

DESIGN AND IMPLEMENTATION OF LOW-COST MOBILE ROBOT FOR MINE DETECTION

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ABSTRACT

There is a dire need for low-cost mobile robots for the purpose of mine detection and disposal. Countries with low gross domestic product (GDP) and infected with landmines generally cannot support expensive high-tech solution. A de-mining mobile robot has to be cost effective compared to local labor costs. Presently commercially available mobile robots consist of mainly custom made parts. The design and manufacturing of such parts make the robots very expensive. This paper describes how careful selection of commercially available parts leads to reducing the development time and costs for a demining robot while ensuring its reliability, convenient operation and application domain. An actual example of how a low cost mine detection robot was successfully integrated within two months is outlined.

INTRODUCTION

There are 40-120 million landmines all over the world today [1]. Landmines are long-term killers and active long after a war is over. According to recent estimates, landmines are killing and maiming more than 26,000 innocent civilians per year [2]. Detection and removal of antipersonnel landmines is a serious problem. Its solution requires the cooperation of various engineering fields. Due to the widespread usage of landmines, there are many diverse environments that a detection device would have to be able to work in. This paper involves designing and constructing the MDBOT robotic vehicle that will scan a predetermined area and detect any landmines that might be present. Upon detecting a landmine the robot will mark the location where the landmine is detected.

This paper concerns the design and implementation of low-cost mobile robot for mine detection. Requirements for a civilian demining mine detection mobile robot are less complicated than their military counterpart, but nevertheless must guarantee full satisfaction of these capabilities [3]:

- Detection of mines in all conditions with near 100% probability.
- Complete coverage of defined area.

In terms of coverage, mobile robot should be capable of following a defined search pattern where off line planning would be performed taking into consideration some environmental constraints. The robot should record and report position during the whole mission, negotiate difficult terrain, walk fast enough to be cost-effective, be faster than a human, while retaining high sensitivity for mine detection.

EXPERIMENTAL PLATFORM

Mechanical System

The GEARS-SMP robot has been selected for the mobile platform that has 4 wheels structure, with 15 pounds payload capacity, and 4.5 inches average ground clearance. A significant portion of MDBOT is built from aluminum in order to minimize weight. The use of steel was kept to a minimum, used only when the strength or ease of fabrication dictated the need for it. The electronics and batteries are placed in two boxes. Four wheels are driven by a high torques gear motors with integrated magnetic encoders. Two left motors and two right motors are controlled each side by one H-bridge. A lightweight robotic arm is attached to the mobile platform for sweeping a mine detector. Four DC motors are linked to 4 revolute joints of manipulator,

allowing the mine detector to move on constrained area. The MDBOT robot is driven by 12 V NiMh batteries.

Computation Hardware

Aiming at low cost and high performance, based on Master Module Controller (involving the XIPMod expansion modules) and embedded real-time operating system, the control system is implemented and the prototype for this platform is developed [4]. The mobile platform has embedded control computer system, input/output module, sensor module, standardized drive modules and wireless communication module. Serial & CAN bus, wireless network are used to connect to embedded control computers and remote base computer, figure 1.

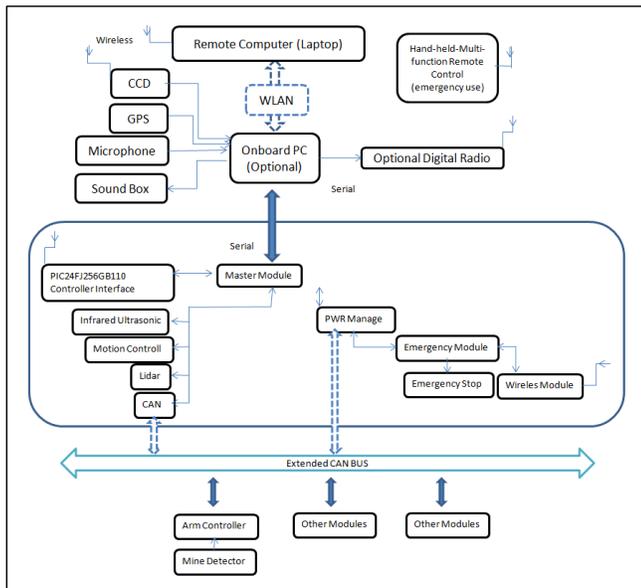


Figure 1: Structure diagram of the mobile platform and the external hardware system.

Sensing Hardware

The vision system consists of the wireless camera. Its main purpose is to follow the swiped area of the robot. The camera can monitor the image for the range of 500 feet. The camera is controlled from the master computer that enables the demining person to have the view of the detected field from distance.

A GPS is controlled under a sensor module that guides the mobile robot to specific latitude, longitude and senses the angle of an incline. Infrared sensors are used on the mobile platform to measure the obstacles in surrounding environment for local navigation and obstacle avoidance. Additionally camera allows navigating the vehicle through minefield. A mine detector attached to a robotic arm

performs the sweeping action for locating suspected objects. The first two axes define the movement of the robot; axes three and four operate with manipulator arm, the commercial mine detector is attached as an end effector. The platform can be operated under autonomous operation and master-slave tele-control.

