Sudan University of Science & Technology
College of Engineering
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Landmines Detection Robot

كاشف الألغام الأرضية

A Project Submitted In Partial Fulfillment for the Requirements of the Degree of B.Sc. (Honor) In Electrical Engineering

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الآيــة

بسم الله الرحيم الرحيم

﴿ قَالَ يَا قَوْمِ أَرَأَيْتُمْ إِنْ كُنْتُ عَلَىٰ بَيِّنَةٍ مِنْ رَبِّي وَرَزَقَنِي مِنْهُ رِزْقًا حَسَنًا وَمَا أُرِيدُ أَنْ أُخَالِفَكُمْ إِلَىٰ مَا أَنْهَاكُمْ عَنْهُ إِنْ أُرِيدُ إِلَّا الْإِصْلَاحَ مَا اسْتَطَعْتُ وَمَا تَوْفِيقِي إِلَّا بِاللَّهِ عَلَيْهِ تَوَكَّلْتُ وَإِلَيْهِ أُنِيبُ ﴾

سورة هود الآية (88) .

DEDICATION

To ..

human teacher and imam of the messenger, prophet Mohamed (peace be him)

To ..

mine's victims, those poor souls who left us.

To ..

the great persons, who is still working to protect innocent people from this danger.

To ..

those who have hearts whiter than their chalks, and they have become like a candle which burning to illuminate the paths of others.

To ..

our colleagues who have suffered hardships and partied the nights in order to gain knowledge and science.

To ..

our mother, the orchard of love and the nectar of compassion.

To ..

our father, the icon of kindness and the hand of tenderness.

To .. the pure spirit of our colleague Mohammed Abu albashar .

Dedicate this humble efforts . . .

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We would also like to thank all people who provided us help and facilities .

ABSTRACT

The purpose of the design of the detection mines robot is to maintain human life in the first place, speed up the detection process, increase the accuracy and reliability of the results and reduce the total cost of removing the mines. To reach that, the number of research on this subject dramatically, featured many modern theories, with the development of the previous applications, this continuation of previous efforts to develop metal detector, by introducing the vapor sensor to practical reality.

These sensors have shown high efficiency to detect mines in the initial experiments.

مستخلص

الغاية من تصميم روبوت للكشف عن الالغام هي المحافظة على حياة الإنسان في المقام الأول، تسريع عملية الكشف، زيادة دقة وإعتمادية النتائج وتقليل التكلفة الإجمالية لإزالة الألغام.

لبلوغ تلك الغاية زاد عدد البحوث في هذا المجال بصورة كبيرة وظهرت العديد من الطرق النظرية الحديثة مع تطوير الطرق التطبيقية السابقة. وهذه مواصلة للمجهودات السابقة لتطوير محساسات كشف المعادن المكونة للألغام مع إبراز محساسات الروائح للواقع العملي وادراجها في انظمة كشف الألغام.

وقد اظهرت هذه المحساسات فعالية عالية للكشف عن الألغام في التجارب المبدئية.

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LIST OF ABBREVIATIONS

IED	Improvised explosive devices
ICBL	International campaign to ban landmines
ERW	Explosive remnants of war
VOIED	Victim operated IED
AP	Anti-personal
AV	Anti-vehicle
TNT	Trinitrotoluene
RDX	Cyclotrimethylentrinitramine
MRI	Magnetic resonance imaging
NQR	Nuclear quadrupole resonance
GPR	Ground penetrating radar
LMC	Low metal content
RC	Radio control
AFHDS	Automatic frequency hopping digital system
RF	Radio frequency
PWM	Pulse width modulation
FTDI	Future Technology Devices International
USB	Universal Serial Bus
PCB	Printed circuit board
I/O	Input / output
SRAM	Static random-access memory
EEPROM	Electrically erasable programmable read-only memory
MCU	Microprocessor unit
LED	Light emitted diode
IC	Integrated circuit
EN	Enable
SnO2	Tin dioxide
Au	Gold
Pt	Platinum
Al203	Aluminium oxide
PPM	Part per million
AC	Alternator current
DC	Direct current
PI	Pulse induction

LIST OF SYMBOLS

VH	Heater voltage , V
VC	Test voltage , V
VRL	voltage on load resistance
Rs	Resistance of sensor
Ps	Power of sensitivity
Ro	Resistance ratio of the sensor

CHAPTER ONE

INTRODUCTION

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INTRODUCTION

1.1 Background

Explosive land mines were first used in the middle of the thirteenth century by the Chinese during the Song dynasty against an assault of the Mongols, who were besieging a city in southern China. Today there are an estimated 110 million anti-personnel mines in the ground around the world and another 100 million in stockpiles. Between 5 and 10 million more mines are produced each year.

Unlike other weapons of war, landmines and unexploded ordnance are unique in that their destructiveness is indiscriminate, and long outlasts the conflicts for which they were used. They endanger generation after generation of civilians. The years after the battle is fought and over, landmines remain hidden in fields, forests, roads and footpaths until someone treads unknowingly and triggers a deadly explosion.

1.2 Problem statement

Landmines have been a major humanitarian problem around the world for two reasons:

- First, their persistence. Mines are the only conventional weapons which, when functioning as designed, are lethal for a period of time after activation. This is their military purpose: to hinder or influence adversary movement or maneuver for a period of time. But if their lethality persists after the combat has ended, they become not military assets but humanitarian liabilities. Most landmine types in use around the world remain lethal for an indefinite period of time.

- Second, many have been hard to detect because of their nonmetallic or low-metallic construction. The primary tool for mine detection has long been a metal detector similar to that used by beachcombers. If a mine is made with less than about 8 grams of iron or the equivalent, it is magnetically indistinguishable from the soil in which it is emplaced and so is not detectable by these devices. Non-detectability immensely compounds the post-combat landmine hazard to civilians, and it renders mine clearance far more expensive, time-consuming, and dangerous.

After more than 20 years of civil war, Sudan is one of the most heavily mined countries in the world, according to the International campaign to ban landmines (ICBL). 10 out of the 17 Sudanese states are contaminated, with the regions of Blue Nile, South Kordofan and eastern Sudan having the highest concentration of explosive remnants of war (ERW).

1.3 Objectives

The research want to give a technology that must satisfy all of the following criteria to improve humanitarian demining

- Help accelerate the demining process.
- Be as safe or safer than existing technology and approaches Alternatives for Landmine Detection.
- Be practical to use and easy to repair and maintain.
- Be affordable.
- Enhance overall cost efficiency of demining.
- Not be too complicated for use by deminers.

1.4 Methodology

In the field of mine detection in spite of the development in various spheres of life and the emergence of new technologies, but the detection methods remain traditional and sometimes unsafe. But through this research we introduced one laboratory detection methods into practice, in addition to one of the traditional methods. Search also takes into consideration not to endanger the experts at risk during the detection process, by using a long-range robot

1.5 Project outlines

This research consists of an abstract and five chapters, Chapter one represent the introduction that contents of background, research problem, research objective and research methodology.

Chapter two is represent the types, parts and uses of landmines, in addition to the explosion theories and the explosive materials.

Chapter three discusses the innovative mines detection system.

Chapter four represent the system operation that contents of components, robot description, action steps, working principle and system diagram.

Chapter five is represent the conclusion and recommendations.

CHAPTER TWO

LAND MINES

CHAPTER TWO

LAND MINES

2.1 Introduction

A landmine is an explosive device designed to destroy or damage vehicles, or to wound, kill or otherwise restrict people's activities. Mines can be victim activated, that is, detonated by the action of their target by being stepped on or struck or can be triggered by direct pressure, tripwires, tilt rods, command detonation, or by some combination of these methods. They can also be booby trapped by using, for example, anti-handling devices, to make their removal more difficult. They may also detonate with the passage of time.

Landmines are almost always hidden and camouflaged to match their surroundings, making them seldom seen and difficult to locate. They are usually buried or hidden in grass or buildings, fixed on stakes or to trees. During conventional warfare, landmines are usually laid in patterns to create consistent barriers, or along roads and around strategic points. In the case of new minefields, locations have to be recorded on maps2, but this is not always reliable.

2.2 Parts of a Landmine

- Belleville Spring - a doughnut shaped piece of steel that cushions heavy loads.
- Firing pin - part of mine that sets off the other components of the mine. Is made of metal, forced down into the detonator.
- Detonator - ignites a large amount of explosives by first lighting a smaller amount.

- Fuse - material that is combustible used to ignite an explosive charge.
- Igniter - metal rod (in bounding mines) that sticks out of the ground and triggers the mine when it is pushed down. It is sometimes called the striker.
- Main Charge - the large amount of explosive material in the mine which causes it to explode.
- Pressure Plate - metal disc on the very top of the mine that is stepped on or driven over, causing the detonation of the mine.
- Projectiles - things (often metal balls or shards of glass) placed into the mine to increase the victim’s injuries. Sometimes the mine's exploded case can become a projectile.
- Propelling Charge - a small amount of explosive material that propels it into the air. (Placed at the bottom of a bounding mine).
- Safety Pin/Clip - a small pin that is placed in the mine to prevent it from being activated while not in use.

Figure (2.1) represents the parts of landmines .

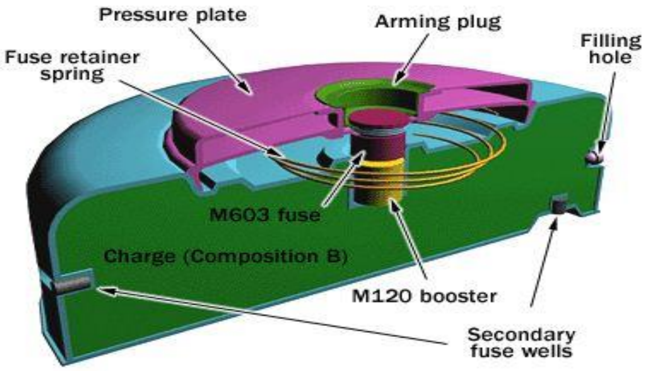

Figure 2.1: Parts of a Landmine

2.3 Theories explosion

- Stress fracture theory Pin.
- Ball control theory.
- The chemical reaction theory.
- The chemical reaction electrical theory.
- Electrical Contact theory.
- Friction theory.
- The gravity theory.
- Other theories (vibration,impact magnetic,electromagnetic,audio waves).

2.4 Uses of landmines

Mines are used as defensive weapons: they provide protection for important military positions or hinder the movement of troops by causing casualties to an enemy and destroying equipment. They are also used offensively: in particular during conflicts they are used to destroy or damage infrastructure and cause terror by denying civilian populations access to their homes, agricultural land, water, roads, schools, health care facilities and other resources. Landmines are often used as parts of an IED. The explosives of a landmine could be used for the main charge or the landmine itself as a trigger for a Victim Operated IED (VOIED)[2].

2.5 Types of landmines

There are currently more than 600 different types of landmines, as well as many improvised mines made by military (opposite) forces engaged in fighting. They are grouped into two broad categories: Anti-Personnel (AP) mines and Anti-Vehicle (AV) mines, also commonly referred to as Anti-Tank mines.

Figure (2.2) represents the types of landmines.

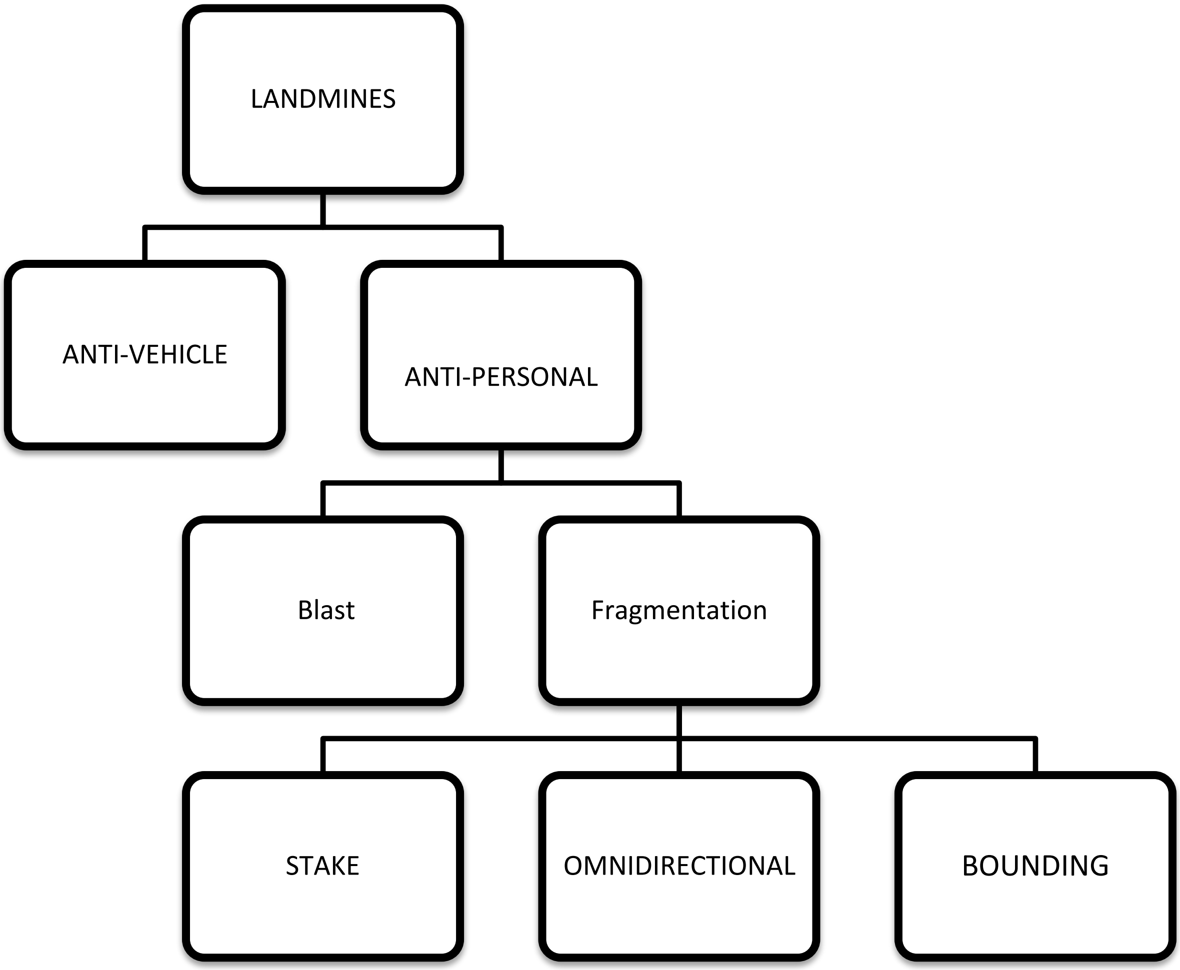

Figure 2.2: landmines types

2.5.1 Anti Personal Landmines (AP)

An Anti-personnel (AP) landmine is designed to be detonated by the presence, proximity or contact of a person, and is intended to incapacitate, injure or kill one or more people. AP mines are usually detonated when they are stepped on or when a tripwire is touched, but they can also be set off by the passage of time or by controlled means.

AP mines can be found on the ground, buried or fixed above ground and are generally small devices that come in many different shapes. Often, they are camouflaged to help them blend into the surroundings and can be fabricated of wood, plastic or metal. Areas suspected of containing AP mines should be avoided.

Once triggered, AP mines cause death or serious injury by an explosive blast and/or flying fragments. They are grouped according to the manner in which they inflict injury: blast, fragmentation or a small shape charge.

