moving in the North-West Direction

Fig. 13 MDR moving in the west direction

Fig.14 MDR moving in the south direction

Fig.15 MDR Moving in the South-west direction

7. CONCLUSION

The developed eight directional metal detection robot exhibits satisfactory results. This model is best suited for finding the conductive metals like gold, silver, nickel, iron at risky locations. This Metal detection robot is best suited on uneven surfaces. The intensity of the emitted electromagnetic rays can detect the conductive material limited to closer objects. The emitted electromagnetic waves intensity also needs to be improved.

In future the developed model is powered with knowledge based system. So that classification of the metals can be accurately determined. The developed working model also needs to be powered with collision avoidance mechanism in order to safeguard the MDR from the unauthorized vehicles and objects in opposite direction.

8. ACKNOWLEDGEMENT

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