# Wifi Remote Land Mine Detection Using Raspberry Pi

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**Abstract**— Millions of landmines are buried beneath the soil in tens of countries, waiting to harm innocent humans. That's why hundreds of organizations around the globe engage in demining process. Traditional demining is a very dangerous and risky operation, where identifying the position of buried mines is the most dangerous of all remaining steps. For this, several researches were done in order to reduce this risk, and several technologies exist. We aim here to introduce a system that eliminates the need for humans in the mine field by replacing them with a remotely controlled detection vehicle. This vehicle will be connected wirelessly to a base station located at a safe distance from the danger zone. Doing so, this system will help in saving lives, reducing costs and enhance productivity in the mine detection process.

**Index Terms**— Land mine detection, Metal detector, Raspberry Pi, Pi-GPS, PI-Camera.

## 1 Introduction

In our modern life, technology is what differs us from earlier ages. It's not technology alone to be precise; it's the rapid advancement and growth in it. We live on a fast planet where everything's moving very fast. The main aim of technology is to solve humans' problems and facilitate their lives. It has done that for ages and will still do that.

Internet of Things, Telecommunications, robotics and many other technological terms have recently equipped a considerable part of our everyday activities. With its pros and cons, technology could solve a lot of major issues and save a lot of lives. However, for a reason, that could be financial or political, investing tech in some domains is still considered very modest if compared to the importance of these areas of research. An example of such domain is the land mine detection. Up to this date and according to Landmine and Cluster Munition Monitor report in 2014 [1], it is estimated to have more than 110 million land mines in the ground scattered in 68 countries. An equal or may be larger number is waiting to be planted.

The non-ignorable truth about a mine is the difference in cost between producing it which is as little as 3$ and removing it which is as much as 1000$ [2]. On the other hand, the risk accompanied with their existence should be always an alarming fact to people living near a suspected area. According to the 'International Campaign to Ban Landmines network', more than 4,200 people, of whom 42% are children, have been falling victim to landmines. Other than direct injury for humans, mines deprive humans from the usage and exploitation of important land resources such as fertile lands for agriculture or any usage. In Cambodia, approximately 40% of the rice fields have been mined and abandoned [3].

Usually, demining is done for military or humanitarian purposes. The former objective is to open a safe passage for troops and vehicles and not to clean the whole area. Hence, a certain level of loss is tolerable. While in the latter, the goal is to completely clean a given area of land from any suspected object that will pose a risk on the lives of civilians living around that land space, including curious children.

A lot of research has been already done in the domain of mine detection, extracting and demining. Sensor technology, ground penetrating radar (GPR), electromagnetic induction (EMI), nuclear quadrupole resonance (NQR) and many others are examples of research done in this area [4]. For all these technologies, detection is most probably done by expert humans (detectors) holding a detector to scan a suspected area of land. This process introduces a high cost in terms of time, money and man power.

A comparison between the importance of detection landmines and the efforts that have been deployed to automate the process and to relieve the human detectors from this highly dangerous work will show the lack of technology needed in this area of research. Consequently, we came to the objective of our project, which is to design and implement an automated communications system for the land mine detection. The system will be mainly composed of a central unit that will provide a wireless access point connection to another small unit that we will be calling Robo-pi. This latter is supposed to replace the human detector to do the mission automatically and send data to the central unit for later analyzing. The main

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needed characteristic in such a unit is to be remotely controlled, low cost and with light weight. Hence, human detector will just need to work as mentor to control it, receive data from it and then analyze this data to extract information. Hence, the risk on his priceless life will be tremendously decreases.

Following in this article, we will first present some related work that has been already done in the domain in Section 2. Then, in Section 3, we introduce more details about the system design and implementation of our prototype. Section 4 introduces an important study that we did to base on while selecting the location of the base station to guarantee its safety. Then, in Section 5 we illustrate the implementation tools and steps that we followed to develop our prototype before concluding the article in Section 6.

## 2 Background and Related Work

We can categorize mines into three different classes: anti-personnel mines APMs, anti-tank mines ATMs and unexploded ordinances UXOs. APMs are generally of small sizes, light weight between 2-3 kilos, yet can cause high damage to human if detonated. They usually contain few metal compositions combined with plastic. ATMs in their turn are crafted to detonate heavy weight vehicles like tanks and military convoys. They are big in size, their weights are between 10-15 kilos and mainly consist of metals. The third type, UXOs are the unexploded bombs or grenades, ammo or any other form that can explode. They don't have similar features since they are a combination of various kinds of elements [5].