– Blast anti-personnel landmines

Blast AP mines are often very cheap and are among the most commonly found in the world. They are designed to be triggered by the pressure caused by physical contact with the mine, mostly by stepping on them. Most mines of this type are designed to cause serious injury, usually the amputation of one or more limbs, rather than death.

Blast AP mines are generally cylindrical in shape, and range in size from 7 to 16 cm in diameter and 5 to 10 cm in height. However, some blast AP mines are rectangular or “shoe box”–shaped. They then range in size from 10 cm x 18 cm to 15 cm x 30 cm. Most AP mines have a relatively small explosive charge, often less than 100 grams. The concentrated blast of the charge is what causes death or injury. Figures (2.3 & 2.4) represents planted and unplanted AP mines .

Figure 2.3: unplanted metal blast AP mines

Figure 2.4: metal blast AP mine planted in the ground.

While some blast AP mines are still made of metal or wood, most are manufactured of plastic. This makes them water resistant or waterproof, and dangerous even when submerged. Following heavy rains, it is not uncommon for some mines to wash out of minefields into previously mine-free areas, or into waterways where they can be swept kilometers downstream before washing ashore. Blast AP mines are usually tan, olive, green, black, brown, grey, or a combination of colors.

In addition to buried Blast AP mines, a common type of mine is the “butterfly” mine (or similar variants), which are scattered over the ground by aircraft or artillery fire. If recently delivered, these mines are usually found lying around in large numbers. Even after months or years, single mines may still be found in cleared areas. Butterfly mines have a combination of odd shapes and often bright colors that can make them unique and attractive to curious children and adults. Figures (2.5 & 2.6) represents plastic and wood AP mines respectively .

Figure 2.5: plastic blast AP mine.

Figure 2.6: wood blast AP mines.

- **Fragmentation AP mines**

Fragmentation Anti-personnel mines are typically designed to cause death, often to a large number of people, from fragments propelled by the mine’s explosive charge. Most of these mines have metal casings, or contain ball bearings or metal fragments that are turned into lethal projectiles by the detonation of the mine.

There are three basic types of fragmentation AP mines: stake mines, directional fragmentation mines and bounding fragmentation mines..

Stake AP mines

The most commonly found fragmentation AP mines are stake mines, which are designed to fit on wooden or metal stakes hammered into the ground until the mine is resting about 20 cm above the surface. They are also fixed to trees. Most look like a small club: a wooden stake, topped by a small metal cylinder and detonator projecting out of the top. They are often painted green, or they may be unpainted wood and metal. Rusty metal surfaces make it easy to overlook the mines, especially in areas with old vegetation.

Stake mines are fitted with one or more tripwires that set the mine off when pulled or cut. Tripwires are very hard to see, and may be strung across paths or doorways, and attached to a solid object such as a tree or to another mine.

Once set off, metal fragments are projected in a 360-degree radius, causing lethal injury to anyone within an unobstructed 4 meter radius and causing death and serious injury to people at much greater distances. One common mine – the Russian POMZ-2M – detonates and shatters to create fragments that are likely to be lethal within a 10 meter radius. Beyond this, the uneven size and distribution of the fragments makes the effect unpredictable; large fragments may injure or kill at a range of 100 meters or more.

Over time stake mines may fall over, or the stake on which they rest may disintegrate. This does not make them less dangerous, and in some cases, when the tripwire is less visible, makes them more dangerous. Figure (2.7) represents stake AP mine.

Figure 2.7: Stake AP mine.

Omni directional Fragmentation AP mines

Omni directional (or “Claymore” type) fragmentation anti-personnel mines are designed to project a dense pattern of fragments in a specified direction. Most look like a curved rectangular or round box about the thickness of a paperback book. This box sits on two sets of legs or a stand, and is generally colored olive, black or brown.

Directional Fragmentation AP mines are usually command detonated, but they can also be initiated by tripwire or pressure-plates. Once detonated, most mines of this type project their fragments within a 60-degree horizontal arc and to a height of about 2 meters. Most are designed to have an “effective range”, causing serious injury or death of around more than 50 meters.

Other versions of these mines are large and circular in shape and project shrapnel in a narrow cone, like a shotgun. They are capable of killing people, as well as disabling or destroying passenger soft-skinned vehicles. Figure (2.8) represents omni directional AP mines.

Figure 2.8: omni-directional AP mine “Claymore”.

Bounding Fragmentation AP mines

Bounding mines are normally buried and often linked to tripwires. Most bounding mines are cylindrical in shape, with a single tubular fuse or a number of prongs sticking out from the top. They are typically around 10 cm in diameter and 28 cm in height. Bounding mines are usually tan, olive green, black, brown, and green, or are left unpainted. After a couple of years the metal surface looks rusty so that the mines are hard to see.

Bounding AP mines are generally triggered by tripwires or direct pressure. Once triggered, an initial explosion lifts the mine out of the ground to about waist height before the main charge detonates. Upon detonation, the explosion shoots out metal fragments in a 360-degree horizontal radius. Design variations mean that the number, size and distribution of fragments vary widely, but a typical bounding mine is likely to be lethal within 25 meters and capable of inflicting serious injury at ranges up to 100 meters. Figure (2.9) represents bounding AP mine.

Figure 2.9: Bounding AP mine

2.5.2 Anti-Vehicle Landmines (AV)

Anti-Vehicle (AV) mines, often referred to as Anti-Tank mines, are designed to disable or destroy vehicles. Like Anti-Personnel mines, Anti-Vehicle mines can be detonated by pressure, though normally much greater weight is needed, by remote control, by magnetic influence or through the disturbance of a tilt rod (a sort of vertical tripwire). A Glass-Fiber-Cable, laid on the road, can also be used to trigger directed AV-Off road mines, firing small fin-stabilized Anti-Tank-Rockets. They can be positioned between 2 and 40 meters on either side of the road, mounted on a small tripod or attached to a tree. Because AV mines are made to destroy vehicles, they are generally found on roads, roadsides, paths, tracks and the verge of the road. Even roads that have been driven on for some time can contain AV mines.

AV mines are much larger than AP mines, and have a far heavier explosive charge. They are generally round or square in shape, and range in size from 40 cm in diameter and 16 cm in height to 23 cm in diameter and 10 cm in height. They can be made of wood, plastic, or metal and come in a range of colors. AV mines charges are about 6 kg HE, but they can also have a shaped charge.

Additionally AV mines are often used as a main charge of an IED. The fuse can be hidden under or built inside the mine. This means the lifting of supposedly unfused mines can be dangerous.

It normally takes considerable pressure to detonate a standard AV mine, around 120 kg to 150 kg. This does not necessarily mean that people weighing less can safely step on an AV mine. Fuse systems may deteriorate or be deliberately adjusted, resulting in a reduction in pressure required to detonate AV mines[2].

Sometimes AV mines are booby trapped to be detonated when they are disturbed. In some cases AP mines have been laid on top of AV mines which, when initiated, will generally cause the AV mine to detonate as well. Be aware also that AP mines are often used to prevent AV mines from being removed, and the technique of laying AP mines and AV mines together in clusters is common.

As AV mines are often designed to disable large military vehicles like tanks, their impact on smaller civilian vehicles is usually catastrophic and results in the destruction of the vehicle, and death or serious injury to the occupants. Figure (2.10) represents AV mines.

Figure 2.10 : Anti Vehicle landmines.

2.6 Explosive Material

The Nature of Explosives are substances that undergo rapid burning (deflagration) or detonation (instantaneous Explosion) resulting in the formation of large volumes of gases, liberation of heat and light, and Sudden pressure effect (shock and blast waves).

Generally, there are three categories of explosives, i.e., chemical, mechanical, and nuclear Explosives. Chemical explosives, the most commonly used explosives, are compounds or Mixtures of compounds that react to produce large volumes of rapidly expanding gases as well as Energy, heat, light, and shock waves that exert sudden pressures on the surroundings.

Mechanical explosives are those substances that tend to undergo a physical change such as overloading a container with compressed air or steam. Nuclear explosives, the most powerful Explosives, produce sustained nuclear reactions while releasing a tremendous amount of heat and Energy.

The characteristics of chemical explosives influence the type of explosives that are used for a Specific application. Such characteristics include, but are not limited to: sensitivity, stability, and rate of detonation, and brisance.

- Sensitivity refers to the ease at which an explosive is ignited or detonated; it reveals the amount and intensity of shock, friction, and heat that is required to initiate Detonation.
- Stability indicates the ability of an explosive to be stored without deterioration.

Deteriorating explosives may be more sensitive and more dangerous to handle. For example, dynamite stored for a long time will allow nitroglycerin (NG) to seep out and will become very unstable.

- Detonation rate refers to the speed at which a detonation wave travels through an explosive and determines whether an explosive will exert a heaving effect or a Shattering effect.
- Brisance describes the shattering effect and is much greater when the rate of

Detonation is high. Brisance is important in determining the effectiveness of an Explosive in fragmenting the likes of shells, bomb casings, and grenades.

2.7 Classification of Chemical Explosive

The Chemical Explosive Classification are represented in figure (2.11)

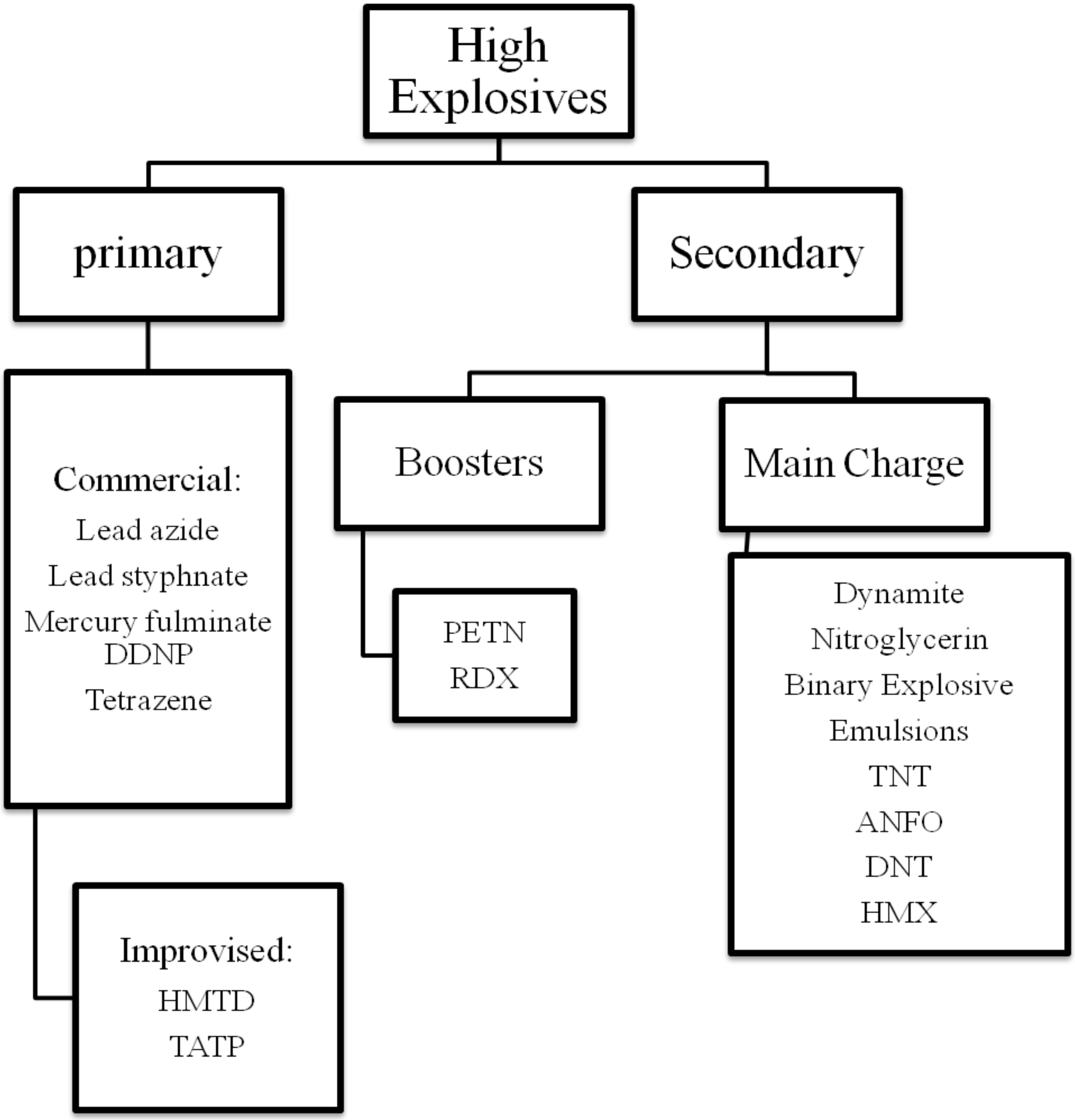

Figure 2.11: Classification of Chemical Explosives.

2.7.1 Common explosives used in land mines

- **Lead Azide (Pb(N3)2)**

It is a highly sensitive and toxic explosive material that is usually handled And stored under water in rubber containers. It is a white to buff powder or colorless crystalline Compound. Lead azide will explode after a fall of around 150 mm (5.9 in) or in the presence of a Static discharge of 7 mJ. Figure (2.12) represents lead azide.

Figure 2.12: lead azide.

- **Mercury Fulminate**

Mercury fulminate (Hg(ONC)2) is highly sensitive to friction and shock and is mainly used in older blasting caps. Mercury fulminate, as a primary explosive, has been replaced by other Primary explosives those are less toxic and more stable. Figure (2.13) represents Mercury Fulminate.

Figure 2.13: Mercury fulminate salt

- RDX

Also known as RDX, cyclonite, hexogen, and T4 is second in Strength to NG among common explosive substances and is used in mixtures with other Explosives. It has a high degree of stability and brisance and is considered the most powerful of the military explosives. As a military explosive, it is used as a base charge in detonators or Mixed with other explosives such as TNT to produce a bursting charge for various munitions. In Addition to military applications, RDX also has commercial applications. Typically, RDX is dyed pink. Figure (2.14) represents Cyclotrimethylenetrinitramine (RDX).

.

Figure 2.14: Cyclotrimethylentrinitramine (RDX).

– Trinitrotoluene (TNT) ($C_6H_2(NO_2)_3CH_3$)

TNT is one of the most commonly used high explosives in military weapons and in civilian Mining and excavation activities. The yellow-colored solid is frequently used as a main charge in artillery projectiles, mortar rounds, and aerial bombs. TNT is classified as a secondary high Explosive because it is less susceptible to ignition and requires a primary explosive to ignite it. It has fairly high explosive power, good chemical and thermal stability, and is compatible with other explosives. TNT is considered the standard measure of strength of explosives. Figure (2.15) represents Trinitrotoluene.

Figure 2.15: Trinitrotoluene (TNT).

CHAPTER THREE

INNOVATIVE MINE DETECTION SYSTEMS

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INNOVATIVE MINE DETECTION SYSTEMS

3.1 Introduction

Predicting the potential for an innovative mine detection system to reduce the false alarm rate and increase the probability of detection is an inherently difficult task. Research is being conducted by a myriad of universities, government institutions, and private companies, with different projects in various stages of development.

However most of the technologies have not yet been field tested. This makes it virtually impossible to assess operating characteristics with any specificity, thus precluding defensible quantitative performance comparisons.

The performance of a landmine detection system depends on the types and depths of mines present, the environment in which the system is operated, and the human operator. For detectors that locate buried objects, such mine properties as size, shape, and metallic content substantially affect detector performance, as do the placements (depth and orientation) of the mines.

