**AN APPROACH FOR LANDMINE DETECTION AND SECURE INFORMATION TRANSFER USING HIGH SENSITIVE AUTONOMOUS ROBOT**

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**ABSTRACT**

Many people lose their lives because of hidden landmines every day all round the world. The effect of landmine is so huge that it has a three-fold effect on humanity. The loss of limb or life has threatened so many people working in landmine prone areas. Also the presence of landmines has deteriorated the lands which could in turn be used as a productive resource. Thus such human factors and delayed sense of insecurity has affected many a countries in their path towards development. The aim of designing this prototype is to enhance and develop the autonomous robot which exploits its ability to detect and mark the landmines accurately with the help of a GPS module and an automatic mail generation system which would send the captured image of its present surroundings in a secured manner. A path planning algorithm based on uninformed search technique is also employed in the model for its motion and obstacle deflection. An image encryption algorithm using IWT and Play-fair Cipher is used for mail transfer. The technique of differential steer drive along with a GPS module helps in better localisation of the robot when compared to the previous prototype. A web based user interface (UI) application is developed which will help control the robot from a remote location. The key advantages of the developed model are its cost effectiveness, dynamic and secured information transfer.

**KEYWORDS** landmine detection; differential steer drive; magnetometer; bug algorithms; path planning; autonomous, spatial domain, frequency domain.

1. **INTRODUCTION**

Land mines are laid explosives found buried into the ground designed to injure or kill people. They can lie dormant or inactive for years until a person or an animal triggers their detonating mechanism. They are activated by pressure, by pulling a switch, by radio signal or any other remote firing method from a predetermined distance. The most alarming factor is that they indiscriminately injure civilians, soldiers or the mine clearance staff and hence are called “victim-activated”. While there are many activists working towards the ban in the manufacture and selling of these landmines, the real challenge lies in the accurate detection of around 100 million landmines buried in over 65 countries. These landmines are left behind after wars and have been an unsolved problem of the world and are a central issue in Europe, Africa, Asia and central South America. Not only do they affect the military domain but pose a serious threat to the agricultural sectors [9] by making agricultural lands uncultivable. An effective solution for the problem must involve accurate detection of landmines with a minimal rate of false alarms without involving actual human interaction thus reducing the death rate caused in manual landmine detection. Secondly the information regarding the buried landmines must be transferred in a secure form to the concerned demining team so as to avoid the intervention of any other anti-social groups. A major factor to be taken into consideration is the reliability of the technology for effective detection and removal and security of information transfer.

1. **RELATED WORKS**

Several methods and techniques have been proposed on the detection of landmines and their safe removal. The promising methods used so far include RF bombardment, NQR, ground-penetrating radars (GPR), Infra-red detection, various types of neutron energy bombardment, acoustic detection (a sort of land-based sonar), EIT ( Electric impedance tomography), X-Ray Back scatter, other types of electrical energy bombardment, and explosive vapour detection[2].

The IR detection involves the difference in the thermo-physical properties of mines and the soil (as the mines and soil retain or release heat at varied rates) thus forming a thermal contrast above the mines which are captured by the IR cameras to show the variations in the temperature over the mines which can be used to detect the mines [14]. However, Infra-red detection is not efficient, again due the lack of resolution. In addition, the thermal difference produced by a small mine laid just below surface level under a 30cm crop of grass is a difficult target for any detector, even when there are wide differences in daily temperature. Pre-heating the target terrain improves the signal to a certain extent, with a trade off considerable energy cost and administrative effort.

The technology which is more promising is so far the GPR which is mainly due to its increased sensitivity and coverage area, but GPR faces difficulties in reaching the necessary soil penetration with a reasonable target resolution, although broad-band radars can be used to overcome this setback. Field able man-portable GPR sets have been used in trials in Cambodia and Thailand. It is not fool proof because sometimes false alarms are raised due to natural inconsistencies in the soil [1].

Acoustic sensors are used for landmine detection in some approaches [11]. The acoustic wave is transmitted into the ground by the means of acoustic sensors. The sound wave gets reflected at the boundaries present in between the materials with different acoustical properties and based on these reflected waves the location and identity of the target body can be found. But this ultrasound detection is affected by the density and bulk modulus of the soil as well as the system’s operating wavelength. The study of these sensors has also revealed that it is very powerful in the wet and heavy ground such as clay though it is inefficient in sandy soils.

