

Wireless Robo-Pi for LandMine Detection

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Abstract— The tremendous recent involvement of technology in our life generates a lot of advantages and disadvantages. Nevertheless, and in order to highly augment its positive influence, at the expense of the negatives, technology must be deployed to serve humanity and society. In this article, we highlight the importance of involving robotics, communication and data analysis in the domain of landmine detection. The main idea is to design and implement a prototype of an efficient low cost automated mine detector that will replace the current employed human detectors in the mission of detecting and extracting mines in a suspected area of land. This detector will wirelessly communicate with a server to transmit the detected information such as the location of the metal object and captured images of the land where does it exist. The proposed system will help in significantly reducing the risk poses to the human detectors lives while they are in a field of mines. Besides, automation will guarantee an easier and faster scanning process that will open the door to more developed possibilities such as automatically investigating the received big sizes of data for recognizing mines from other left behind normal objects.

Keywords— Land mine detection, Metal detector, Raspberry Pi, Pi-GPS, PI-Camera.

I. INTRODUCTION

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 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 Section2. Then, in Section3, we introduce more details about the system design and implementation of our prototype. Section4 in its turn will be dedicated to illustrate the goal of choosing the components utilized in building the system before concluding the article in Section5

II. BACK GROUND 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. A lot of research have been done on the methods mine detection 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.

III. ROBO-PI SYSTEM DESIGN

As it is illustrated in Figure1, 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.

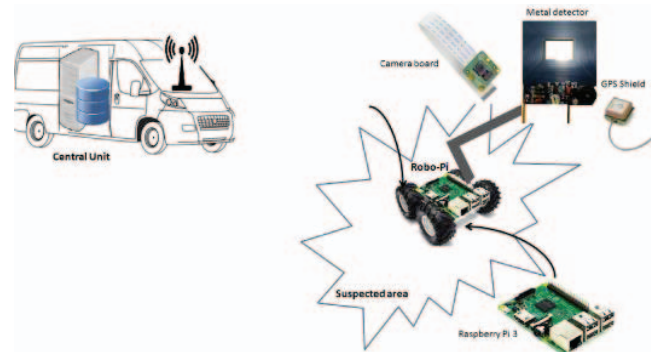


Figure1-General Architecture of the System

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.

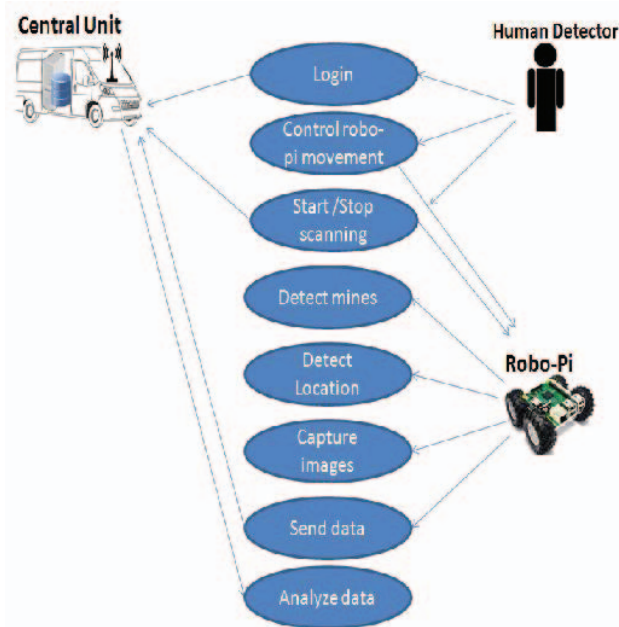


Figure2-Use cases of Robo-Pi system

A list of the use cases targeted in the proposed system is shown in Figure2. 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.

A sequence diagram of the system functionality scenario is represented in Figure3, 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.

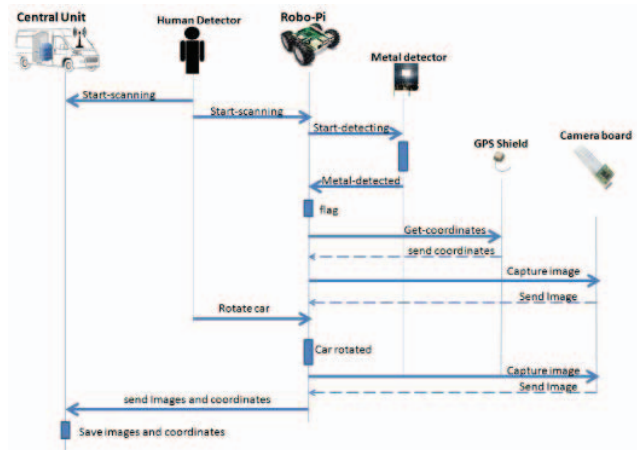


Figure3-Sequence Diagram of a Detection and Data Transferring Scenario

IV. IMPEMETATION TOOLS AND FACILITIES

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.

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. A snapshot of the login page for the web server is shown in Figure4.



Figure4-Central Unit Login Web Page

In its turn, Robo-Pi is composed of a vehicle equipped with a Raspberry Pi as its brain, with a metal detector, GPS shield and camera that are all connected and managed by the Pi.

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.



Figure5- Raspberry Pi 3 Model B

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 [9]. To implement our project, we have chosen to use Raspberry Pi 3 model B (Figure5), 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).

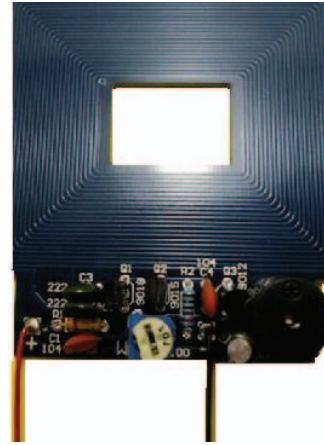


Figure6-Metal Detector Circuit

The used metal detector as it is shown in Figure 6 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 [10]. 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.

V. CONCLUSION

Land 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

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