Although most of the existing mines contain a metal part that helps to detect them via a metal detector, recently planted mines and a part of the already existing ones are well covered in a plastic envelop that will render the process of detection so complex.

As it is known now, traditional mine detection process as it's still being done in many places around the world, has a lots of disadvantages. By using no more than traditional metal detectors, this process endangers the life of humans on field. Moreover, it takes a lot of time due to safety issues that should make human detectors move slowly. That would mean a lot of wasted time, and huge time to finish small areas, in addition to the need of a big manpower to finish the smallest of zones.

All over the world, there are a lot of researchers working on mine detection techniques. They focus on finding and inventing new techniques using new technologies that make mine detection easier and faster than traditional metal detectors. There are ongoing researches on many sensing techniques including ground penetrating radar (GPR), electromagnetic induction (EMI), nuclear quadrupole resonance (NQR) Infrared detectors (IR), Ultrasound and also Explosives vapor detection (EVD) [4,6].

Robotics and wireless communication to transfer data to a server are the domains with the less part of existing efficient related works, especially if we will consider the high speed advancement achieved in these domains and that should be applied in an area of research that is as important as mine detection. Several articles could be found in the literature review such as the approaches presented in [7,8]. Most of them use an ordinary microcontroller to control the moving detection vehicle. This could be appropriate for a narrow scope that is only concerned about a simple metal detector and sending few images to the central unit. Nevertheless, when the detection unit needs to be clever to take decisions and also to connect more developed equipments to it such as developed detectors or cameras, microcontroller will be a blocking stone in the face of improving the proposed project.

In other words, a machine that is as powerful as a real computer is needed to control the unit. But the weight of a real computer is not accepted to be used in such context. Besides, its price will always be a problem when the unit is damaged and needs to be replaced. Raspberry Pi would be the best well-fit solution as we will see later in this article.

## 3 Robo-Pi System Design

As it is illustrated in Figure 1, the system will be mainly composed of a central unit that is responsible of receiving information, and a moving robo-pi unit for detecting, data collecting and transferring to the central unit. This latter is the automated detector that is supposed to replace human detectors. It is implemented with as low cost as possible to render its replacement affordable in case of a sudden explosion because of undetected mine.

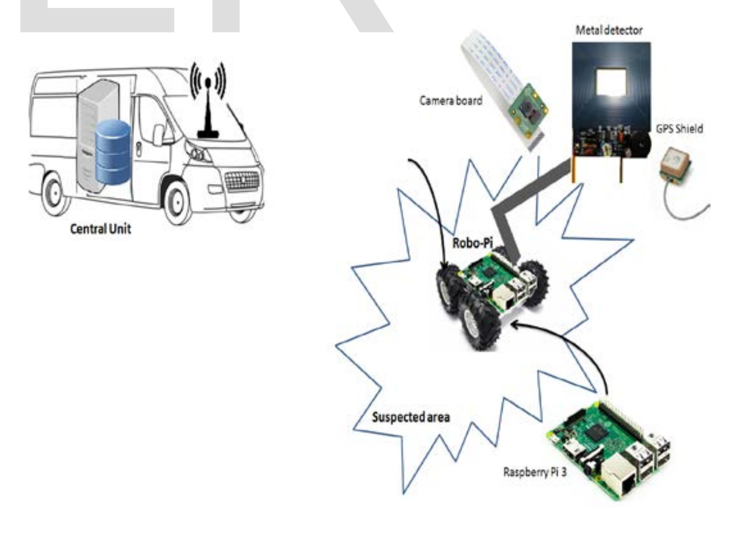



Figure 1- General Architecture of the System.

Human detectors will in this case act as mentors to control the unit. This will guarantee a high reduction of risk on their lives.

Robo-pi unit will communicate wirelessly with the central unit to send the detected information as soon as collecting them. This will insure the receiving of all necessary data even in case of losing the unit. Information transferred is typically the location of each detected suspected object and images from that location.

A list of the use cases targeted in the proposed system is shown in Figure 2. For confidentiality, system access should require credentials for data security and confidentiality. This will be done by allowing only authorized soldiers or humanitarian detectors to control the system.

