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A METHOD FOR SECURE INFORMATION TRANSFER AND PATH PLANNING DURING LANDMINE DETECTION

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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. Objective of designing this prototype is the development of an autonomous robot which can detect and locate 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 major advantages of this prototype are its cost effectiveness, dynamic and secured information transfer.

Keywords: **:**Differential steer drive, Bug algorithms, Landmine detection, Path planning, Autonomous, magnetometer, 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 65countries. 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 [8] 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. One major objective should be the secure transfer of information mainly with regards to the image containing landmine location.

2. 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, types of neutron energy bombardment, acoustic detection, Infra-red detection, Electric impedance tomography), X-Ray Back scatter and explosive vapour detection [2].The IR detection involves the difference in the soil's thermo-physical properties as well as the mines thus forming a thermal contrast above the mines that are captured by IR cameras to show the variations in the temperature over mines that can be used to detect the mines [5,13]. However, Infra-red detection is inefficient, due to no presence of resolution. Moreover, the thermal difference produced by mines laid below surface level is a difficult target for any detector, keeping in mind large differences in day-to-day 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 problems in reaching the required soil penetration along with good target resolution. Broad-band radars could be used to overcome this setback. Field able (portable by man) GPR sets have been used in Cambodia and Thailand's trials. It is not fool proof because sometimes false alarms arise due to naturally present inconsistencies in soil [1].

Some other ways that landmines are detected are through the use of acoustic sensors that transmit waves in to the ground [11]. Based on the differences in properties these waves get rebounded at the boundaries and the property and location of the specified object is found. The other factors determining this ultrasonic detection are density of the soil, its bulk modulus and the wavelength at which the system is operating. Recent studies have also indicated that these sensors are extremely powerful in heavy and wet ground but not so much with respect to sandy soils.

Electric Impedance Tomography runs based on the concept of distribution of conductivity. This model is suitable for mines and mine-like objects that are buried deep inside waters, since the substrate's moisture leads to sensitivity due to high conductivity of moisture. Electricity is used here to get an image that explains conductivity distribution. A prototype built on this model would be basic, low cost and would have physical advantages like less weight. It contains an array of electrodes (two-dimensional) that is kept on surface for the capture of signals from the conductivity distribution. Information thus got could be used for the detection of mines. Additionally, there is also greater possibility of anomalies in conductivity where the mine is buried. Therefore, it can find metallic and non-metallic mines present in water. It functions fine in wet soil. Unfortunately, poor conductivity of desert soil (dry) 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.

By passing of photons through the object, it can be detected [10]. X-ray has a variety of wavelengths In comparison to a landmine's size, the amount and variety of X-ray wavelengths is high. This leads to high quality resolution images of the landmines buried. In this method, the object is passed with photons and based on the X-rays backscatter, 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 .To identify buried objects, low energy incident photons are used. Unfortunately, penetration of the soil low for such devices. For this reason it is problematic to mark objects present at depths lower than 10 cms. Thus, through this method it is not only strenuous to acquire high spatial resolution images but also takes a long time [10].

Based on quadrupole moment, the Nuclear Quadrupole Resonance technique is also used for detection. But, one can only find the location of explosives like TNT or RDX using this. A radio pulse is externally applied generates an oscillating Nuclear Magnetic Moment [10] which is detected by a receiver with high sensitivity. The moment found in this way is used to detect the presence of landmines and explosives. Researches are undergoing for improvement of high quality electronics that can detect even extremely weak signals. The required time to find explosives currently ranges from 0.1-1s for hand-held mine detection systems [10]. 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 uses new fluorescent polymers used to detect concentrations of nitroatomic compounds found in landmines, but the range low and is within a few square meters. These were designed to detect TNT that is used for explosive in 85 percent of mines. Reports on trace landmine chemical signatures inform that such explosive chemical signatures emanating from the mines are unlocalized over the mine, rather they show a different location. Therefore, these 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 are global and local path planning .Local path planning is taken into consideration since 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 [9]. 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 digital encryption which is based on 1D random scrambling transforms 2D image into 1D vector and then applies random shuffling to perform anti transformation on the shuffled vector to encrypt the image. Unfortunately, this image's histogram 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.

3. Proposed System

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

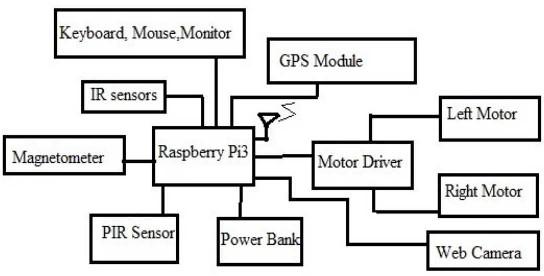


Figure 1. Basic block diagram of proposed system

The magnetometer connected to the Raspberry Pi3 is used for sensing the landmines. The update from AT Mega 128 microcontroller to Raspberry Pi3 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 Pi3'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.