Detectors that search for explosives can be sensitive to the type of explosive contained within the mine. Detector performance is also tied to persistent environmental attributes (such as soil type, terrain, vegetation, and clutter density) and transient atmospheric conditions (wind, humidity, soil moisture, and radio frequency or acoustic interference). Finally, such human factors as individual operator tuning of the detector and interpretation of the signals introduce additional sources of variability.

3.2 Innovative mines detection system

Figure (3.1) represent innovative mines detection system.

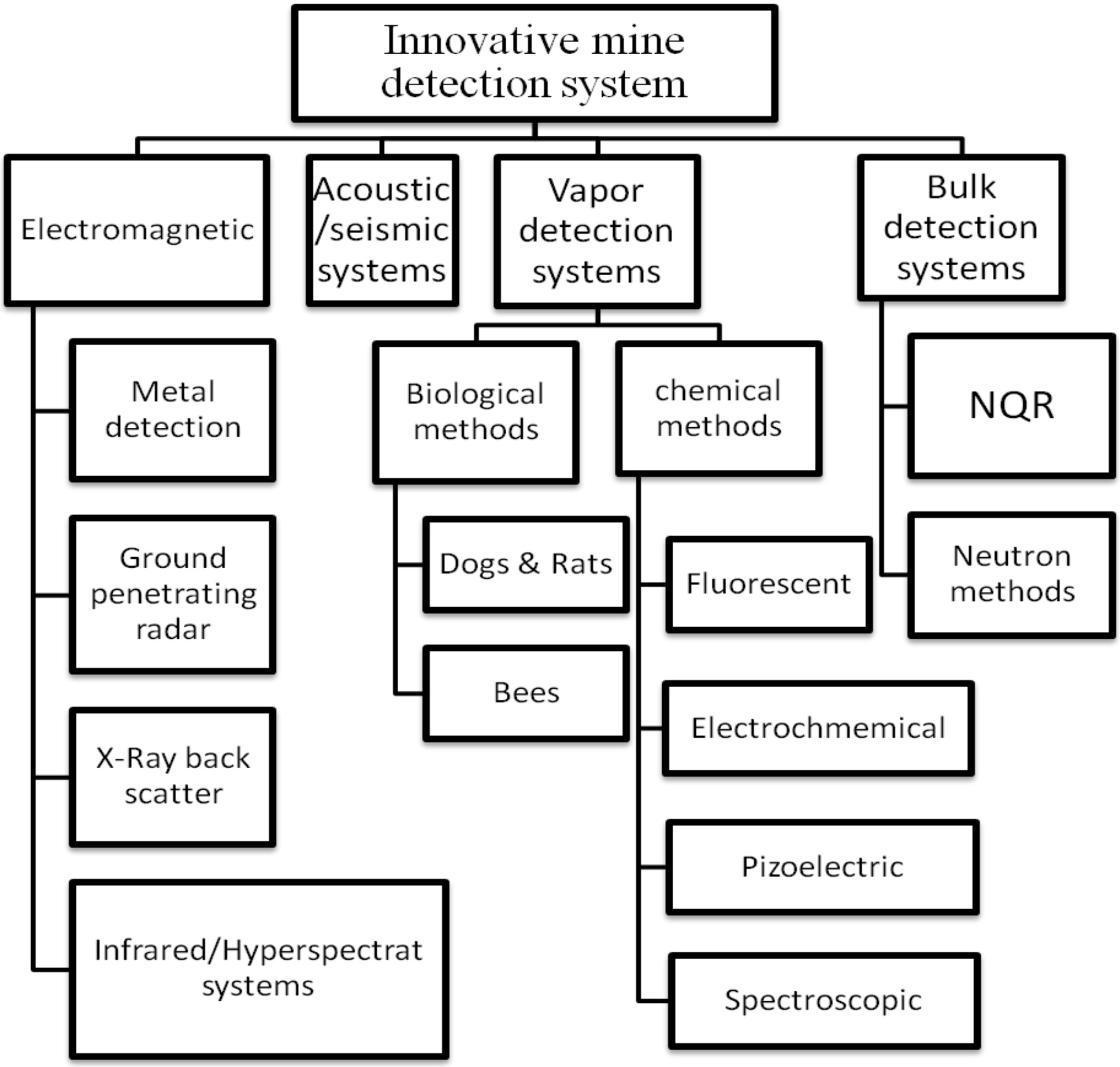


Figure 3.1: innovative mines detection system.

3.2.1 Electromagnetic detection system

A number of innovative methods are being explored that search for buried mines based on changes in the electromagnetic properties of the surface soil and shallow subsurface. These methods include Metal Detection, ground-penetrating radar (GPR), x-ray backscatter, and infrared/hyper spectral systems.

i. Metal detection

Stealth is a buried landmine's major defense against neutralization. Since the primary tool to find a landmine has historically been the metal detector, landmine manufacturers have developed low metal content (LMC) plastic-encased landmines to minimize the chance of detection. These landmines have as little as 0.5 g of metal content. Currently, the best hobbyist and military metal detectors can find, with high confidence, these LMC landmines at a distance of about 20 cm. However, the increased metal detection sensitivity subjects the de-miner to increased false alarms owing to small metal clutter not previously detectable. It has been estimated that for every real landmine detected there are as many as 100 to 1000 metal clutter objects detected. Obviously, it is desirable to be able to discriminate the metal clutter from the real landmine[3]. Figure (3.2) shows a simplified diagram of the metal detector.

- **Technology basics**

A current loop transmitter is turn-on transients in the object to dissipate. The loop current is then turned off. According to Faraday's law, the collapsing magnetic field induces an electromotive force in the metal object. This force causes eddy currents to flow in the metal. Because there is no energy to sustain the eddy currents, they begin to decrease with a characteristic decay time that depends on the size, shape, and electrical and magnetic properties of the metal. The decay currents generate a secondary magnetic field, and the time rate-of-change of the field is detected by a receiver coil located at the sensor. If a conductive object is shown to have a unique time-decay response, a signature library of conductive objects can be developed. When a concealed metal object is encountered, its time-decay signature can be compared to those in the library and, if a match is found, the object can potentially be classified. Classification allows discrimination between potential threat and non-threat objects.

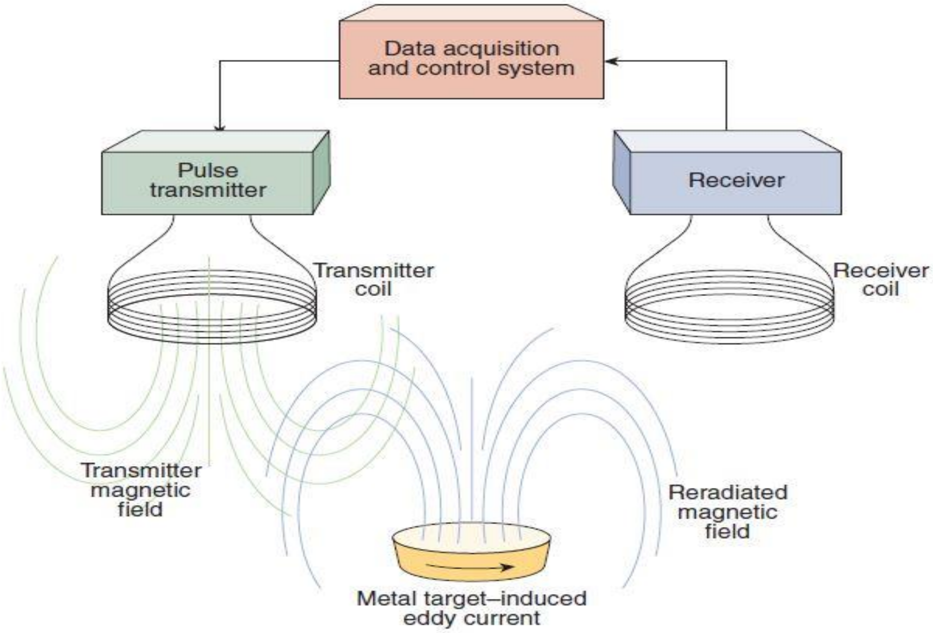


Figure 3.2: a simplified diagram of the metal detector.

- **Advantages**

This method of detecting mines is that it is less risky than prick because the operator of a metal detector holding the device in the field .also metal detectors can detect small metal objects at shallow depths and large metal objects at greater depths under a wide range of environmental and soil conditions.

- **Limitations**

Nonlethal metal (clutter) objects commonly found in the environment are a major issue. Because these clutter objects represent false targets, they create a false alarm when detected by a conventional metal detector.

- **Summary**

Great effort has been expended by metal detector manufacturers to develop sensitive metal detectors to identify these small metal objects at depths of tens of centimeters in all soil types.

ii. Ground-Penetrating Radar (GPR)

GPR detects buried objects by emitting radio waves into the ground and then analyzing the return signals generated by reflections of the waves at the boundaries of materials with different indexes of refraction caused by differences in electrical properties. Generally, reflections occur at discontinuities in the dielectric constant, such as at the boundary between soil and a landmine or between soil and a large rock. A GPR system consists of an antenna or series of antennas that emit the waves and then pick up the return signal. A small computerized signal-processing system interprets the return signal to determine the object's shape and position. The result is a visual image of the object (see, for example, figure (3.3) or an audio signal indicating that its shape resembles a landmine, based on comparison with a mine reference library.

The major design control in a GPR system is the frequency of the radio wave. The scale at which GPR can detect objects is proportional to the wavelength of the input signal, so the quality of the image improves as the wavelength decreases and the frequency increases.

However, at high frequencies, penetration of the incident wave into the soil can be poor. As a result, the designer must make a tradeoff between quality of the image and required penetration depth. The optimal design for maximizing image quality while ensuring sufficient penetration depth changes with environmental conditions, soil type, mine size, and mine position. Various alternative GPR designs are being explored to optimize the tradeoff between penetration depth and image quality under a wide range of conditions. Also critical in the design of a GPR system are signal-processing algorithms, which filter out clutter signals and select objects to be declared as mines[1].

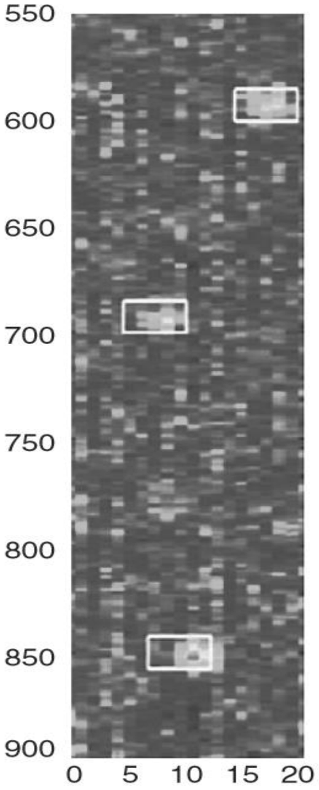


Figure 3.3: Landmines Produced by GPR System.

NOTE: The bottom target is a metallic mine, the top two targets are low-metal mines.

- **Advantage**

First, it is complementary to conventional metal detectors. Rather than cueing exclusively off the presence of metal, it senses changes in the dielectric constant and therefore can find mines with a wide variety of types of casing (not just those with metal). Generating an image of the mine oranother buried object based on dielectric constant variations is often possible because the required radar wavelength is generally smaller than most mines at frequencies that still have reasonable penetration depth. Second, GPR is a mature technology, with a long performance history from other applications. Finally, GPR can be made lightweight and easy to operate.

- **Limitations**

Natural subsurface in-homogeneities (such as roots, rocks, and water pockets) can cause the GPR to register return signals that resemble those of landmines and thus are a source of false alarms. In addition, GPR performance can be highly sensitive to complex interactions among mine metal content, interrogation frequency, soil moisture profiles, and the smoothness of the ground surface boundary. Also GPR can be very effective or ineffective, depending on soil moisture and mine location; such complex interplays make performance highly variable and difficult to predict. An additional limitation is that unless the GPR system is tuned to a sufficiently high frequency, it will miss very small plastic mines buried at shallow depths because the signal "bounce" at the ground surface (caused by the electrical property differences between air and soil) will mask the return signal from the mine. Finally, the GPR system designer must make a tradeoff between resolution of the return signal and depth, because high-frequency signals yield the best resolution but do not penetrate to depth.

- **Summary**

GPR systems would be able to provide high-resolution images to a signal processing system that could decide whether a buried object is a root, rock, clutter object, or landmine.

iii. X-Ray backscatter

Traditional x-ray radiography produces an image of an object by passing photons through the object. X rays have a very small wavelength with respect to mine sizes, so in principle they could produce high-quality images of mines. Although pass through x-ray imaging of the subsurface is physically impossible, the backscatter of x rays may still be used to provide information about buried, irradiated objects. X-ray backscatter exploits the fact that mines and soils have slightly different mass densities and effective atomic numbers that differ by a factor of about two. There are two basic approaches to using backscattered x rays to create images of buried mines. Methods that collimate (i.e., align) the x rays employ focused beams and collimated detectors to form an image. The collimation process increases size and weight and dramatically reduces the number of photons available for imaging.

Thus, high-power x-ray generators must be used as sources. The large size, weight, and power requirements of such systems are not amenable to person-portable detectors. Alternatively, un-collimated methods illuminate a broad area with x rays and then use a spatial filter to de-convolve the system response. They may be suitable for person-portable detection.

- **Advantages**

To readily distinguish mines from soils, it is necessary to use low-energy incident photons (60–200 keV). In this energy range, cross sections are roughly 10 or more times larger than is possible with most other nuclear reactions that would be applicable to mine. In addition, because of the reduced shielding thickness needed to stop low-energy photons, un-collimated systems can be made small and relatively lightweight. Largely because of the medical imaging industry, compact x-ray generators are now obtainable. Low-energy isotopic sources have been readily available for a long time. Practical imaging detectors are becoming more widespread, although it may be necessary to custom build for mine detection purposes. The medical imaging industry is likely to drive further advances in x-ray imaging hardware.

- **Limitations**

In the required energy range, soil penetration of x-ray backscatter devices is poor. This limits detection to shallow mines (less than 10 cm deep). If source strengths are kept low enough to be safe for a person-portable system, the time required to obtain an image may be impractically long. In addition, the technology is sensitive to source/detector standoff variations and ground-surface fluctuations. Further, to image antipersonnel mines, high spatial resolution (on the order of 1 cm) is required. This may be difficult to achieve in the field. Finally, the technology emits radiation and thus will meet resistance to use because of actual or perceived risks.

- **Summary**

X-ray detection using the un-collimated imaging approach may be useful for handheld confirmatory detection of antipersonnel landmines. In fielded systems, images of mines are likely to be fuzzy but should still allow mines to be distinguished from most diffuse or elongated false alarms.

iv. Infrared/Hyper spectral systems

Infrared/hyper spectral methods detect anomalous variations in electromagnetic radiation reflected or emitted by either surface mines or the soil and vegetation immediately above buried mines (as show in figure 3.4). The category encompasses technologies of diverse modes of action, including active and passive irradiation using a broad range of electromagnetic wavelengths.

Thermal detection methods exploit diurnal variations in temperatures of areas near mines relative to surrounding areas. For example mines or the soil above them tend to be warmer than surrounding areas during the day but lose heat more quickly at night. Laser illumination or high-powered microwave radiation can be used to induce these differential temperature profiles.

Non-thermal detection methods rely on the fact that areas near mines reflect light (either natural or artificial) differently than surrounding areas. Anthropogenic materials tend to preserve polarization because of their characteristically smooth surfaces, allowing discernment of surface mines. Moreover, the physical activity of emplacing mines changes the natural soil particle distribution by bringing small particles to the surface, which in turn affects the way in which the soil scatters light. Systematic changes in vegetation moisture levels immediately above buried mines also may be leveraged[1].