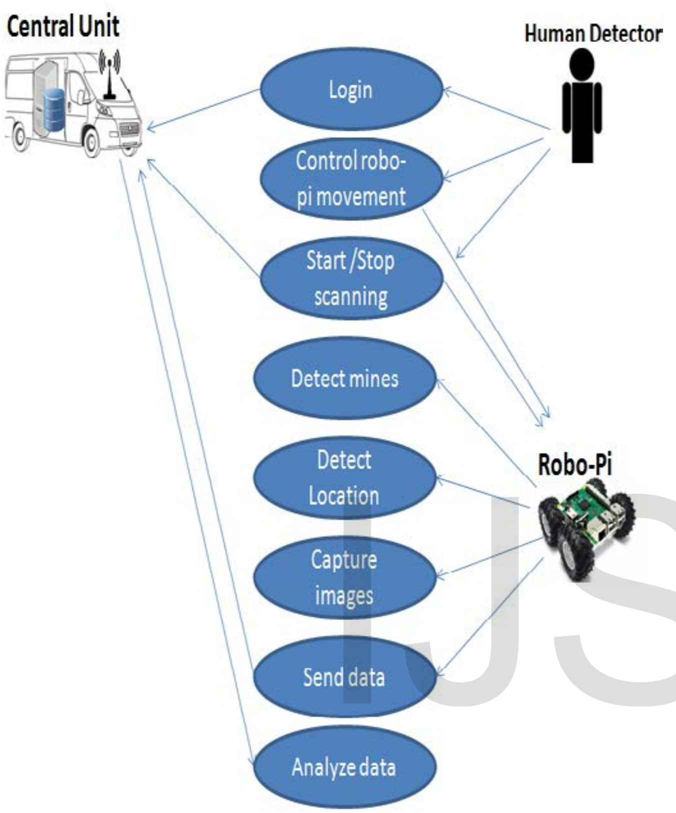
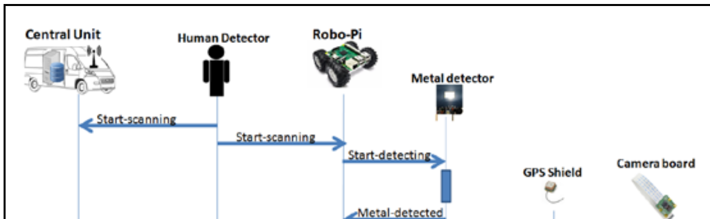



Figure 2-Use cases of Robo-Pi system

A sequence diagram of the system functionality scenario is represented in Figure 3, where the steps done by the three actors of the system, central unit, Robo-Pi unit and human detector are illustrated in order of executing.

## 4 Safe Distance Study

As it is known, mines are of different size, weights and blasting power. So each mine has a danger zone or diameter in which any person inside it will be in great danger of death or at least sever injuries. That's why any choice for a safe distance to put the base station should be studied well in every field depending on the kinds of mines they are expecting to find,




and taking safety issues into consideration. Among the various types and categories of landmines, we studied samples of the most known and used mines like: M18A1 claymore (Figure 4) as an antipersonnel mine, and M15 and TM-65 mine.

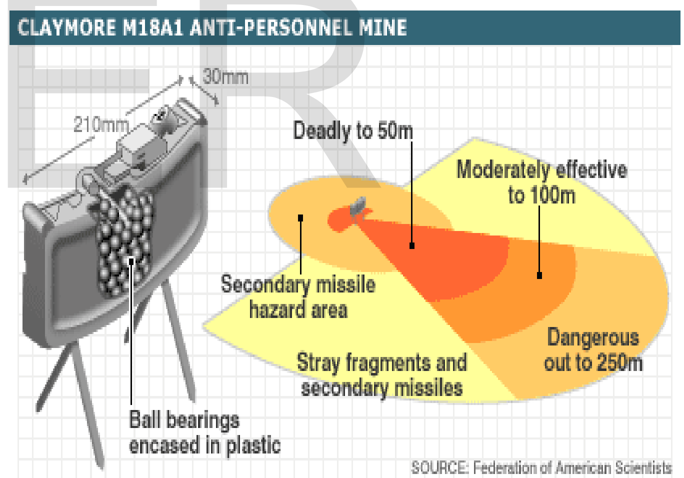



Figure 4- Mine Kill range

The firing diameter depends on the weight of the explosive materials in the mine, as well as the design of mine. Fragmentation mines are an example. "Most of these mines have metal casings designed to rupture into fragments upon the detonation of the mine, or are stuffed with ball bearings, flechettes (tiny metal darts), or metal fragments that are turned into lethal projectiles by the detonation of the mine. They can cause extensive damage to the legs, stomach and chest. Most AP mines shoot their fragments within a 60° horizontal arc and a 2 meter vertical height and can kill up to 50 meters from the mine" [9].