Electric Impedance Tomography (EIT) works on the basis of conductivity distribution. This detection system is best suited for mines and explosives which are buried under water, since the moisture of the substrate leads to the sensitivity due to the increased conductivity of moisture. It uses electricity to generate an image of the conductivity distribution. The system is simple, low cost and weighs less. It consists of bi-dimensional array of electrodes that is placed over the surface to capture signals from the distribution of the conductivity. The information thus obtained can be used for the detection of mines. There is a greater possibility of conductivity anomalies where the mine is buried; hence this system can detect metallic as well as non-metallic mines. This works well in wet soil but poor conductivity of the dry soil in deserts and rocky surfaces makes the system ineffective in those areas. The greatest disadvantage is that sensors must be set in such a manner that they are close to the surface and can be used to detect objects close to the surface. But this increases the risk of detonation of the mines.

The object can be detected by passing the photons through the object. [11]. X-ray has a variety of wavelengths as compared to the size of landmine. This in turn results in high resolution images of buried landmines. In this technique, photons are passed through the object and based on the backscatter of X-rays, information about the target object is found out. The slight difference in mass densities and effective atomic numbers of landmines and soils has been exploited by the X-ray backscatter. They use mobile 450kV scanners. Low energy incident photons are required to detect buried objects, but for such photon backscatter devices soil penetration is poor. Due to this it becomes difficult to locate shallowly buried objects at depths less than 10 cm deep. It is hard to acquire high spatial resolution images by using X-ray, and the time required is long [11].

Nuclear Quadrupole Resonance (NQR): The Nuclear Quadrupole Resonance technique takes advantage of quadrupole moment. Quadrupole moment is the spinning property possessed by nitrogen atom nuclei which is present in the TNT. Hence it is suitable in the detection of actual explosive materials like TNT or RDX. The externally applied radio frequency pulse at the precession frequency generates an oscillating Nuclear Magnetic Moment [11] which is detected by a sensitive receiver. The moment thus found is used to detect the presence of explosives. Researches are still going on in the development of electronics required to generate precisely timed spins at the correct frequencies and to detect even very weak signals. The time required to detect explosives varies in between 0.1 to 1 second for hand held mine detection systems at present [11]. However, the two limitations in this method are, the explosives that don’t show NQR signals are not detected and the liquid explosives are ignored.

Chemical vapour detection [3] includes the project under DARPA that developed a sensor which utilizes novel fluorescent polymers to detect ultra- trace concentrations of nitro atomic compounds released from the landmines, but the range low and is within a few square meters. These polymers were specifically engineered to detect TNT, the most often used explosive in mines (around 85% of mines). Recent field and laboratory investigations of trace landmine chemical signatures suggest that the explosive chemical signature emanating from mines is not necessarily localized immediately over the mine but can extend a significant distance from the mine center. Hence, trace chemical detectors are more useful in detecting chemical signatures rather than locating mines.

Several other methodologies have also been proposed which are more accurate but are not economically advantageous. So the proposed model strives to achieve a mine detection which is optimal as well as economical in nature. Hence electromagnetic induction method of using magneto-meters has been proposed owing to its cost effectiveness and wide range availability with various desired precisions. An effective path planning is also necessary for the efficient functioning of the land mine detection systems. Of the two methods already prevailing, namely, the global path planning and local path planning, local path planning is taken into consideration as the information about obstacles and the environment is unknown.

D\* search and focused D\* algorithms use dynamic path planning but it involves longer calculations and re-planning. Artificial Potential field algorithm suffers a local minima problem when tested in complex environments. In case of Basic theta\* there is time complexity involved in path determination [10] Complex environment navigation is still a big challenge. So several latest techniques are proposed namely the Corridor paths and Bug algorithm families. Corridor paths use collision free corridors along with a reference path for path planning. The technique is fast but however the major setback is the mentioning of a backbone trajectory which becomes quite impossible in case of certain unknown environments. The proposed system thus uses Bug family algorithms which is best suited for the complex environments. This algorithm overcomes the local minima problem and computes the minimum distance to the goal.

The other important aspect is the secured transfer of information regarding the landmines to the appropriate demining personnel to avoid the intervention of antisocial groups. The image encryption using Affine Transform operates on transformation on original image and an XOR operation being performed on this transformed image to get the encrypted image. This system lacks complexity and does not provide complete security [6].The novel digital encryption based on one dimensional random scrambling transforms 2D image into 1D vector and then applies random shuffling and then performing anti transformation on the shuffled vector to encrypt the image. But the histogram of this image reveals excess information so not suitable for highly secretive information [6].An Alternate technique uses enhanced play-fair cipher along with Integer Wavelet Transform (IWT) to work with the image in spatial and frequency domain and the metrics PSNR, MSE, SSIM and correlation coefficient values makes it a highly secure and efficient method [7].

**3.1 PROPOSED SYSTEM**

The prototype design is depicted in figure 1. A Raspberry Pi 3 module is centrally used for its in-built wireless communication capabilities.