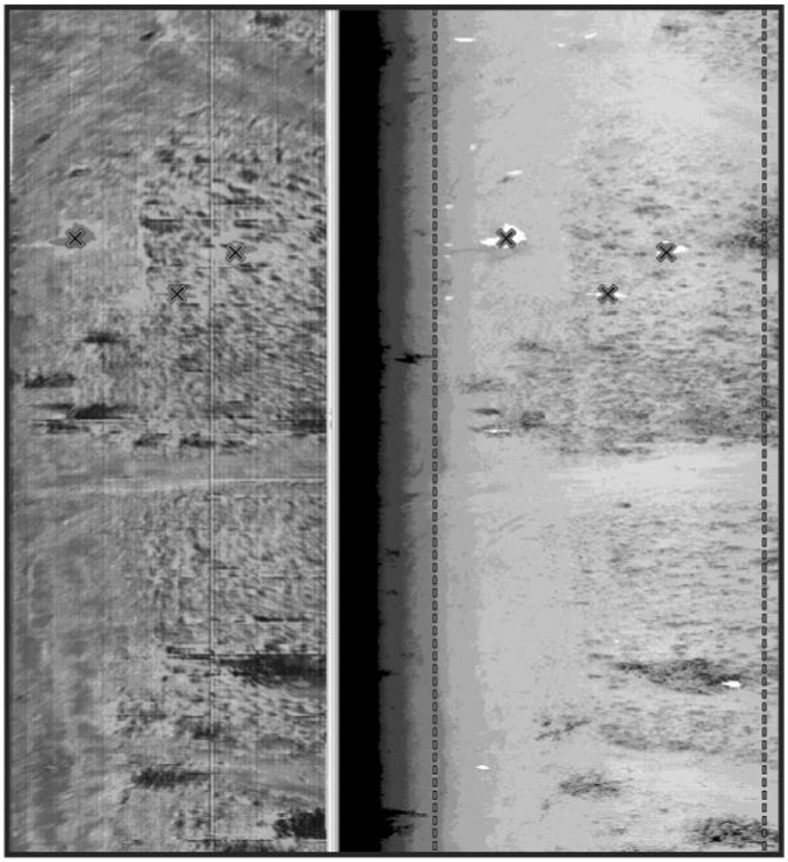


Figure 3.4: Infrared Image of Mines.

NOTE: The left pane shows the infrared image, while the right pane shows the visible image. Mine locations are denoted with “x.”

- **Advantages**

These methods are attractive because they do not involve physical contact and can be used from a safe standoff distance. They are lightweight and are effective at scanning wide areas relatively quickly. When deployed from airborne platforms, they are particularly effective for detecting surface mines.

- **Limitations**

The methods, particularly thermal imaging, have been used in several prototype multisensory systems, but extreme variability in performance as a function of dynamic environmental characteristics has precluded their use for close-in detection and accurate identification of mine locations. Despite maturity of the sensor, the algorithms to process the signals in an informative way are relatively undeveloped and are not linked to physical phenomena. Thermal signatures currently are not well understood, and a comprehensive predictive model does not exist. Moreover, waves at the frequencies used by the methods cannot penetrate soil surfaces, and the localized hyper spectral anomalies produced by mine emplacement are ephemeral and are quickly eliminated by weathering. Thus, the technologies are able to detect buried mines under only limited transient conditions.

- **Summary**

With the possible exception of methods that would simulate solar heating as a means to enhance the thermal signatures of buried targets, infrared/hyper spectral methods are not particularly suitable for close-in buried mine detection. The underlying phenomena are not sufficiently characterized, and natural processes quickly erase the detectable surface anomalies. The technology has demonstrated ability and expected future promise for airborne minefield detection, especially for surface mines, but it is not expected to be useful for close-in detection of buried mines.

3.2.2 Acoustic/Seismic Systems

Acoustic/Seismic methods look for mines by “vibrating” them with sound or seismic waves that are introduced into the ground. This process is analogous to tapping on a wall to search for wooden studs: materials with different properties vibrate differently when exposed to sound waves. These methods are unique among detection methods that identify the mine casing and components in that they are not based on electromagnetic properties. Acoustic/seismic mine detection systems typically generate sound (above ground) from an off-the-shelf loudspeaker, although there are many possible configurations. Some of the acoustic energy reflects off the ground surface, but the rest penetrates the ground in the form of waves that propagate through the soil. When an object such as a mine is buried, some of the energy reflects upward toward the ground surface, causing vibration at the surface. Specialized sensors can detect these vibrations without contacting the ground. A variety of different kinds of sensors (laser Doppler vibrometers, radars, ultrasonic devices, microphones) have been tried.

- **Advantages**

Acoustic/Seismic sensors are based on completely different physical effects than any other sensor. For example, they sense differences in mechanical properties of the mine and soil, while GPR sensor detect differences in electromagnetic properties. Thus, acoustic/ seismic sensors would complement existing sensors well. also have the potential for very low false alarm rates. An additional advantage is that, unlike GPR systems, these sensors are unaffected by moisture and weather, although frozen ground may limit the sensor's capability.

- **Limitations**

The greatest limitation of acoustic/seismic systems is that they do not detect mines at depth because the resonant response attenuates significantly with depth. With current experimental systems, mines deeper than approximately one mine diameter are difficult to find.

Also problematic is the slow speed of existing systems. Finally limitation of existing systems is that moderate to heavy vegetation can interfere with the laser Doppler vibrometers that are commonly used to sense the vibrations at the ground surface.

- **Summary**

Interactions between the seismic waves and buried mines and clutter are much better understood, as are the seismic sources and displacement sensors. The systems show great potential, but more research is needed to make them practical.

3.2.3 Explosives vapor detection system

Each detection technology discussed above searches for the casing or mechanical components of a mine. Additional research is taking place to develop methods—both biological and chemical—that identify the presence of explosive vapors emanating from mines. Ideally, such sensors would determine whether explosive vapors are present above an anomaly located by a metal detector or other device. Although each method has a different theoretical basis, all are designed to sense low concentrations of explosive compounds or their derivatives in soil or the boundary layer of air at the soil surface. Determining the performance potential of each chemical- or biological- sensing technology requires an understanding of how explosives migrate away from landmines as well as knowledge of the chemical and physical principles of the sensor. When a mine is buried in the soil, it almost always will gradually release explosives or chemical derivatives to the surrounding soil through either leakage from cracks and seams or vapor transport through the mine casing (in the case of plastic mines). While typically about 95 percent of the explosive will adsorb to the surrounding soil, the remaining 5 percent will travel away from the mine, mostly through dissolution in water in the soil pores. Some of this explosive will migrate to the ground surface in vapor form.

One of the key issues in detecting explosive vapors and residues is that the concentrations available for detection are extremely. Thus the sensor must be able to operate at a very low detection threshold. The analyte that is the focus of most explosive detection research is 2,4-dinitrotoluene (2,4-DNT), which is a byproduct of trinitrotoluene (TNT) manufacturing that is present as an impurity in military-grade TNT. TNT has a very short half-life in soil (about a day at 22°C) because it is easily biodegraded and has very low vapor pressure; 2,4-DNT is much less easily biodegraded and has a higher vapor pressure, so it is the dominant chemical present in the explosive signature from most landmines. The

2,4-DNT and 2,4,6-TNT concentrations in air above the soil were 200 × 10–15 g per milliliter and 1 × 10–15 g per milliliter, respectively. Figure (3.5) summarizes the ranges of concentrations of 2,4-DNT and TNT vapors likely to be found in surface soils above landmines. To be effective, an explosive vapor detection system must be sensitive to concentrations as low as 10–18 g per milliliter if the soil is very dry or as low as 10–15 g per milliliter if the soil is moist.

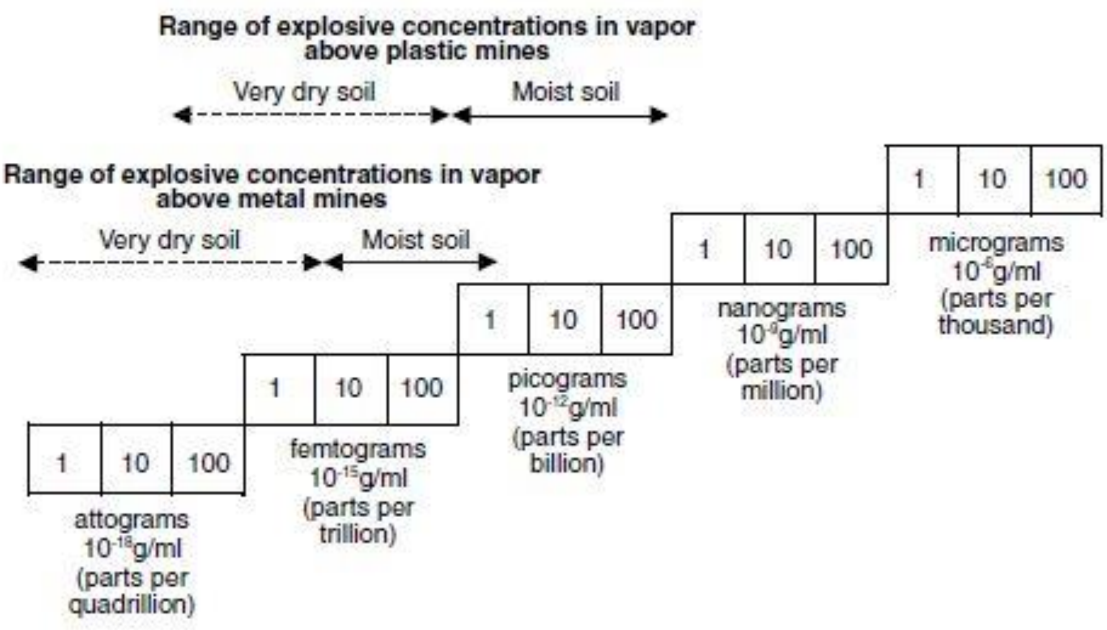


Figure 3.5: Range of Concentrations of 2,4-DNT and TNT in Boundary Layer of Air Near Soil Above Landmines.

NOTE: To be effective in all environments, a vapor detector ideally would sense concentrations as low as 10–18 g per milliliter in dry soil and 10–15 g per milliliter in moist soil.

i. Biological Methods

Biological detection methods involve the use of mammals, insects, or microorganisms to detect explosives. Like chemical sensors, these methods rely on detection of explosive compounds rather than on detection of metal or changes in the physical properties of the subsurface. Thus, they have the potential for reducing false alarm rates from metal clutter. Each of the different methods operates on a different set of principles and is at a different stage of development.

- **Dogs and Rats**

Mine dog detection teams have long assisted in humanitarian demining efforts. These dogs can detect mines about 95 percent of the time under favorable weather and soil moisture conditions.

Currently, dogs are capable of detecting explosive vapors at concentrations lower than those measurable by the best chemical sensors, so the lower limit at which they can detect explosives is uncertain. The researchers tested the ability of three different teams of trained dogs to identify explosives in samples from the various dilutions. They found that a few of the dogs could correctly identify samples containing an estimated 10–16 g per milliliter of TNT or DNT.

The rats are trained using food rewards to signal the presence of explosives by scratching the ground surface with their feet. Field tests of the use of rats in mine detection have begun. .

Figure 3.6: Mine-Detecting Dog.

- **Advantages**

Canines are proven to work exceptionally well in many scenarios and under many environmental conditions. The olfactory sensitivity of some, but not all, dogs is higher than the best currently available mechanical detection methods. Advantages of using rats include the possibility that they could be deployed in large numbers and that they do not weigh enough to trigger mines, which reduces the possibility of injury.

- **Limitations**

Dog performance varies widely depending on the individual dog, how it was trained, and the capabilities of the handler. Further, dogs may need to be retrained periodically because they can become confused if they discover behaviors other than explosives detection that lead to a reward. An additional limitation is that when trained to detect high levels of explosives, dogs may not automatically detect much lower levels and may need to be specially trained for this purpose. Like other methods that rely on vapor detection, performance of mine detection dogs can be confounded by environmental or weather conditions that cause explosive vapors to migrate away from the mine or that result in concentrations of vapors that are too low even for dogs to detect. Rats likely would have similar limitations.

- **Summary**

Continued investigation of the sensitivity of canine olfaction and how this varies with the dog and with training is necessary to understand the factors that affect reliability. Additionally, the vapor and particle signature of the mine in the field must continue to be investigated to better understand performance potential for canines.

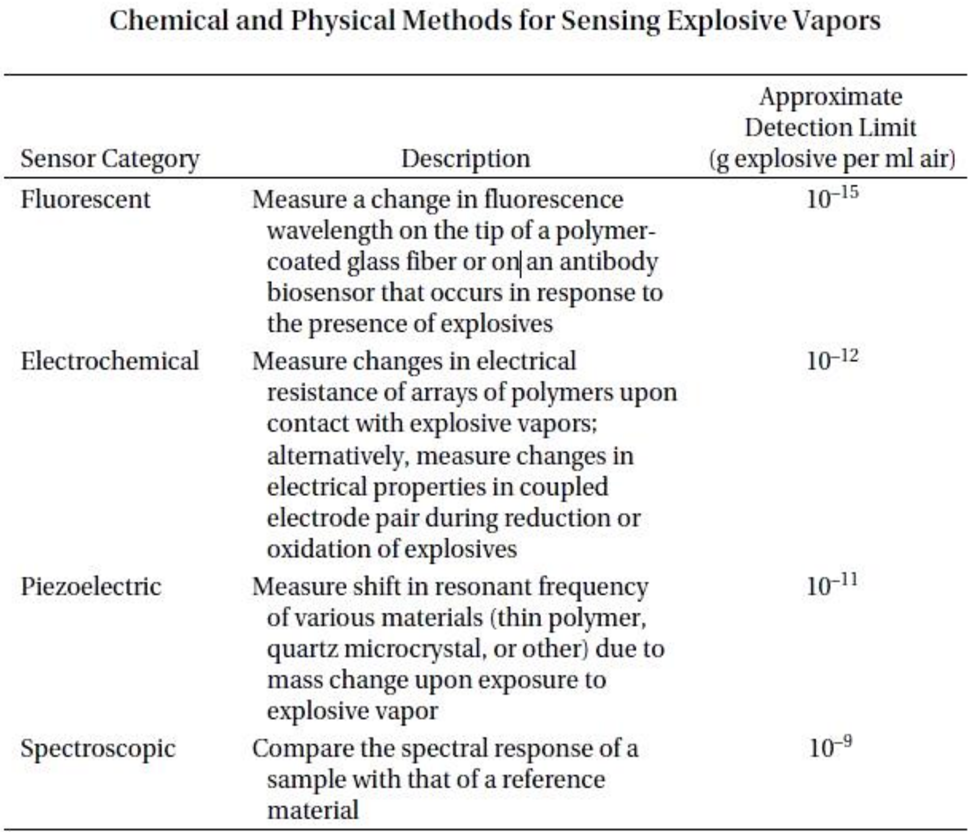
- **Bees**

By lacing sugar with a target chemical and placing the sugar in the bees' natural foraging area, bees can be trained to associate the chemical odor with food and to swarm over any location containing the target odorant. Entomologists have trained bees to detect a variety of explosives and have been researching ways to use trained bees in humanitarian demining. There are two suggested strategies. The first involves monitoring the movement of bees trained to detect explosives and keeping track of the locations where they swarm. The second involves sampling the beehive for the presence of explosives, which can be transported to the hive on the bees' mop-like hairs.

ii. Chemical Methods

A variety of possible non-biological mechanisms for detecting low concentrations of explosives in air or in soil samples have been investigated in recent years (as show in Table 3.1). Most of these investigations resulted from DARPA's "Dog's Nose" program, which sponsored R&D leading to the development of highly sensitive odor detection devices. Some of the techniques were patterned after the mammalian nose.