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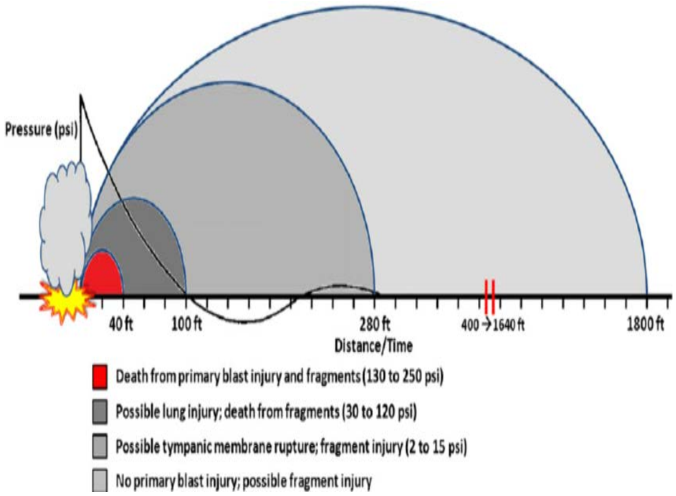


In general, if we want to put a general model for basic safe distances, Figure 5 describes the effective firing power, kill radius and injury radius. Generally to maintain a safe distance regarding most mines, the base station controller must be around 300 meters far from the mine field.

## 5 Implemetation Tools and Details

To guarantee the recipient of all detected data with no losses, a frequent communication between the moving Robo-Pi unit and the central unit is needed. The communication channel capacity, the data transferring speed and the transmission quality will all improve with a less distance to the central unit. Hence, we propose to have a portable server hold on a vehicle providing a communication access point for Robo-Pi unit and positioned at a given distance from the currently scanned area. A balance between the safety of the central unit from any possible explosion and the quality of communication is the based-on factor to choose the location of the central unit for each area in regards to the study that we did and presented in Section IV.

A web server application with a database server is hosted on the central unit to receive collected detection data and maybe analyze it directly in the field when it is possible. This data could be removed when the analysis is done or could be copied to a permanent location for future investigation in case of need. However, for the objective of our current proposal, the data are to be saved in the database for future investigation. Only authorized users are able to access the system based on their credentials as administrators or as soldiers.


As it is shown in Figure 6, the administrator is able to add a new soldier to the system, show the already detected mine images, add an image if an already detected mine to the database for further image processing and analysis tasks and many other functionalities provided in his main page.

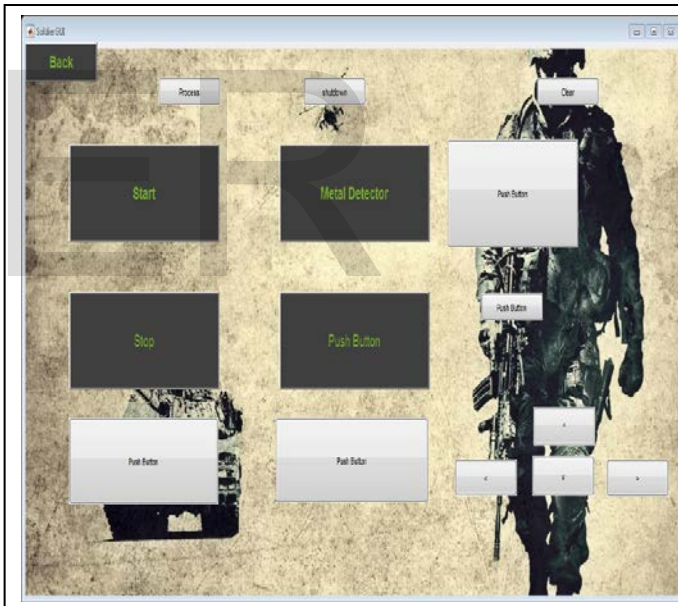


Figure 7- Soldeir main page and actions

On the other hand, the soldier will be directed to the page shown in Figure 7, where he will have different in action options that will allow him to control the ingoing session of detection by controlling the Robo-Pi remotely from his page and controlling the metal detector or the camera to take images when he founds necessary even if there is no detected metal
In its turn, Robo-Pi is composed of a vehicle equipped with a mini computer as its brain, with a metal detector, GPS shield and camera that are all connected and managed by the Pi.