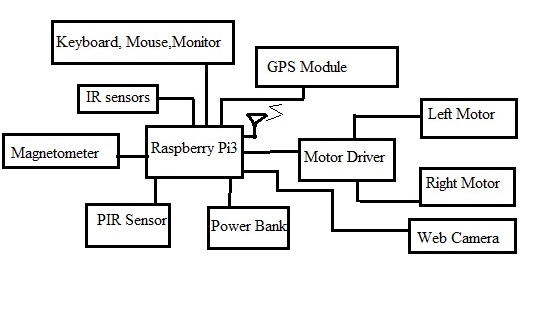


Fig. 1 Basic block diagram of Proposed system

The magnetometer connected to the Raspberry Pi 3 is used for sensing the landmines. The update from AT Mega 128 microcontroller to Raspberry Pi 3 has enabled better and easier way of interfacing with mine detection sensors. The localisation data from the GPS module is dynamically conveyed to the remote terminal that greatly reduces memory requirement from Raspberry Pi 3‘s point of view. The UI developed for the control of the robot reports status of detection of metals or obstacles based on sensor information.

Differential steering along with the GPS method is used for estimating the actual position of the robot. A high precision proximity sensor and two other IR sensors position at the right and left side of the robot helps in obstacle detection and corresponding deflection based on bug algorithms.

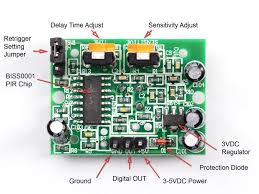
The in-built Wi-Fi in Pi 3 helps establish communication between the controller in the robot and the control stations that are operated remotely. An uninformed search technique helps the robot to traverse it from a given location to another without the actual knowledge of the entire environment. The prototype has several physical and economic advantages such as less dimension around 18.5 × 9.5 cm, approximately weighs 0.77 Kg. With the usage of two 9V batteries to power the wheels, power source for motion can be replaced in quite an economic way. Mine Hunter Beta Version has an on board rechargeable power bank which can power robot for approximately 4 hours.

**3.2 THE LANDMINE HUNTING** **ROBOT**

The designed mine hunting robot is capable of detecting a landmine that is buried even to a depth of 5–10 m. The robot’s top speed is 20 cm/sec that allows for scanning the area effectively. The path planning algorithm used enables in obstacle deflection of the bot that is an enhancement to the existing prototype helping the robot stay away from detection by the enemy. The reliability of the robot is high as it is faster and uses no external communication module that can be tampered with. The robot allows the operator to remain at a safer distance to control and monitor the robot remotely through wireless medium. The robot is designed to use the Raspberry Pi-3 which has its processing unit as ARM 1176JZF-S (armv6k) 700MHz and RISC Architecture with low power draw. The performance of R-Pi 3 as compared to ATmega128 is thus vastly improved.

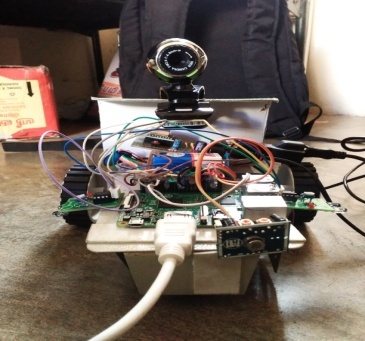
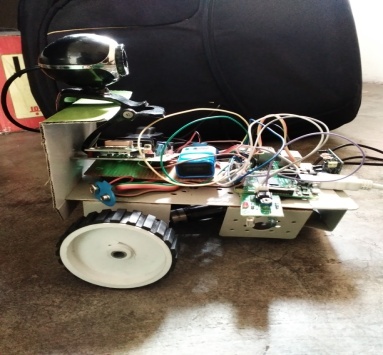
The magnetometer HMC1022 is proposed to be used here as well. [1] “It provides a wider field as its field ranges up to ±6 Gauss. The Magnetometer is designed to enable tri-axis representation for depicting the sensitivity.” In addition its internal components eliminate effects due to signal loss and variation in temperature.

The components of the prototype are shown in Figure 2 .The robot’s various views are shown in Figure 3.

(a) PIR Sensor BIS0001 (b)Magenetometer

Figure 2. Components used

(a)Front view (b) Top view (c) Side view

Figure 3. The various views of the robot (mine hunter beta version)

Differential steering is used to provide independent movement of motors and varying wheel speeds for the robot. Mine hunter Beta version’s stability is managed with two geared motors for its wheels. The robot moves at a maximum of 20 cm/sec but a lower speed can be achieved using a single 9V battery for better mine detection. A L293D motor controller controls the motors in this prototype for the orientation and velocity.