Table 3.1



Chemical and Physical Methods for Sensing Explosive Vapors

Sensor Category	Description	Approximate Detection Limit (g explosive per ml air)
Fluorescent	Measure a change in fluorescence wavelength on the tip of a polymer-coated glass fiber or on an antibody biosensor that occurs in response to the presence of explosives	10^{-15}
Electrochemical	Measure changes in electrical resistance of arrays of polymers upon contact with explosive vapors; alternatively, measure changes in electrical properties in coupled electrode pair during reduction or oxidation of explosives	10^{-12}
Piezoelectric	Measure shift in resonant frequency of various materials (thin polymer, quartz microcrystal, or other) due to mass change upon exposure to explosive vapor	10^{-11}
Spectroscopic	Compare the spectral response of a sample with that of a reference material	10^{-9}

- **Advantages**

Vapor and residue sensors detect explosives and therefore could serve as complements to detection devices that rely on physical features of the mine. In addition, most of the methods have the potential to be engineered as small, lightweight, easily transportable, and simple-to-operate systems with relatively low power requirements. The Nomadic prototype already available is comparable in size to a typical metal detector and, like a metal detector, can operate at a walking pace. It has an extremely low detection threshold (10–15 g per milliliter).

- **Limitations**

The detection sensitivity of current technologies, with the exception of the fluorescent polymer approach, is not low enough to provide for reliable detection of metal encased mines in dry soil, and even this method may not perform well in the driest of environments. Another problem is that the presence of explosive residues in soil from sources other than landmines will trigger false alarms. Further, the location at which explosive vapors are present at the highest concentration is often displaced from the mine location. Current understanding of explosives fate and transport from buried mines is insufficient to allow for the reliable location of a mine based on measurement of the extended explosive vapor signal.

- **Summary**

Explosive vapor and residue detectors have the potential to be used as confirmatory sensors for landmines if the probability of detection can be increased to near one. Whether this is possible cannot be determined without additional basic research. Research is necessary to establish the lower limits of detection for the different types of vapor sensors. Also needed are further investigations to allow quantitative modeling of the amounts and locations of explosives available for detection at the surface under different environmental conditions.

3.2.4 Bulk explosive detection systems

Biological and chemical methods for detecting explosive vapors currently are limited by incomplete knowledge of how explosive vapors migrate in the shallow subsurface. An additional category of explosive detection technologies overcomes this limitation by searching for the bulk explosive inside the mine. Methods being explored for this purpose include nuclear quad rupole resonance (NQR) and a variety of methods that use the interaction of neutrons with components of the explosive. These technologies emerged from interest in detecting bulk explosives in passenger baggage for the airline industry and in investigating the potential presence of explosive devices in other settings.

i. Nuclear Quadrupole Resonance (NQR)

NQR is a radio frequency (RF) technique that can be used to interrogate and detect specific chemical compounds, including explosives. An NQR device induces an RF pulse of an appropriate frequency in the subsurface via a coil suspended above ground. This RF pulse causes the explosives' nuclei to resonate and induce an electric potential in a receiver coil. This phenomenon is similar to that exploited by magnetic resonance imaging (MRI) used in medical testing, but NQR uses the internal electric field gradient of the crystalline material rather than an external static magnetic field to initially align the nuclei.

- **Advantages**

NQR has a number of features that make it particularly well suited for landmine detection. NQR can achieve nearly perfect operating characteristics (probability of detection near one with probability of false alarm near zero). The NQR signal from cyclotrimethylenenitramine (RDX) is particularly large, implying high performance and small interrogation times (less than three seconds) for detection of mines containing RDX. Another positive feature of NQR is that it is relatively robust to diverse soil conditions.

- **Limitations**

The major weakness of NQR is the fact that, because of its nuclear properties, TNT, which comprises the explosive fill of most landmines, provides a substantially weaker signal than either RDX or tetryl, posing a formidable SNR problem. Another significant limitation is the susceptibility of NQR to RF interference from the environment. An additional weakness is that NQR cannot locate explosives that are encased in metal because the RF waves will not penetrate the case. This is not a major weakness because a large majority of antipersonnel mines have plastic cases.

- **Summary**

The most promising role of NQR is that of a confirmation sensor used in conjunction with a conventional scanning sensor or as part of an integrated multisensory detection system.

ii. Neutron Methods

Neutron interrogation techniques involve distinguishing the explosives in landmines from surrounding soil materials by probing the soil with neutrons and/or detecting returning neutrons. Differences in the intensity, energy, and other characteristics of the returning radiation can be used to indicate the presence of explosives.

- **Advantages**

The physical properties of neutron moderation allow the technology to use low-strength source radiation, which reduces shielding required to protect workers from radiation exposure. Thus, designing a handheld system may be possible. Costs of a production imager are expected to be moderate.

- **Limitations**

Neutron activation methods can, at best, measure relative numbers of specific atoms but cannot determine what molecular structure is present. Because neutron moderation is most sensitive to hydrogen, hydrogenous materials, particularly water, produce many false alarms. Also, there is a perceived (more than actual) radiation hazard associated with nuclear techniques that must be overcome by the users.

- **Summary**

In fielded systems, images of these mines are likely to appear as fuzzy blobs, but that will still allow mines to be distinguished from most diffuse or elongated false alarms generated by moisture. On balance, however, neutron moderation imaging is very unlikely to yield substantial improvements in detection speed beyond what is capable with other confirming detectors.

CHAPTER FOUR

SYSTEM APPLICATION

CHAPTER FOUR

SYSTEM APPLICATION

4.1 Introduction

There are two methods used which fall under different classifications in the rankings for the basic methods of detecting mines namely (electromagnetic) and (vapor detection method) and specifically (Metal detection) in first Category and (electrochemical) in the second classification.

The two method are combined together making a model to give reliable results, more accurate and more reliable.

An experiment of the model has been successfully done at Sudanese corps engineers.

4.2 system components

The main block diagram of the system is shown in figure (4.1).

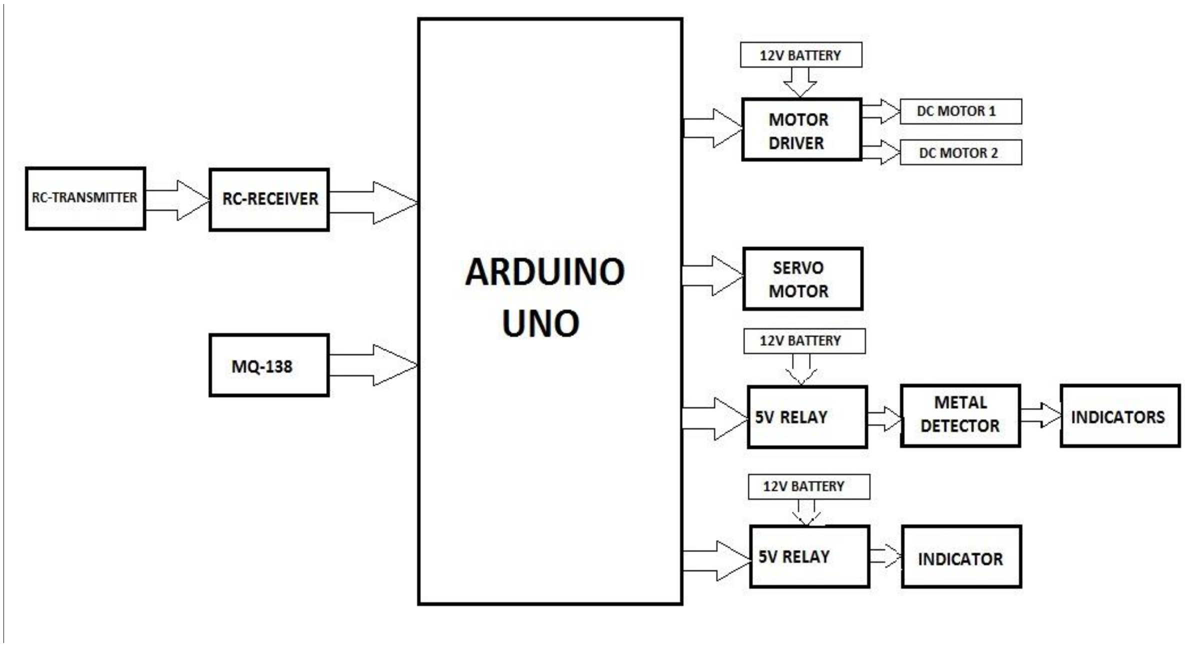


Figure 4.1: System block diagram

This robotic system for mines detection based on arduino board and consists of:

- Arduino Uno.
- RC Transmitter & Receiver.
- Gas Sensor MQ-138.
- Metal Detector.
- Servo motor.
- Motor Driver.
- Metal Car Chassis.
- Volt Regulator.
- 5v-Relay.
- Jumping wire.
- Alarm objects (LEDs).
- Batteries.

4.2.1 Arduino uno R3(ATmega328)

The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter. Figure (4.2) shows atmega328 board.

- **The eneral info of the Arduino represented in table (4.1)**

Table 4.1: specifications of arduino ATmega328.

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB of which 0.5 KB used by boot loader
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

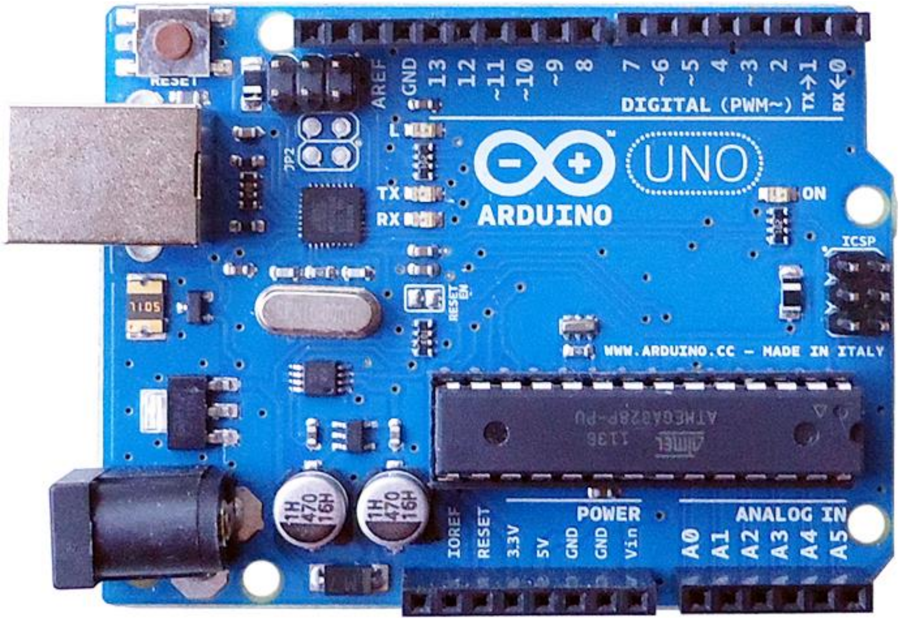


Figure 4.2: ATmega328p board.

4.2.2 RC Transmitter & Receiver (FlySky FS-T6)

FlySky FST6 2.4GHz digital proportional 6 channel transmitter and receiver system. FlySky's AFHDS (Automatic Frequency Hopping Digital System) 2.4GHz system offers a lot of advantages. It is equipped with a super active and passive anti-jamming capability and has very low power consumption with high receiver sensitivity. Figure (4.3)(a) shows the receiver and (4.3)(b) the transmitter.

The 2.4GHz system puts the radio out of the frequency range by any "noise" generated by other electronic components in the model such as the brushless motor, speed controller, servos, or other metal to metal noise. This eliminates interference and glitching that can plague a traditional radio system. Extreme rigorous testing by FlySky engineers makes this AFHDS system solid and worthy.

- **The eneral info of the RC represented in table (4.2)**

Table 4.2: specifications of FS-T6

Channels	6 Channels
Model Type	Glider/Heli/Airplane
RF Range	2.402.48GHz
Bandwidth	500Hz
Band	160
RF Power	Less Than 20dB
2.4GHz System	AFHDS
Code Type	GFSK
Sensitivity	1024
Low Voltage Warning	9V
Output	PPM
Charger Port	Yes
Power	12V DC 1.5AA*8
Weight	590g
ANT Length	26mm

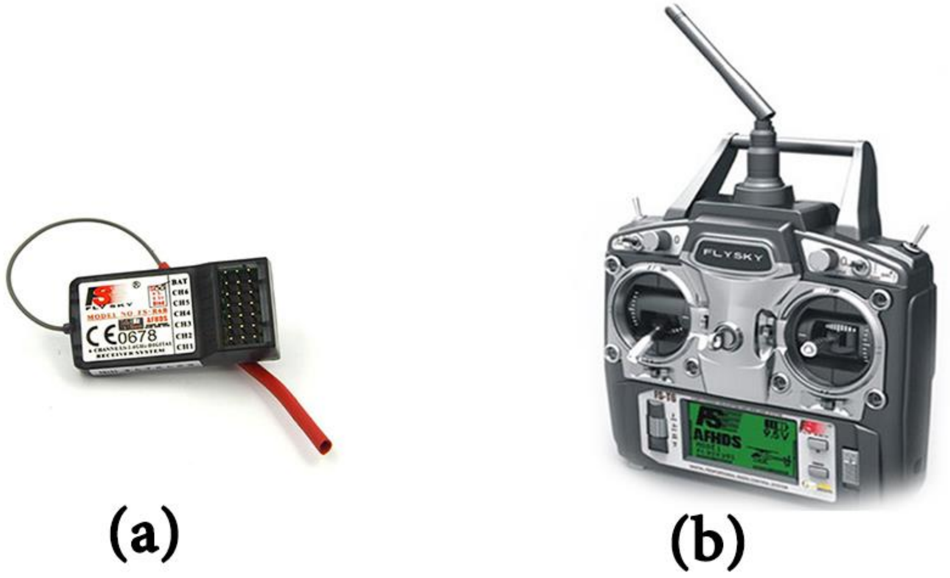


Figure 4.3: transmitter and receiver.

4.2.3 Gas sensor (MQ-138)

MQ138 is Semiconductor Sensor for Organic Steam. Sensitive material of MQ138 gas sensor is SnO2, which with lower conductivity in clean air. When the target organic steam exist, the sensor’s conductivity is more higher along with the gas concentration rising. Please use simple electro-circuit, Convert change of conductivity to correspond output signal of gas concentration. MQ138 gas sensor has high sensitivity to Toluene, Acetone, Ethanol and Formaldehyde, also to other organic steam. The sensor could be used to detect different organic steam. It is with low cost and suitable for different application.