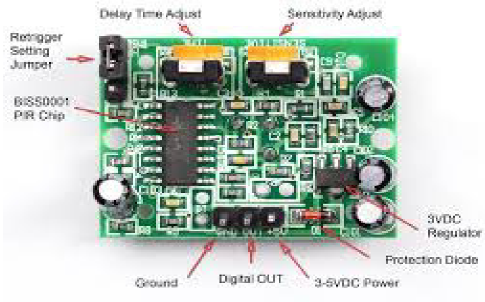
Differential steering along with the GPS is used in marking the correct location of the robot [4]. A high precision proximity sensor and two other IR sensors position at the right and left side of the robot helps in obstacle detection and corresponding deflection based on bug algorithms. The in-built Wi-Fi in Pi 3 helps establish communication between the Pi in the robot and remote control stations. 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 robot called Mine Hunter Beta version has many physical and economic high points such as area dimensions of 18.5 cm × 9.5 cm and weighs only 0.77 kg. 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 that can power it for 4 hours, that is significantly more than the previous prototype's power time.

3.1 The Design of Landmine Hunting Robot

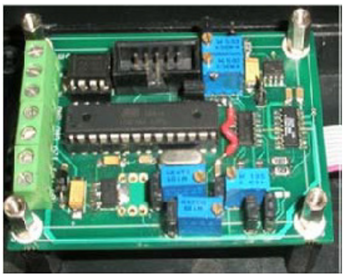
The mine detecting robot can detect a landmine that is buried up to 5 to 10 metres in depth. It's top speed is 20 cm/sec that allows for scanning the area effectively. The path planning algorithm used enables in obstacle deflection of the bot that is an enhancement to the existing prototype helping the robot stay away from detection by the enemy. The robot is faster and uses no external communication module that can be tampered with. The robot can be controlled by remote operator through the wireless medium that is inbuilt. The robot is designed to use the Raspberry Pi-3 which has its processing unit as ARM 1176JZF-S (armv6k) with processor clock speed of 700MHz and a RISC Architecture with low power draw. The performance of Raspberry Pi 3 as compared to ATmega128 is thus vastly improved.

The magnetometer HMC1022 is proposed to be used here as well [1]. It's field ranges reach up to ±6 Gauss. It also enables tri-axis representation for sensitivity depiction. Additionally, 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.



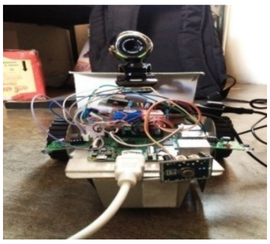
(a)



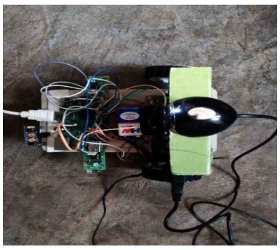
(b)

Figure 2. Components used: (a) PIR Sensor BIS0001(b) Magnetometer

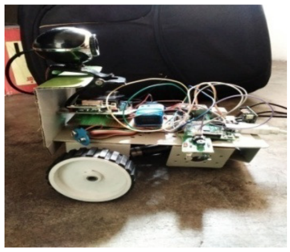
Differential steering is used to provide independent movement of motors and varying wheel speeds for the robot.Mine hunter Beta version's stability is managed with 2 geared motors for wheels. A L293D motor controller controls the motors in this prototype for the orientation and velocity.



(a)



(b)



(c)

Figure 3. Various views of the robot (mine hunter beta version) (a) Front view (b) Top view (c) Side view

3.3 Path planning and Localisation

With great advancements in localisation methods [7, 9, 12] 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 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[11].

4. Analysis

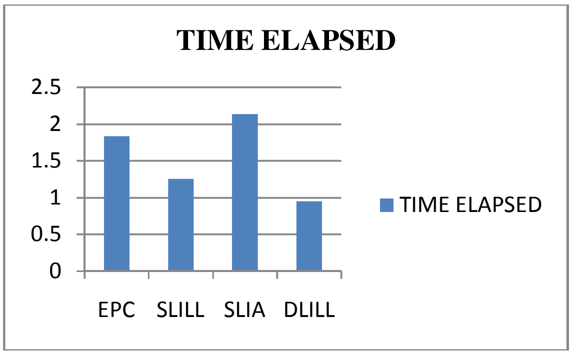
This prototype developed enhances the speed and security of the landmine detection. This robot could be used for demining in dangerous areas. Moreover its semi-auto mode makes it easier for novice users to handle the robot. This prototype could be used where landmines are found at a depth of 5- 10 m. 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 in table 1.

Table 1. Comparison of various parameters of the two versions

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

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.

Acknowledgments

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