**3.3 PATH PLANNING AND LOCALISATION**

With great advancements in localisation methods there still remains the need for improvement. The GPS module used in this prototype finds the location of the landmine and simultaneously notifies the remote server as well. Such a system combined with a path planning algorithm namely the uniformed search technique called bug algorithm has been used in this prototype. The best algorithms help in effective area coverage and non-repetition of paths. By extending our Bug-0 implemented prototype to a Bug-1, such repetition can also be avoided. But such a system requires calling the GPS every now and then and storing it in the memory to avoid repeated states. This may lead to memory overload and in turn might affect the optimal nature of this algorithm. Additional memory hardware needs to be provided if a larger area is to be traversed and scanned, which may also increase the weight of the robot. Thus speed is reduced. Thus the Bug-0 is simpler and more effective in hardware implementation due to these reasons.

**3.4 SECURITY**

Using DLILL algorithm, in the image captured by the camera module, the IWT (Inverse Wavelet Transform) is applied to get 4 different matrices with transformed values. Leaving the LL matrix undisturbed while encrypting all the 4 matrices obtained by IWT, followed by combining all the matrices and applying Inverse IWT gives the resultant encrypted image. This method gives a maximum encryption with minimal loss in the image data. The advantages of this technique is that unlike all other image encryptions which works either in spatial or frequency domains, this method combines both the frequency domain (by conversion from spatial to frequency domain) and spatial domain (after encryption of frequency domain intermediate) aspects [7] on decryption of the image there is zero mean square error and the original image is obtained back lossless.

**3.5 PLOTTING OF LANDMINES**

The plotting and marking of landmines is done through a mail generation system that has a dual functionality. It notifies the remote server with an encrypted image of the location of landmine once a landmine is detected. The security for the image enables better protection of critical data against anti-national groups. The exact location of the mine is specified by the GPS module in latitude longitude notation. It could be converted to a more readable notation before demining.

The GUI for control of the robot is a simple web application that enables start and stop of a bot. Through this interface, the robot can be operated in a semi-auto mode. Every now and then with a simple refresh of the page, a brief status of the robot can be seen, for example ‘landmine detected at [Latitude, Longitude]’ or ‘obstacle detected’ etc. Thus the status changes with change in sensor information. Through such an interface a more user-friendly application is experienced that does not demand a pre-requisite knowledge base from the operator.

**4. EXPERIMENTAL ANALYSIS**

This prototype developed enhances the speed and security of the landmine detection. This robot could be used for demining in dangerous areas. Moreover its semi-auto mode makes it easier for novice users to handle the robot. This prototype could be used where landmines are found at a depth of 5- 10 m. The percentage of false alarms for this prototype is 10-12% .With the increased security and path planning mechanism along with the proposed hardware setup used here, this prototype is hugely beneficial. Thus Mine Hunter Beta version is more up-to-date, compatible and optimal with better security of information transfer.

A comparison of Mine Hunter and Mine Hunter Beta version is shown below in table 1.

|  |  |  |  |
| --- | --- | --- | --- |
| Features | Mine Hunter | Mine Hunter Beta Version | Advantages of Beta version over the first version |
| Weight(in kg) | 1.3 | 0.77 | Easier mobility |
| Processor clock speed(in Mhz) | 16 | 700 | Faster program execution |
| Sensitivity(in Gauss) | ±6 | ±6 | Equal sensitivity |
| Speed of robot(in cm/sec) | 15 | 20 | Covers large area in minimum time |

Table 1.Comparison of various parameters of the two versions.

The cryptographic algorithms run on Raspberry pi 3 shows the following results as in graph1.

Graph 1.-Method versus Time elapsed for various algorithms

Hence DLILL method for encryption implemented in the prototype shows lesser response time and is most optimal.

**5. CONCLUSION**

The given local environment is scanned thoroughly with minimal false alarms and a better accuracy. The prototype is has light-weight, commercially available components which are cost effective which makes it a better solution for mine hunting without involving much manual interaction. The free movement of the robot is also enhanced as well as owing to its weightlessness, the ability to detect mines without detonating them makes this model a suitable choice. The user-interface is minimal and is aimed at satisfying personnel with a non-technical background. The transfer of image using Wi-Fi through electronic mail system achieved by the enhanced play-fair cipher encryption adds the security factor of the robot. The camera module ensures that the images of the environment are captured accurately in case if a landmine is detected. The future scope of the project lies in the introducing better methods for path planning and more efficient encryption strategies while testing the robot in different environments and scenarios, taking into consideration the weather factors. The overall optimisation of the robot in terms of cost effectiveness, accuracy and the algorithmic complexity can also be improved in the future versions of the project.

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