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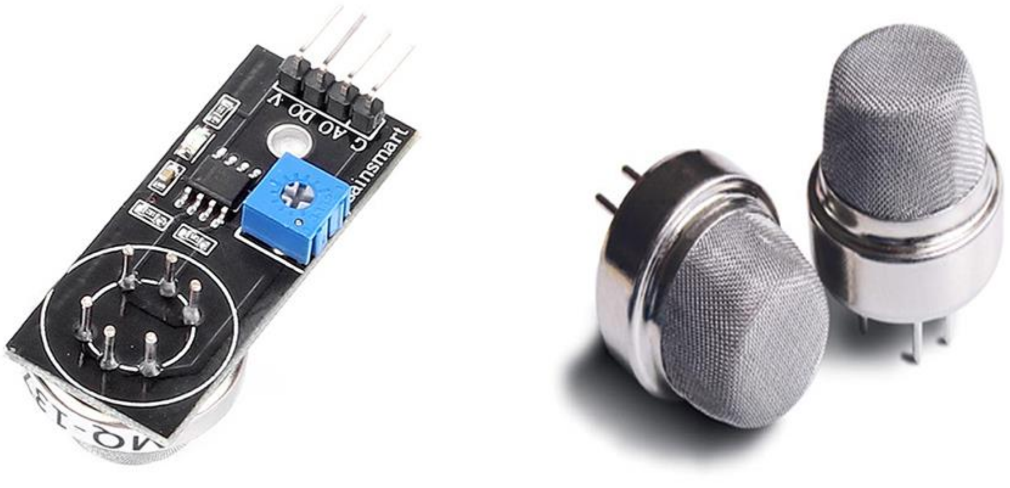


Figure 4.4: MQ-138 gas sensor.

4.2.4 Metal detector (NH-126)

It's a devise that generally use for Deep searching for metal underground, Underwater and Searching landmines.

- **The eneral info of the Metal detector represented in table (4.3)**

Table 4.3: specifications of MQ-138

Mode	motion/non-motion
Search coil	20 cm
Indication	sound, 10 LEDs
Power	12V
Consumption	6575 mA
Dimensions of PCB	96 x 69 mm
Dimensions of front panel	69 x 39 mm

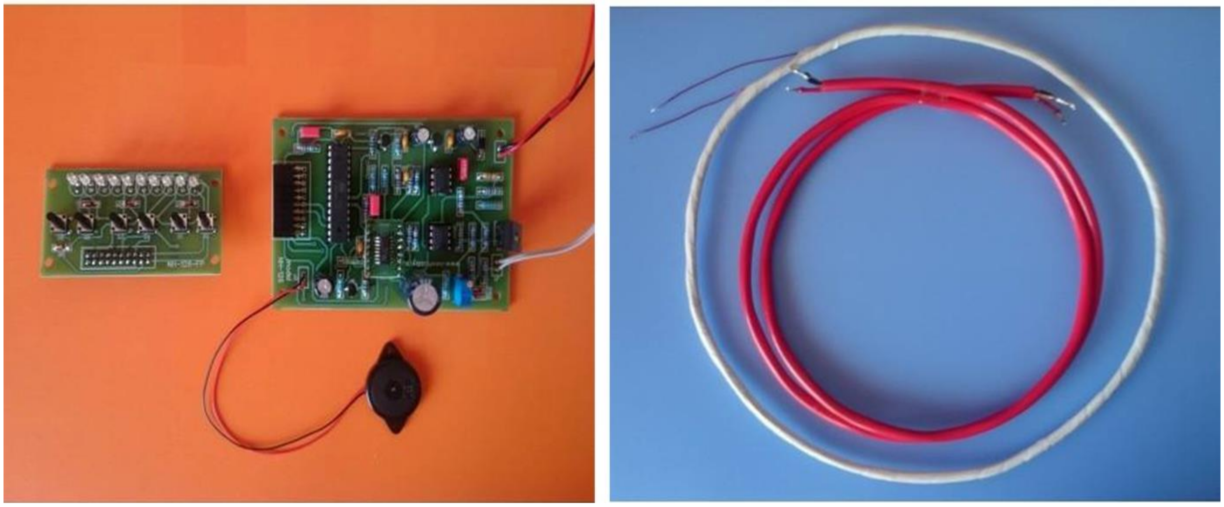


Figure 4.5: Metal detector and search coil.

4.2.5 Servo motor (MG996R)

MG996R is a high torque metal gear dual ball bearing servo. This High-Torque MG996R Digital Servo features metal gearing resulting in extra high 10kg stalling torque in a tiny package. The MG996R is essentially an upgraded version of the famous MG995 servo, and features upgraded shock-proofing and a redesigned PCB and IC control system that make it much more accurate than its predecessor. The gearing and motor have also been upgraded to improve dead bandwidth and centering.

- **The eneral info of the Servo motor represented in table (4.4)**

Table 4.4: specifications of MG996R Servo.

Dimension	40.7 x 19.7 x 42.9 mm approx.
Weight	55 g
Stall torque	9.4 kgf·cm (4.8 V), 11 kgf·cm (6 V)
Operating speed	0.17 s/60º (4.8 V), 0.14 s/60º (6 V)
Operating voltage	4.8 V a 7.2 V
Running Current	500 mA –900 mA
Stall Current	2.5 A (6V)
Dead band width	5 µs
Temperature range	**4** ºC –55 ºC

Figure 4.6: MG996R Servo Motor.

4.2.6 Motor Driver (l293D)

The L293D are quadruple high-current half-H drivers. The L293D is designed to provide bidirectional drive currents of up to 1 A at voltages from 4.5 V to 36 V. The L293D is designed to provide bidirectional drive currents of up to 600-mA at voltages from 4.5 V to 36 V. Both devices are designed to drive inductive loads such as relays, solenoids, dc and bipolar stepping motors, as well as other high-current/high-voltage loads in positive-supply applications.

All inputs are TTL compatible. Each output is a complete totem-pole drive circuit, with a Darlington transistor sink and a pseudo Darlington source. Drivers are enabled in pairs, with drivers 1 and 2 enabled by 1,2EN and drivers 3 and 4 enabled by 3,4EN. When an enable input is high, the associated drivers are enabled and their outputs are active and in phase with their inputs. When the enable input is low, those drivers are disabled, and their outputs are off and in the high-impedance state. With the proper data inputs, each pair of drivers forms a full-H (or bridge) reversible drive suitable for solenoid or motor applications.

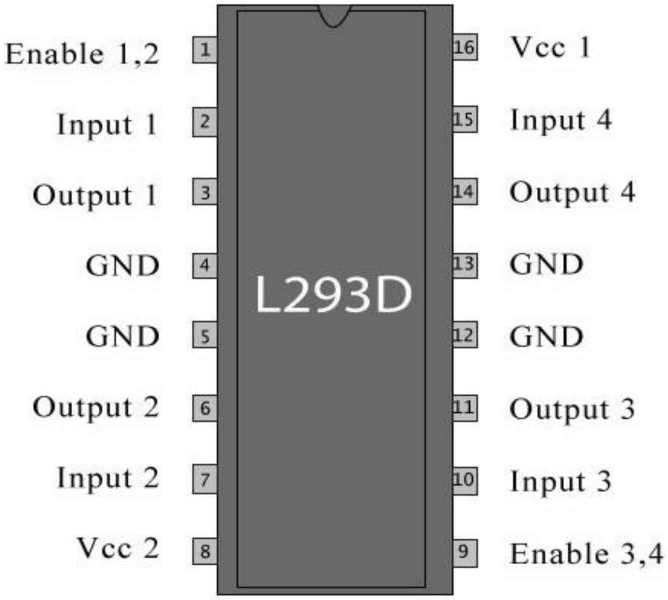


Figure 4.7: L293D chip.

4.2.7 Metal Car Chassis

The tank chassis body and gear train and independent shock absorption system are produced by all metal Delicate and beautiful, firm and stable 2 strong power motor traction powerful functions can Forward and backward Turn left turn right circle around and Other functions Smooth running Smooth unimpeded At the same time, the chassis is equipped with an independent suspension damping system To make it run on uneven road surface can easily cope with Fuselage intermediate obligate a steering gear mouth install steering gear provides convenient installation And the wide flat chassis platform Provide enough space for the customer to install control circuit.

- Size : 241mm*212mm*78mm
- working voltage : 9-12V

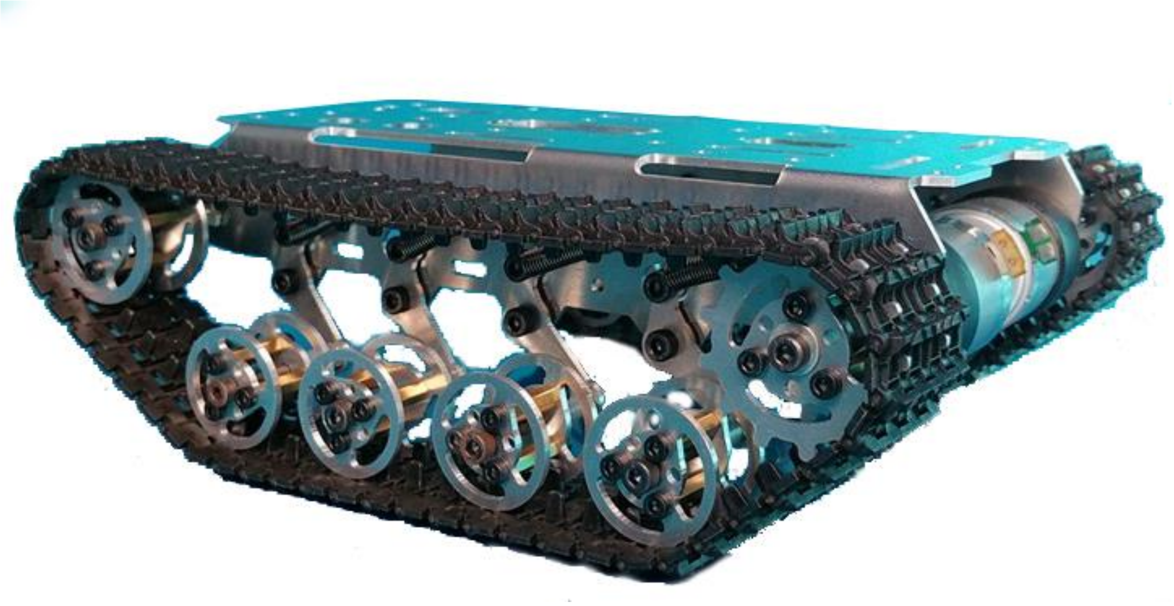


Figure 4.8: Metal car chassis.

4.3 Robot description

Summed up the qualities of the robot via the following table .

Table 4.5: specifications of robot

specification	Description
Dimensions	Length 642 mm - Width 212 mm - Height 208
weight	2800 g
Speed	50000 mm/min
Movement	Robot Forward – Reveries - Left - Right (circular motion around the axis)
	Search coil 60 degrees in both directions
Work environment	All kinds of soil and all kinds of nature land
Control range	800 meters or more
Detection range	Detection range for the metal part of mines 250 mm of the mines with non-metal casing 300 mm of the mines with metal casing
	Detection range for explosive material in mines Range depends on the type and age of the explosive material and the
Detection response time	1 microseconds to detect metal part of mines . 1 second to detect explosive material through the vapor sensor .

Figures (4.9 & 4.10) shows the model of landmines detection robot.

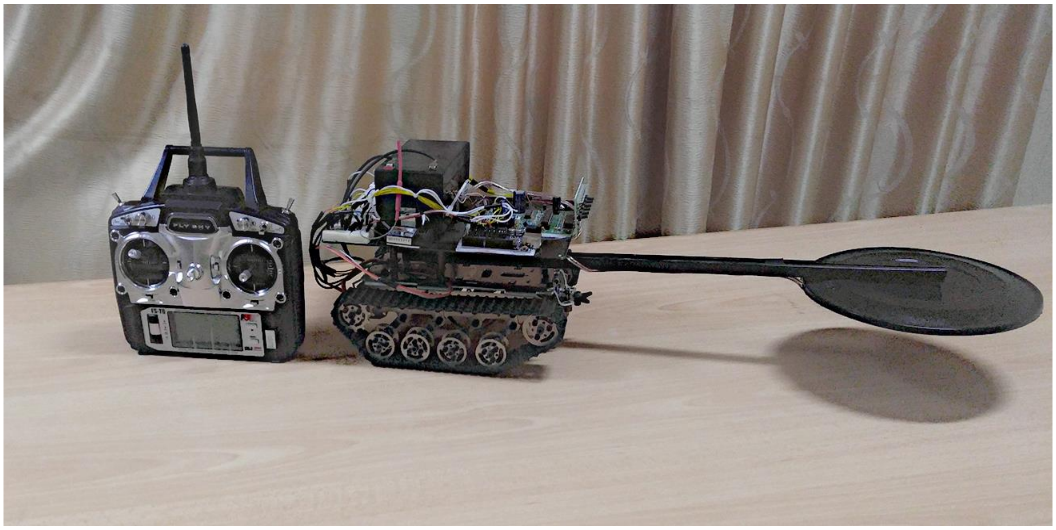


Figure 4.9: landmines detection robot model.

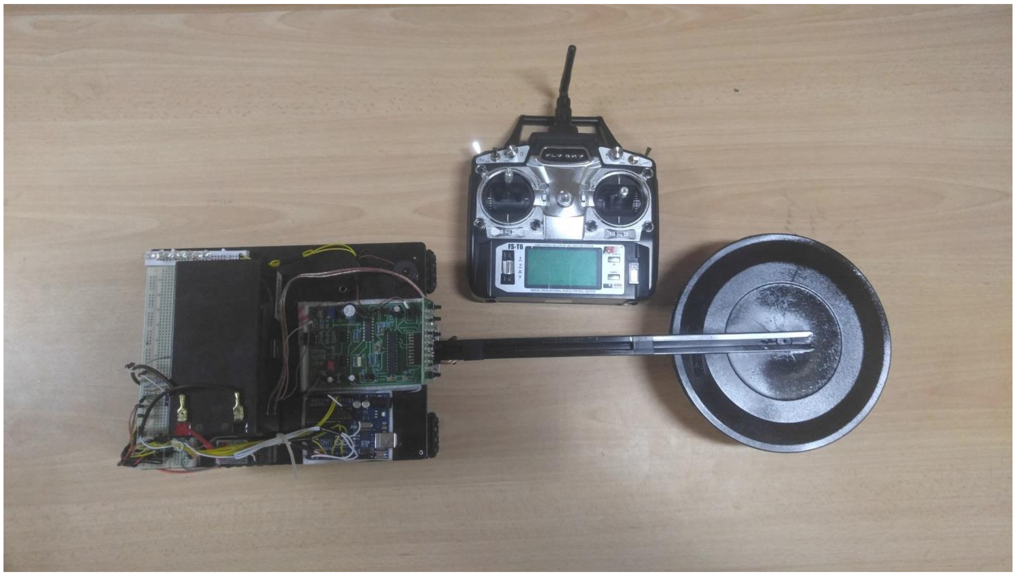


Figure 4.10: landmines detection robot model.

4.4 System operation

As previously mentioned was the use of metal detection method and vapor detection system (electrochemical).

In this part known how to work the system components to achieve detection.

4.4.1 Action Steps

- It is controlled movement of the robot and arm detection by sending the signal by Rc transmitter device through a change in the position of the joystick .
- The reception of the signal concerned through Rc receiver device and pass the signal to Arduino .
- The Arduino processing the received signal in accordance with the saved code .
- Arduino then sends a signal to the motor driver in accordance with the signal processed .
- The motor driver passing electric current to robot motors .
- Movement be synchronized with the detection process .
- First it is detected by detecting the metal part in the mine through the metal detector circuit .
- Metal detector contains a search coil in the movement is controlled by servo motor .
- Servo motor connected to the Arduino and is controlled by RC device by the same way that moves the robot .
- When the target detected by searching coil the detector give an audio alarm and lighting LEDs .
- Finally the person directing the vapor sensor to the target and stop the robot for a period of not more than five seconds .
- The vapor sensor identify the type of target if explosive material found , responds by giving a signal to the Arduino, which is the lighting of the lamp belong to the sensor .
- It is determined the mine site until it is removed .
- If the sensor does not respond for more than five seconds the target is just a metal object .