Landmine Detector

Many countries around the world are impacted by the past and present wars where landmines and other unexploded items remain a danger to people and the environment far beyond the conflict [5]. Landmine detector for military or humanitarian use is highly dependable and easy to set-up, however, it requires trained personnel to perform these tasks which over time it cost us many lives and money. Metal detector used is made by Garrett, which is well known in the metal detection industry, more so, it is fairly priced which makes it affordable to purchase it, figure 2.



Figure 2: LCD screen of metal detector.

Garret metal detector has an independent power supply (6V), which is in use while the robot is sweeping (PhaseMode#4). While operating/driving the robot to its specific sweeping coordinate, metal detector is in sleep mode (not powered). Once the robot reaches its desired starting coordinate, landmine detector receives a wake-up signal achieved using TTL switching relay which is manipulated via data acquisition. In parallel the RFI Noise Elimination switch is activated using the above data acquisition in junction with the TTL switching relay, in order to pin point the exact location and the size of the landmine. Once we sense a landmine we send out a switch signal to the mainframe, to halt the robot from moving while in parallel start Phase “Mode#3” of the robot, which entails that the robot will perform 4 sweeps while the robot maintains the exact same position. The extra sweeps are implemented to better understand the exact location, size, and depth of the landmine, as well as give the GPS receiver enough time to gather multiple coordinate samples to improve the accuracy. More importantly, the GPS coordinates are translated from the center (CG of robot) to the location of the landmine, using other sensors as well as

the pre-determined sweep path which uses specific robotic arm coordinates.

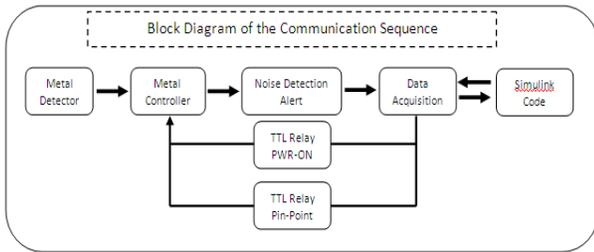


Figure 3: Block diagram of the communication sequence.

Lidar

Lidar is used for many applications such as: Rail traffic technology, wood-work, security/area monitoring system, distance and speed monitoring, as well as object detection. Given the fact that this device is widely used in the automotive industry for many applications such as: object detection, distance and speed monitoring, it shows that the device is durable and reliable. Hence, we decided to use lidar for object detection and possibly in the future incorporate distance and speed monitoring, figure 4. The device is not fully incorporated in the existing stage, however, it is in works to fully incorporate the device in the future stages of the project. This particular Lidar is fairly priced as well as capable of sensing object in 2-D, which is an improvement when considering the older generation of Lidar, where they were able to only detect objects in 1-D. Another special feature of this particular Lidar is the capability of measuring distance and velocity of multiple objects in 3 independent measuring channels in the range of up to 10 meters, which could increase our capability of performing sensor fusion with our other sensors and increase our accuracy for object, speed, and range detection which is highly important when dealing with a project which potentially saves lives in the field.

Incremental Encoders

A photo electric sensor is used to simulate wheel encoders, which would help us in obtaining the distance traveled, figure 5. This idea will be implemented in the upcoming phases of the De-mining Robot. One of the main reasons as to why we are engaging in this approach is due to pricing of the motors with the encoders as well as the existing motors were purchased without encoders.



Figure 4: Lidar.



Figure 5: Photo electric sensor.

Sweep Switch

Two proximity switches are implemented as an end of travel confirmation for the robotic arm, figure 6. There are a few reasons as to why we implemented this feature, such as: eliminating overdrive, position confirmation, sweep orientation status (left to right/right to left), etc. The future use of this sensor will help us in calculating the GPS coordinates of the landmine location, furthermore, it will help us in confirming that the sweep is applied throughout the whole path.

IR Displacement Sensor

Infrared sensor is implemented near the head of the landmine detector, in order to calculate the height of the detector with respect to the ground, figure 7. The sensor will help us in maintaining a constant distance to the ground, by feeding the current distance to the Matlab/Simulink. More so, once the signal (height) is implemented in the Matlab/Simulink, we can adjust the arm kinematics in order to maintain the constant height of the detector with respect to the ground.



Figure 6: Proximity sensor.



Figure 7: IR sensor.

Communication Network

The demining robot is steered by a 4 channel FM Radio Transmitter. The remote controlled operation identifies the existing movement of the mobile platform and paves the way for a potential future upgrade to full autonomous navigation. In order to meet the design requirements, a large number of experiments using physical, mathematical or analytical models as well as simulations were carried out. Performance of the mobile robot is being evaluated with a large number of experiments to test its motion performance,

long running reliability and application in the mine field. The prototype tests have shown promising results.