The minicomputer we are using is the Raspberry Pi. It's a small size electronic board, yet it has a powerful processor

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relative to its size. It supports many peripherals, which gives great connectivity for multiple and various usages. It also supports an operating system with a shell window for advanced scripting purposes, and moreover, a graphical interface which gives easy access to a wide amount of applications. It also has a lot of pins that can be connected to many devices or circuits and act as a microcontroller. All these reasons made it the perfect choice. Here, it is responsible of almost all the important tasks. It is connected to all the sensors and takes data from them. It's also connected to the location equipment like the GPS module and camera board, and it takes all the data from them. It creates and maintains a communication channel with the central unit is order to exchange data up and down. This enables the operator to monitor and control the entire system from a safe distance. Moreover, the Pi is also responsible for the movement of the vehicle carrying it. It controls the velocity, acceleration and steering of the vehicle, with the help of GPS and can support manual driving for the operator. This module is also responsible for the task of supplying the system with all the data needed for the task of mine detection. It consists of:

The mine detector to be used on the Robo-Pi could be any type of sensors: metal detectors, Infra-red imaging, Ground Penetrating Radar (GPR), or ultrasonic radars. For the sake of simplicity, cost and availability of equipment, we chose the metal detector to be our sensor. Yet, the same is applicable to any other type of sensors if an organization affords to buy expensive sensors or radars, however we picked a metal detector to be used in this project since most of the existing mines especially the old ones (such like the ones in Lebanon) contain usually a metal pieces to be detected. Besides, most of the existing detection methods are still based on the metal sensors. However, the prototype that we are presenting in this article, can accept with slight modifications any other type of detectors.

Figure 8- Raspberry Pi 3 Model B

Our server side web application contains a preliminary image processing code that we implemented in the objective of trying this developed and needed functionality for future integration into the system. This option takes the image captured by the camera, and then compares its similarity to previously saved images of mines. After comparison, we define the minimum acceptable similarity rate to decide if this is a mine or not based on the already saved images.

Since mines usually explode whenever they detect the weight they are designed for, and although we have chosen the component of our Robo-Pi unit to be as light-weight as possible, but its passage over the mine before detecting it will expose it to high risk. Hence, metal detector is fixed on the bottom of a plastic arm that is attached to the side of the vehicle to detect the mine before the arrival to its location. The GPS shield is also attached on the top of the arm so the location of the detected object is what to be sent to the central unit and not that of the vehicle.

Technically, Raspberry Pi is a single-board, low-cost, high-performance computer that was developed by the UK Raspberry Pi Foundation for educational and later on for a lot of applications and projects [10]. To implement our project, we have chosen to use Raspberry Pi 3 model B (Figure 8), which is the latest edition of this series, a powerful mini-computer with tremendous connectivity options. It has A 1.2GHz 64-bit quad-core ARMv8 CPU with 1GB RAM 4 USB ports, 40 GPIO pins, Full HDMI port, Ethernet port, Combined 3.5mm audio jack and composite video and a Camera interface (CSI).

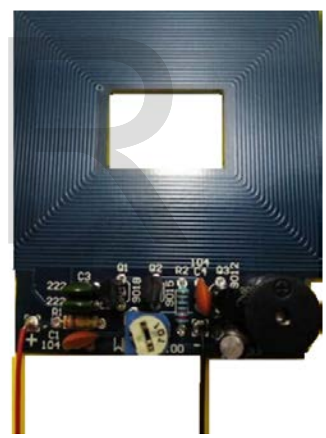

Figure 9- Metal Detector Circuit

The used metal detector as it is shown in Figure 9 is a circuit with a single transistor and old pocket radio. This is nothing but a colpitts oscillator working in the medium band frequency and a radio tuned to the same frequency. When this circuit is set near to a metal object, the inductance of its coil and also the frequency of oscillations will change. Consequently, the difference in the two frequencies would not allow the cancelling of sound and the metal will be detected [11].
This technique of functioning allows the used metal detector to detect objects without the need of direct contact to them. Hence, not only metal objects laid on the ground will be detected, in contrast, detecting buried elements in a depth of 10 to 15cm from the ground surface will be possible also.