- robot has a camera sends live broadcast to control center .
- The camera helps to control if the robot is runs in extent outside the scope of vision It also helps in choosing the right path and avoid collision .

4.4.2 Working principle

The system can be divided into two main parts :

- Part responsible for the movement.
- Part responsible for detection

Firstly: Part responsible for the movement

Consists of RC (transmitter and receiver) , Arduino , motor driver ,camera and motors(2 DC motor 12V and servo motor).

i. Arduino

It is the most important unit in the system where it performs all responsible for the movement and the other, which is to send a signal to turn on the motors across the motor driver where all processing operations according to the Code on appendix .

ii. RC (transmitter and receiver)

Is the mediator between the person and robot . It is a device depends on his work on radio waves will transmit and receive signals in the same how they are transmitter and receiver in the radio broadcasting . But the difference in the transmitted data shows that in terms of radio broadcasts are sent a series of signals and channels. They are selected one channel them through the receiver . Either in RC (transmitter and receiver) each mode joystick representing private channel has its own frequency .

The work of RC is based on :

- When you move the joystick in the transmitter is converted ang decoded to digital wave .
- The modelator modelate carrier wave properties according to the digital wave . And maximized modified wave by amplifier .
- The transmitter antenna converts the modified wave to the electromagnetic wave and broadcast in a vacuum .
- The receiver receives the electromagnetic wave through the receiving antenna .
- Selecting the channal Transmitter that has been through it in the RC. receiverMaximize wave and separate the digital wave from carrier wave .
- Finally send digital wave to Arduino, where it is processed according to the Code .

iii. Motor driver

An integrated chip used as a key to start and stop and reverse the movement of motors through the signal coming from the Arduino. It consists of (16) pins can be divided into three groups represents by following table

Table 4.6: motor driver pins.

Group	Pins	Function
Powe group	4 , 5 ,12 ,13	Ground
	16	+5V
	8	0-12V

Speed control group	1	motor 1
	9	motor 2
Movement direction	2 , 7	Motor 1
	10 , 15	Motor 2

Figure(4.9) shows how to connect the motor driver.

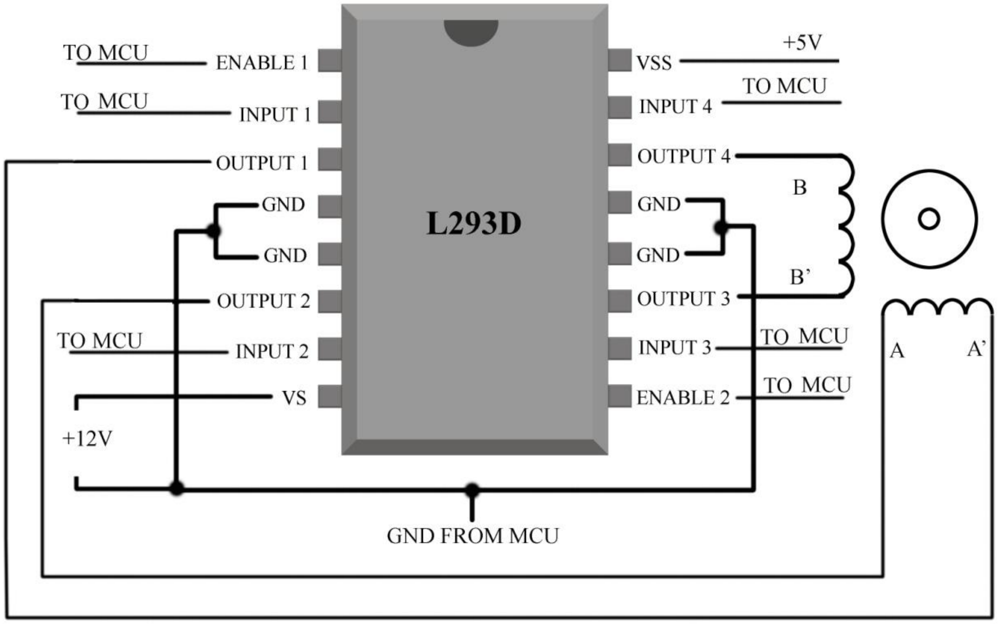


Figure 4.11: the motor driver connecting.

iv. Live broadcast

As we mentioned earlier it's help to control of robot and It is done by the following steps :

- Download and step (IP Webcam) program in the mobile phone .
- Connecting the mobile phone to the Internet .

- Open (IP Webcam) program on a mobile phone .
- Selection start server .
- Copies broadcast link from the display screen and open it on computer (for example .. http://192.168.43.1:8080/).
- Finally turn on Video renderer and Audio player on computer .

Secondly : Part responsible for detection

It is the part that was designed for it robot . And It is consists of a metal detector and vapor explosive detector .

v. Metal detector pulse induction

It is used to detect metal part in the mouth and the principle of it's work will be described in the following paragraph . A single coil of wire is commonly used for both the transmit and receive functions.

- **Transmitter**

The transmitter circuitry consists of a simple electronic switch which briefly connects this coil across the battery in the metal detector. The resistance of the coil is very low, which allows a current of several amperes to flow in the coil. Even though the current is high, the actual time it flows is very brief. Pulse Induction metal detectors switch on a pulse of transmit current, then shut off, then switch on another transmit pulse. The duty cycle, the time the transmit current is on with reference to the time it is off, is typically about 4%. This prevents the transmitter and coil from overheating and reduces the drain on the battery.

As previously mentioned a typical PI search loop contains a single coil of wire which serves as both the transmit and receive coil. The transmitter operates in a manner similar to an automobile ignition system. Each time a pulse of current is switched into the transmit coil it generates a magnetic field. As the current pulse shuts off, the magnetic field around the coil suddenly collapses. When this happens, a voltage spike of a high intensity and opposite polarity appears across the coil. This voltage spike is called a counter electromotive force, or counter emf.

- **Receiver**

Resistance is placed across the search coil to control the time it takes the reflected pulse to decay to zero. If no resistance, or very high resistance is used, it will cause the reflected pulse to "ring". The result is similar to dropping a rubber ball onto a hard surface, it will bounce several times before returning to rest. If a low resistance is used the decay time will increase and cause the reflected pulse to widen. It is similar to dropping a rubber ball onto a pillow. Since we are interested in having it bounce once critical damping for a rubber ball might be like dropping it onto carpet. A PI coil is said to be critically damped when the reflected pulse decays quickly to zero without ringing. An over or under dampened coil will cause instability and or mask the fast conducting metals such as gold as well as reduce detection depth.

When a metal object nears the loop it will store some of the energy from the reflected pulse and will increase the time it takes for the pulse to decay to zero. The change in the width of the reflected pulse is measured to signal the presents of a metal target.

In order to detect a metal object we need to concern ourselves with the portion of the reflected pulse where it decays to zero. The transmit coil is coupled to the receiver through a resister and a diode clipping circuit. The diodes limit the amount of transmit coil voltage reaching the receiver to less than one volt so as not to overload it. The signal from the receiver contains both the transmit pulse and the reflected pulse.

vi. MQ138 vapor sensor

Is the material that TNT is a common materials used manufacturing landmines . Interview that 90% of mines are buried in Sudan is composed of TNT.

MQ138 vapor sensor has high sensitity to most gases involved in th formation of TNT like toluene, acetone, ethanol and formaldehyde, also to other gass like smoke and organic steam. The sensor could be used to detect different organic steam, it is with low cost and suitable for different application.

Sensitive material of MQ138 vapor sensor is (SnO2) , which with lower conductivity in clean air. When the target Organic Steam exist, The sensor's conductivity is more higher along with the gas concentration rising . Figure (4.9) represents Simplified installation of MQ138 sensor .

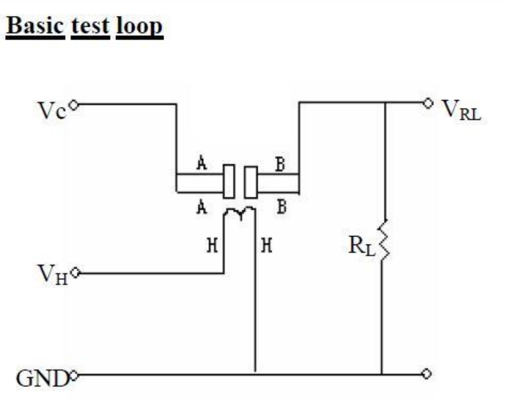


Figure 4.12: Simplified installation of MQ138 sensor.

The above is basic test circuit of the sensor .The sensor need to be put 2 voltage, heater voltage (VH) and test voltage (VC). VH used to supply certified working temperature to the sensor, while VC used to detect voltage (VRL) on load resistance (RL) whom is in series with sensor. The sensor has light polarity, VC need DC power. VC and VH could use same power circuit with precondition to assure performance of sensor. In order to make the sensor with better performance, suitable RL value is needed . figures (4.13 and 4.14) shows characteristics of sensitivity and influence of temperature/humidity respectively.

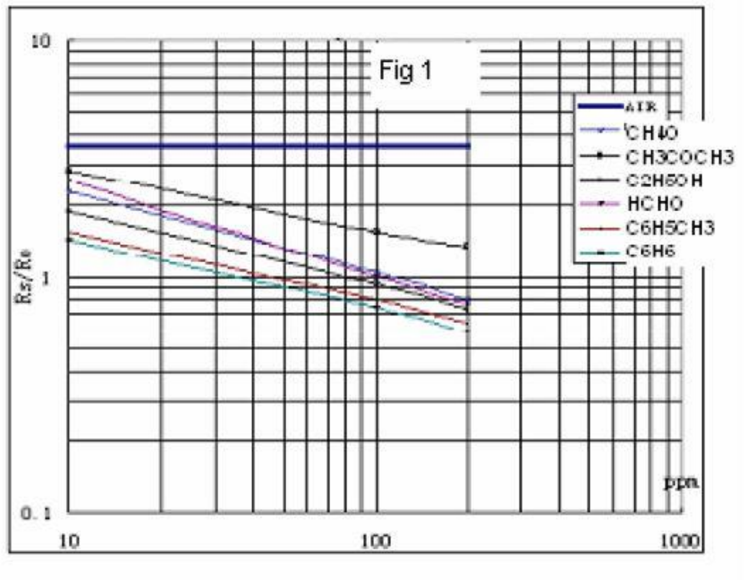


Figure 4.13: Sensitivity Characteristics of MQ-138.

The MQ138, ordinate means resistance ratio of the sensor **(**Rs/Ro**),** abscissa is concentration of gases. Rs means resistance in different gases, Ro means resistance of sensor in 100 ppm Toluene. All test are under standard test conditions

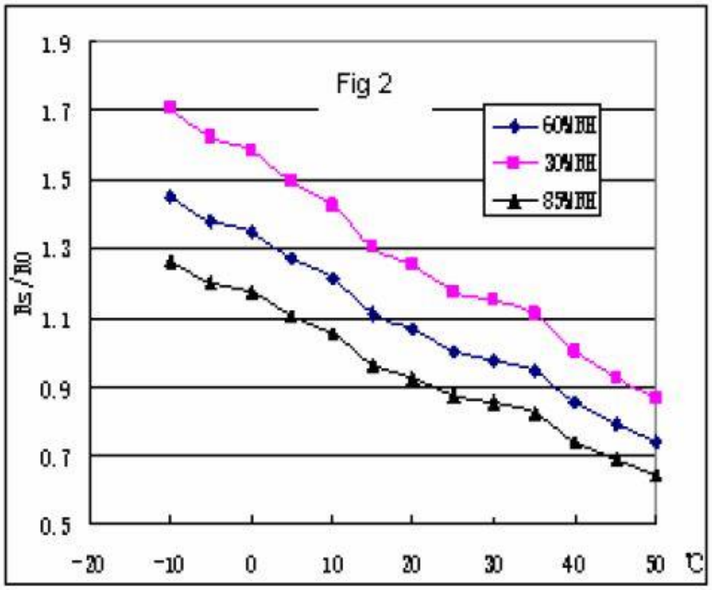


Figure 4.14: Influence of Temperature/Humidity.

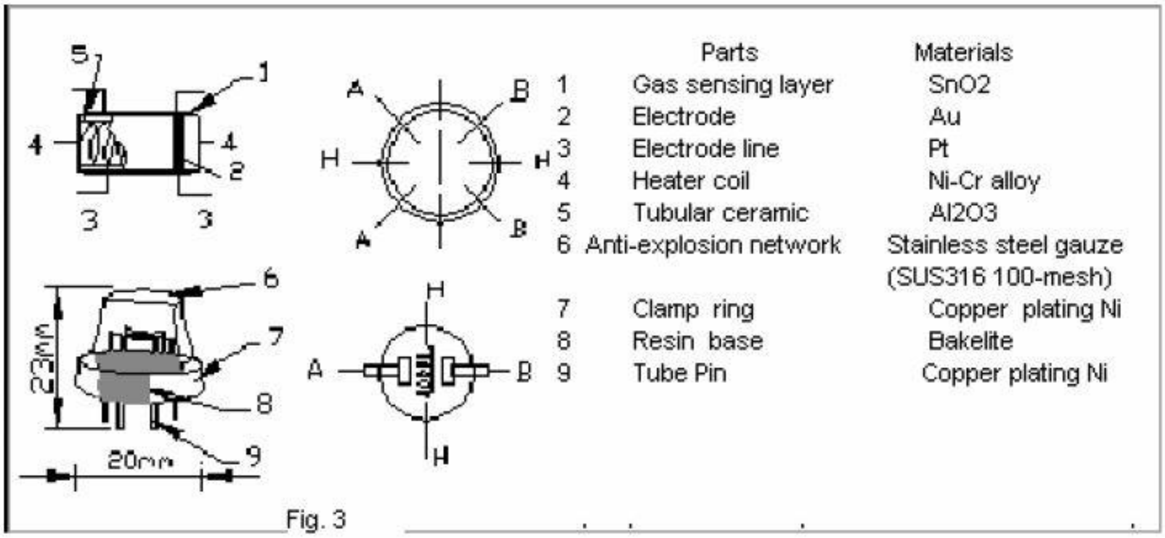
Ordinate means resistance ratio of the sensor (Rs/Ro), Rs means resistance of sensor in 100ppm Toluene under different tem. and humidity Ro means resistance of the sensor in environment of 100ppm Toluene, 20℃/65%RH .

Resistance of sensor(Rs): Rs=(Vc / VRL-1) × RL .

Power of Sensitivity body(Ps): $Ps=Vc^2 \times Rs / (Rs+RL)^2$.

- **Structure and configuration**

Structure and configuration of MQ138 vapor sensor is shown as figure (4.12) sensor composed by micro AL2O3 ceramic tube, Tin Dioxide (SnO2) sensitive layer, measuring electrode and heater are fixed into a crust made by plastic and stainless steel net. The heater provides necessary work conditions for work of sensitive components. The enveloped MQ138 have 6 pin, 4 of them are used to fetch signals, and other 2 are used for providing heating current.



	Parts	Materials
1	Gas sensing layer	SnO2
2	Electrode	Au
3	Electrode line	Pt
4	Heater coil	Ni-Cr alloy
5	Tubular ceramic	Al2O3
6	Anti-explosion network	Stainless steel gauze (SUS316 100-mesh)
7	Clamp ring	Copper plating Ni
8	Resin base	Bakelite
9	Tube Pin	Copper plating Ni

Figure 4.15: MQ138 Structure and configuration.

4.5 system circuit diagram

The component of robot connecting together as shown in figure (4.1).