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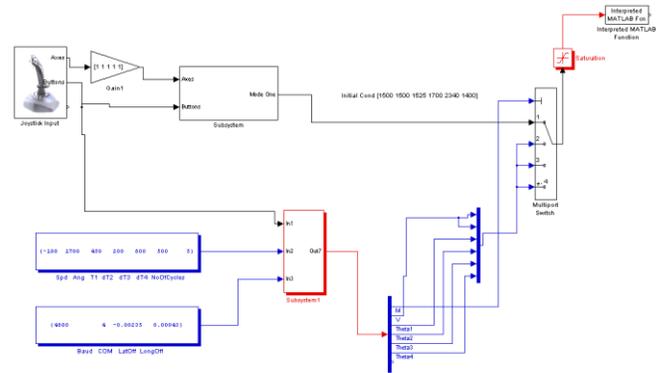


Figure 8: Matlab Main program.

MOTION PLANNING DERIVATION

Robot manipulators mounted on mobile platforms are used in both terrestrial and space applications [6-7]. The mobile platform increases the size of the robot workspace substantially enabling positioning of the manipulator for task execution. Wheeled mobile platforms are subject to non-integrable kinematic constraints. Such constraints are generally caused by one or several rolling contacts between rigid bodies, and the fact that the wheeled platform must move in the direction of its axis of symmetry.

The metal detector attached to manipulator is intended to detect landmines while mobile robot traverses the infected area. Therefore, in order to have complete coverage of the defined area the scanning procedure is broken into two subsystems. Subsystem 1 - mobile platform is stopped until subsystem 2 – manipulator arm is seeking for buried mines while turning left and the band equal to the wheel step rotation.

SIMULATION RESULTS

The simulation is carried out using MATLAB Ver.2011b, figure 8. The MDBOT runs on 4 modes. First mode is manual to setup the rest position, second mode is moving the manipulator arm to initial sweep position, third mode is running the manipulator around the detected mine area, while fourth mode is running the manipulator to sweep and the mobile platform moving straight forward. Upon detecting a landmine the robot will mark the location where the landmine is detected.

The control simulation of MDBOT was visualized using the VRML environment included in the Virtual Reality toolbox of Simulink. Figure 9 shows a diagram of the 3-D model of the vehicle. The dynamics of the motors were modeled to make the virtual robot behave the same as the real world robot, figure 10.

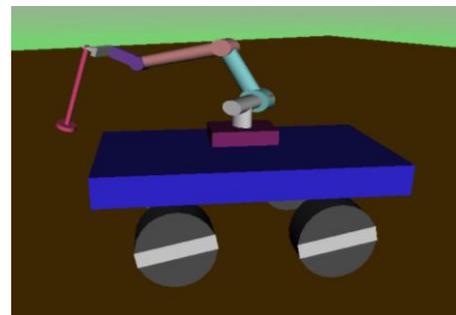


Figure 9: VRML model of the MDBOT.



Figure 10: MDBOT.

EXPERIMENTAL RESULTS

The Matlab GUI shows the traveled path drawn by the blue line, figure 11. The “M” labeled markers show the

detected mines and the “D” labeled marker showing the current position of the robot.



Figure 11: GPS Matlab GUI.

GPS Localization and Tracking

To accomplish such task, GPS location is read from the GPS receiver via serial communication. \$GPGGA NMEA sentence is read to obtain latitude, longitude and satellites in view. The latitude and longitude obtained are in DEG: MIN: SEC format and are converted into decimal degree for use in Google Maps. Additionally the converted latitude and longitude are logged on a local file, figure 12.

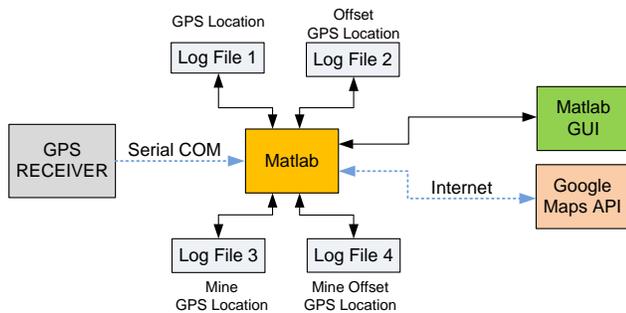


Figure 12: GPS Tracking.

A Google Maps URL is generated for loading a visual map of our current GPS location. The obtained GPS coordinates are inputted in the Google Maps URL which then loads a “.jpg” picture of our location and displayed on the GUI interface. In the URL there are other defined details such as

zoom level, map type and the type of markers that point our location.

For higher accuracy or in cases where GPS is denied, the use of alternative localization method such as an ultra-wideband tracking technique [8] is recommended.

CONCLUSION

In summary, this paper reveals an approach and actual example to building a high-value low-cost mobile robot for mine detection that is able to satisfy most demands of mine detection requirements. The robotic system has been described and control architecture has been presented. Needs for such function robot is genuinely tangible in many countries affected by landmines leftover from wars. MDOBT will contribute to autonomous antipersonnel-landmine detection process.

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