For the proof of concept, we used to implement the prototype, a Raspberry Pi camera board, which is the v2 module board 8MP Webcam video 1080p 720p official camera for raspberry with a very small size of a few centimeters length and width. However, for images with higher resolution and of buried or semi buried objects, another variation of cameras will be adopted later on. Since Raspberry Pi contains digital pins, serial input/output and a USB port, connecting any type of camera will be as easy as connecting it to any normal computer, which makes the camera replacement an easy task to be accomplished in the future.

Some extra specifications about the used parts of the prototype are listed below:

- A small to mid-sized RC vehicle.
- Lithium ion rechargeable batteries: that will supply power to the vehicle and the Pi while the Robo-Pi is in the field.
- Motor drive microcontroller: to control movement of the vehicle by taking orders from the Raspberry and transferring them to the motors and wheels.

## 6 Conclusion

Lind mine existence is one of the main concerns that Impedes the retrieval of the normal life parameters after war to many countries and regions. Detection process of these mines usually takes a lot of time and effort and hence, it is usually neglected to the last step of priority levels. The objective of this project was to design and implement an efficient low-cost and small size automatic land mine detector. This detector is based on a Raspberry Pi minicomputer ship that will act as the brain of a small robot to automatically detect and transfer the information about any found metal object to a central unit that will be later responsible of investigating the received data to benefit from it in determining the location and maybe the danger of the found object and hence, find a way to extract or disable it.

The detection process that was used is based on a metal detector that can detect metal objects even with no direct contact with them and even if they are buried to about 10 cm depth. Tests have been done to detect metal objects on different area of lands and the detector could transfer the required information such as the exact location of the objects and the images of the area where the object was found with very good precision. The proposed Robo-pi unit can be considered as a prototype that still need real tests to show its efficiency.

Different future enhancement can be applied to improve the performance of the unit. The usage of an unmanned aerial vehicle (Drone) that flies at a fixed height of the ground is now under progress to be also tested and deployed. This approach will help in reducing the risk of accident explosion of the vehicle via a mine prior to detecting it. Another interesting research has also starting in the domain of image processing to recognize the mine from the other left behind normal objects using the captured images from the detection location. Besides, the type of detector will be considered to improve the performance of the system in terms of non-metal mines that became very common lately.

## References

[1] Cluster Munition Monitor 2014, http://archives.the-monitor.org/index.php/LM/OurResearchProduct/CMM14, Aug 27 [Mar.30,2017].

[2] Alaa Khamis "Minesweepers : Facts about landmines, Internet: http://www.landminefree.org/2016/index.php/ support/facts-about-landmines", Oct. 30 2016 [Mar. 30, 2017 ].

[3] A. Mahmoud and H. Farouk, "An Efficient Detection and Classification Method for Landmine Types Based on IR Images Using Neural Network", International Journal of Geology, Vol.4 iss. 4, 2010.

[4] L. Robledo, M. Carrasco, and D. Mery, "A survey of land mine detection technology", International Journal Of Remote Sensing , Vol. 30 , Iss. 9, 2009.

[5] P. Rapillard and M. Walton, "Humanitarian and Developmental Impact of Anti-vehicle Mines", Journal of Conventional Weapons Destruction, Vol. 18, Iss. 3 ,2014.

[6] M.Kale, V.Ratnaparkhe and A.Bhalchandra, "Sensors for Landmine Detection And Techniques: A Review", International Journal of Engineering Research & Technology, Vol.2, Iss. 1, 2013.

[7] A. Patri, A. Nayak and S. Jayanthu, "Wireless Communication Systems ForUnderground Mines – A Critical Appraisal ",International Journal of Engineering Trends and Technology (IJETT), Vol.4, Iss. 7, 2013.

[8] Facts about Landmines Publication Info (2010, 3, 16) [Online].Available:http://www.care.org/emergencies/facts-about-landmines

[9] J. Bharath, "Automatic Land Mine Detection and Sweeper Robot Using Microcontroller", International Journal of Mechanical Engineering and Robotics Research, Vol. 4, No. 1, Jan, 2015.

[10] Raspberry Pi " https://www.raspberrypi.org/", [Mar. 30, 2017 ].

[11] Metal detector, Intenet: "http://www.circuitstoday.com/ metal-detector-circuit", [Mar. 30, 2017 ].