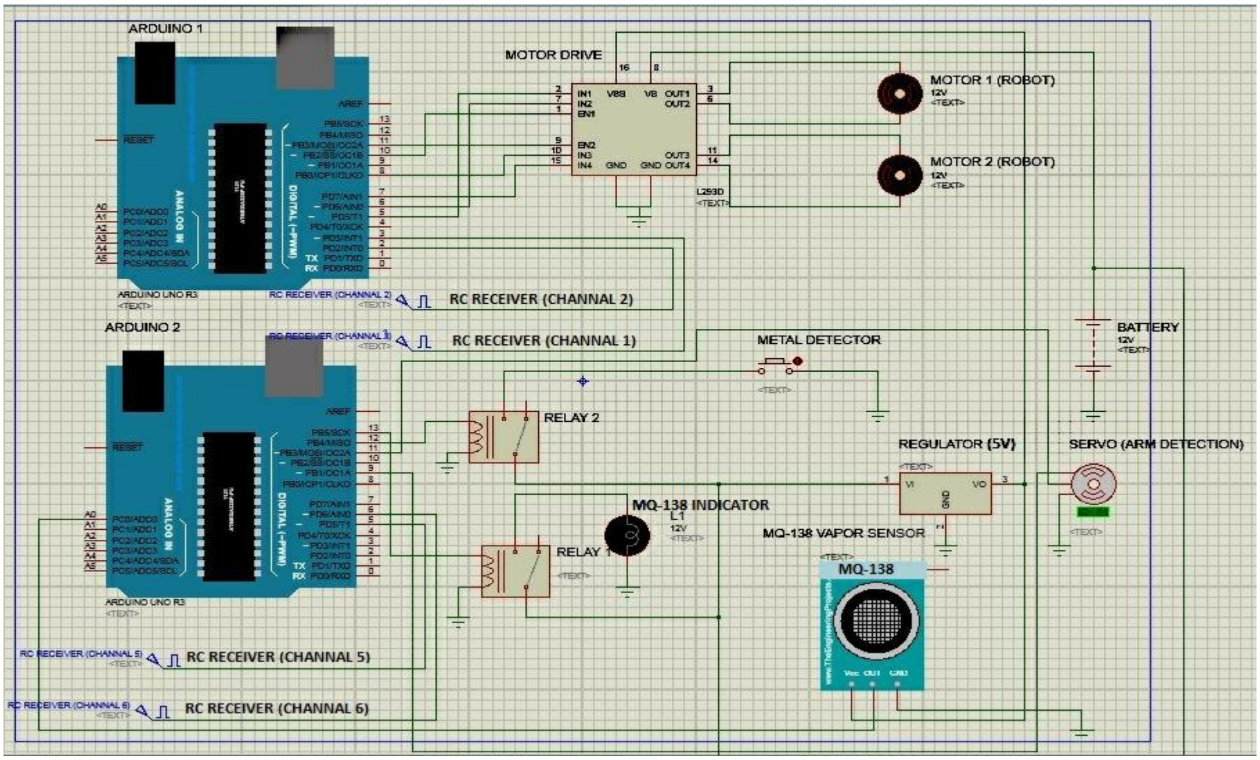


Figure 4.16 : system circuit diagram

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

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CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

At the beginning the idea of detection it method by aircraft , flying at low altitude, it is detected by ultrasound . It faced some difficulties, such as how to penetrate the ultrasound among several media at the same time(The air, cover the mine), through laboratory experiments in collaboration with the university of medical Science and Technology (UMST) and the department of Physics at the Sudan university of science and technology (SUST) .

Ultrasound replaced by thermal infra-red, which handled the problem of penetrating media at the same time. But the method has failed due to the lack penetration crust, relative to acquire the mine the same degree heat of the Earth's crust, which makes differentiate the mine was extremely difficult, during laboratory experiments with Sudan's air defense – reconnaissance unit .

Then thermal infra-red replaced by image processing through aircraft digital camera , method failed for inability to provide appropriate camera that guarantee good results, through cooperation with the department of surveying engineering at the Sudan university of science and technology and the Sudanese Corps of Engineers .

In the same part of the aircraft was used to detect using nuclear method , one of the best theoretical innovative methods to detect landmines . But the cost is high and getting a nuclear source has prevented the implementation of method through cooperation with Atomic Energy Research Centre of the Sudanese and the Department of Nuclear Physics, University of Khartoum .

Also was a try in many other methods such as laser and terahertz but provide appropriate source prevented completion.

All previous methods considers a theory methods needs more research and studies to be applied .

After all that it has already changed the idea of detection from aircraft to robot that detects explosive material mine by electrochemical method (MQ-138 vapor sensor) .

Since all land mines contain metal part was used metal detection method to determine the initial sites to activate (MQ-138 vapor sensor) .

After all of the above, robot achieved the research objectives with High percentage and gives good results .

5.2 Recommendations

- The development of the robot size to work in more difficult terrain .
- Improvement the sensitivity of detecting the old explosive materials that smell fade with the passage of time.
- Improvement Speed response of detecting explosive material, less than two seconds .
- Increment the range of the metal detection to more than 25 cm for grams .

REFERENCES

[1] Jacqueline MacDonald, J.R. Lockwood, John McFee, Thomas Altshuler, Thomas Broach, Lawrence Carin, Russell Harmon, Carey Rappaport, Waymond Scott, Richard Weaver, “Alternatives for Landmine detection”, Science and Technology Policy Institute, 2003.

[2] Dr. Alim A. Fatah, Richard D. Arcilesi, Jr, Dr. Joseph A. McClintock, Charlotte H. Lattin, Michael Helinski, Martin Hutchings, “Guide for the Selection of Explosives Detection and Blast Mitigation Equipment for Emergency First Responders”, Preparedness Directorate Office of Grants and Training , February, 2008.

[3] Carl V. Nelson, “Metal Detection and Classification Technologies”, Number, 2004.

APPENDIXS

APPENDIXS

Arduino (1) code :

```
#define SRC_NEUTRAL 1500
#define SRC_MAX 2000
#define SRC_MIN 1000
#define TRC_NEUTRAL 1500
#define TRC_MAX 2000
#define TRC_MIN 1000
#define RC_DEADBAND 50
#define ERROR_center 50
#define pERROR 100
uint16_t unSteeringMin = SRC_MIN + pERROR;
uint16_t unSteeringMax = SRC_MAX - pERROR;
uint16_t unSteeringCenter = SRC_NEUTRAL;
uint16_t unThrottleMin = TRC_MIN + pERROR;
uint16_t unThrottleMax = TRC_MAX - pERROR;
uint16_t unThrottleCenter = TRC_NEUTRAL;
#define PWM_MIN 0
#define PWM_MAX 255
#define GEAR_NONE 1
#define GEAR_IDLE 1
#define GEAR_FULL 2
#define PWM_SPEED_LEFT 10
#define PWM_SPEED_RIGHT 11
#define LEFT1 5
#define LEFT2 6
#define RIGHT1 7
```

```
#define RIGHT2 8
#define PROGRAM_PIN 9
#define THROTTLE_IN_PIN 2
#define STEERING_IN_PIN 3
#define THROTTLE_FLAG 1
#define STEERING_FLAG 2
volatile uint8_t bUpdateFlagsShared;
volatile uint16_t unThrottleInShared;
volatile uint16_t unSteeringInShared;
uint32_t ulThrottleStart;
uint32_t ulSteeringStart;
uint8_t gThrottle = 0;
uint8_t gGear = GEAR_NONE;
uint8_t gOldGear = GEAR_NONE;
#define DIRECTION_STOP 0
#define DIRECTION_FORWARD 1
#define DIRECTION_REVERSE 2
#define DIRECTION_ROTATE_RIGHT 3
#define DIRECTION_ROTATE_LEFT 4
uint8_t gThrottleDirection = DIRECTION_STOP;
uint8_t gDirection = DIRECTION_STOP;
uint8_t gOldDirection = DIRECTION_STOP;
#define IDLE_MAX 50
#define MODE_RUN 0
uint8_t gMode = MODE_RUN;
unsigned long pulse_time  ;
  Serial.begin(9600);
  Serial.println("hello");
```

```
  attachInterrupt(0 /* INT0 = THROTTLE_IN_PIN */,calcThrottle,CHANGE);
  attachInterrupt(1 /* INT1 = STEERING_IN_PIN */,calcSteering,CHANGE);
  pinMode(PWM_SPEED_LEFT,OUTPUT);
  pinMode(PWM_SPEED_RIGHT,OUTPUT);
  pinMode(LEFT1,OUTPUT);
  pinMode(LEFT2,OUTPUT);
  pinMode(RIGHT1,OUTPUT);
  pinMode(RIGHT2,OUTPUT);
  pinMode(12,OUTPUT);
  pulse_time =millis() ;
  pinMode(PROGRAM_PIN,INPUT);
   }
void loop()
{
  static uint16_t unThrottleIn;
  static uint16_t unSteeringIn;
    static uint8_t bUpdateFlags;
  if(bUpdateFlagsShared)
  {
    noInterrupts();
     pulse_time =millis() ;
    bUpdateFlags = bUpdateFlagsShared;
    if(bUpdateFlags & THROTTLE_FLAG)
    {
      unThrottleIn = unThrottleInShared;
    }
    if(bUpdateFlags & STEERING_FLAG)
    {
```

```
      unSteeringIn = unSteeringInShared;
    }
    bUpdateFlagsShared = 0;
  }
  if(gMode == MODE_RUN)
  {
    if(bUpdateFlags & THROTTLE_FLAG)
    {
      unThrottleIn = constrain(unThrottleIn,unThrottleMin,unThrottleMax);
      if(unThrottleIn > (unThrottleCenter + ERROR_center))
      {
        gThrottle = map(unThrottleIn,(unThrottleCenter +
ERROR_center),unThrottleMax,PWM_MIN,PWM_MAX);
        gThrottleDirection = DIRECTION_FORWARD;
      }
      else if (unThrottleIn < (unThrottleCenter - ERROR_center))
      {
        gThrottle = map(unThrottleIn,unThrottleMin,(unThrottleCenter-
ERROR_center),PWM_MAX,PWM_MIN);
        gThrottleDirection = DIRECTION_REVERSE;
      }
      else
      {
      gThrottleDirection =DIRECTION_STOP;
      gThrottle=0;
      }
      if(gThrottle < IDLE_MAX)
      {
        gGear = GEAR_IDLE;
```

```
      }
      else
      {
        gGear = GEAR_FULL;
      }
    }

    if(bUpdateFlags & STEERING_FLAG)
    {
      uint8_t throttleLeft = gThrottle;
      uint8_t throttleRight = gThrottle;
      gDirection = gThrottleDirection;
      unSteeringIn = constrain(unSteeringIn,unSteeringMin,unSteeringMax);
      switch(gGear)
      {
      case GEAR_IDLE:
        if(unSteeringIn > (unSteeringCenter + RC_DEADBAND))
        {
          gDirection = DIRECTION_ROTATE_RIGHT;
          throttleRight = throttleLeft =
map(unSteeringIn,unSteeringCenter,unSteeringMax,PWM_MIN,PWM_MAX);
        }
        else if(unSteeringIn < (unSteeringCenter - RC_DEADBAND))
        {
          gDirection = DIRECTION_ROTATE_LEFT;
          throttleRight = throttleLeft =
map(unSteeringIn,unSteeringMin,unSteeringCenter,PWM_MAX,PWM_MIN);
        }
        break;
```

```
   case GEAR_FULL:
    if(unSteeringIn > (unSteeringCenter + RC_DEADBAND))
    {
     throttleLeft =
map(unSteeringIn,unSteeringCenter,unSteeringMax,gThrottle,PWM_MIN);
    }
    else if(unSteeringIn < (unSteeringCenter - RC_DEADBAND))
    {
     throttleRight =
map(unSteeringIn,unSteeringMin,unSteeringCenter,PWM_MIN,gThrottle);
    }
    break;
   }
   analogWrite(PWM_SPEED_LEFT,throttleLeft);
   analogWrite(PWM_SPEED_RIGHT,throttleRight);
  }
 }
 if((gDirection != gOldDirection) || (gGear != gOldGear))
 {
  gOldDirection = gDirection;
  gOldGear = gGear;
  digitalWrite(LEFT1,LOW);
  digitalWrite(LEFT2,LOW);
  digitalWrite(RIGHT1,LOW);
  digitalWrite(RIGHT2,LOW);
  switch(gDirection)
  {
  case DIRECTION_FORWARD:
   digitalWrite(LEFT1,LOW);
```

```
  digitalWrite(LEFT2,HIGH);
  digitalWrite(RIGHT1,LOW);
  digitalWrite(RIGHT2,HIGH);
  break;
case DIRECTION_REVERSE:
  digitalWrite(LEFT1,HIGH);
  digitalWrite(LEFT2,LOW);
  digitalWrite(RIGHT1,HIGH);
  digitalWrite(RIGHT2,LOW);
  break;
case DIRECTION_ROTATE_RIGHT:
  digitalWrite(LEFT1,HIGH);
  digitalWrite(LEFT2,LOW);
  digitalWrite(RIGHT1,LOW);
  digitalWrite(RIGHT2,HIGH);
  break;
case DIRECTION_ROTATE_LEFT:
  digitalWrite(LEFT1,LOW);
  digitalWrite(LEFT2,HIGH);
  digitalWrite(RIGHT1,HIGH);
  digitalWrite(RIGHT2,LOW);
  break;
case DIRECTION_STOP:
  digitalWrite(LEFT1,LOW);
  digitalWrite(LEFT2,LOW);
  digitalWrite(RIGHT1,LOW);
  digitalWrite(RIGHT2,LOW);
  break;
```

```
    }
  }
  bUpdateFlags = 0;
}
void calcThrottle()
{
  if(digitalRead(THROTTLE_IN_PIN) == HIGH)
  {
    ulThrottleStart = micros();
  }
  else
  {
    unThrottleInShared = (uint16_t)(micros() - ulThrottleStart);
    bUpdateFlagsShared |= THROTTLE_FLAG;
  }
}
void calcSteering()
{
  if(digitalRead(STEERING_IN_PIN) == HIGH)
  {
    ulSteeringStart = micros();
  }
  else
  {
    unSteeringInShared = (uint16_t)(micros() - ulSteeringStart);
    bUpdateFlagsShared |= STEERING_FLAG;
  }
}
```

Arduino (2) code :

```
#include <Servo.h>
Servo myservo;
#define PROGRAM_PIN 9
#define DETECTOR_PIN 5
#define ARM_PIN 5
int pos = 0;
int ch5 = 0;
int ch6 = 0;
void setup()
{
  myservo.attach(PROGRAM_PIN);
pinMode(A0,INPUT);
  pinMode(11,OUTPUT);
pinMode(5,INPUT);
pinMode(6,INPUT);
pinMode(9,OUTPUT);
pinMode(12,OUTPUT);
  pinMode(13,OUTPUT);
   }
void loop()
{
for (pos = 60; pos <= 135; pos += 1)
 {
    myservo.write(pos);
    delay(15);                          }
  for (pos = 135; pos >= 60; pos -= 1)
 {
```

```
    myservo.write(pos);
    delay(15);
  }
  ch5 = pulseIn(DETECTOR_PIN , HIGH, 25000);
  if (ch5<1000)
 { digitalWrite(12,HIGH);
  delay(15);}
  else{
  digitalWrite(12,LOW);
}
  ch6 = pulseIn(ARM_PIN , HIGH, 25000);
  if (ch6<1000)
 { digitalWrite(11,HIGH);
  delay(15);}
  else{
  digitalWrite(11,LOW);
}
 int val=analogRead(A0);
if (val>60)
{
  digitalWrite(13,HIGH);
  delay(15);
}
else {
  digitalWrite(13,LOW);
}}
```