Abstract

Most of landmine detection robots proposed so far have been strongly restricted from locomotion inside the minefield because they cannot cross over the mine. So we have proposed a mine detection robot with hybrid locomotion, which can enter minefield with low ground surface contact, which can cross over the mine instead of changing its path and scan landmines directly using EMI (Electro Magnetic Induction) sensor. The hybrid locomotion proposed in the robot uses the frame walking technique and the conventional wheeled locomotion. The robot switches over the locomotion mechanism from wheeled to leg when mine is detected and vice versa with a lead screw mechanism. The leg locomotion is achieved by frame walking technique where the two frames translate with the help of lead screw mechanism. Very purpose of adopting this combination is to evade anti-personnel landmines which are relatively smaller in comparison to their anti-tank landmine counterparts. With frame walking the robot passes over the mine instead of going around the mine. The robot initially starts in wheeled mode and upon detection of metal, pulls in the frame walking algorithm. The robot also deploys an obstacle avoidance algorithm when working in wheeled mode.

Keywords: Anti-Personnel Landmines, Anti-Tank Landmines, Frame Walking, Ground Penetrating Radar, Hybrid Locomotion.

1. Introduction

In war situations and during military activities, Land mine detection plays a major role. With an estimated 100 million landmines buried in over 60 different countries around the world, landmines have proven to be one of the most serious obstacles to sustainable development in many of the world’s poorest countries. According to the UNICEF, around 2,000 persons are involved in monthly landmine accidents, 800 (40%) of whom are innocent civilians; that is, an average of a victim every 20 minutes dies. According to the UN, even though about 100,000 mines are removed every year; two million more replace them. At the beginning of the 20th century, nearly 80% of landmine victims were military personnel. Today, 90% of landmine victims are civilians, most of whom are children. These mines, not only inflict physical and psychological damages on civilians, but also disturb the economic development of nations where buried mines abound, and prevent these countries from achieving socioeconomic stabilization.

Land mine is a weight-triggered explosive device which is intended to damage a target either human or inanimate by means of a blast or fragment impact. Landmines were mainly designed as area-denial weapons, and are used to create tactical barriers in order to prevent direct attack or to deny access by military and civilians from a defined area. Landmines are perfect soldiers that never eat, sleep, miss, fall ill or disobey. Moreover the landmine perfectly completes its job for much less U.S. dollars than the human soldier; in addition landmines are long-term killers, active long after a war has ended. Landmines which are a serious threat to the human society come in various forms namely Anti-Personnel (AP) mines and Anti-Tank (AT) mines. AP mines are designed to kill or injure enemies with their counterparts doing the work of exploding

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battle tanks, which are usually placed under earth, close to the surface; while AT mines are usually placed on the surface of the earth.

This project aims at developing hybrid locomotion robot for Anti-personnel Mine detection. Two ways of locomotion are considered namely legged and wheeled locomotion. This robot has special foot mechanism where there is a change over in locomotion from legged locomotion to wheeled locomotion and vice versa. The legged locomotion will cross over the mine instead of moving around the mine. Designing the stable mechanical structure of the hybrid locomotive robot is the main objective of this project. Legged locomotion is considered because the area of contact will be less while considering other locomotion. And with the legged locomotion, we can cross over the mine and we can manoeuvre legs more accurately. They will be stable and they can travel over the rugged terrain and they will be more efficiency than other locomotion. But drawback with the legged motion is that other than mine detection areas, distance covered with respect to time will be less so this the reason for need of hybrid locomotion. So next locomotion which we go for is wheeled locomotion, where this locomotion will be considerable fast and can be used for horizontal terrain regions. After the literature review design of legged locomotion mobile robot and wheeled locomotion mobile robots. Based on the literature reviewed, a design of stable mechanical structure for hybrid robot by analysing the best combination of legged and wheeled robot. The robot’s mechanical structure is designed in such a way that it, with the help of its hybrid combination passes over the anti-personnel landmine without detonating it.

2. Techniques and Design

The Hybrid Locomotion robot comprised of five main parts, listed in front to back and its layout is shown in Figure 1.

- fixed arm with metal detection sensor attached
- Outer frame with legs, wheels, arms and lead screw
- inner frame with legs
- Lead screws translating frames with guide ways
- rack mechanism actuating legs

The technique adopted for hybrid locomotion such as combination of sliding and rolling mobility in a single platform to the robot system. The legs and wheels are assembled in such a way that the sliding and rolling motion to the robot is achieved independently and also simultaneously. The sliding motion of outer and inner leg assembly is done using the lead screw mechanism. Which is useful for safe maneuvering in the infected areas like land mines buried location especially in uneven surfaces. The robot platform consists of inner leg assembly and outer leg assembly with linear contacts so that the sliding motion to the robot is achieved. The wheel and arm assembly are integrated on the outer leg assembly in such a way to provide the rolling mobility to the robot.

The robot has a feature of sliding motion by legs which will provide low area of contact on the ground as well as the uneven of the ground has been taken care by adjusting the legs on the outer and inner leg assembly. In order to reduce the no of motors, the front and rear legs are operated using two motors each, meant that front both the legs will be combined with a beam and beam will possess the rack, such that legs can be triggered using rack and pinion mechanism. The wheel will be in ground contact when all the legs are raised up, further the robot moves by the triggering rack and pinion mechanism on front and rear of the outer leg base. In wheel mobility, the neutral turn and steering can be achieved by changing the direction of rotation and vary the speed of the wheels on sides of the outer base legs respectively.

The speed in walking will be low but it can easily manoeuvre the dangerous locations. In the case of wheeled mobility speed will be high but manoeuvrings will be difficult. By this invention the optimization of mission speed is achieved combining the merits of the sliding and wheeled locomotion combination to the robot.
sliding locomotion will be utilized in dangerous field hence decoupling the path of the body and the sequence of legs motion will facilitate higher degree of mobility in a constrained environment and the other places the wheels will be in action so that speed is optimized for the specific mission. The robot with the combined actions of legs and wheel in specified sequence thereby achieve even the larger undulation of ground. The trench and vertical obstacle crossing has been done by the wheels but in some situation the legs and wheels need to act simultaneously.

3. Velocity, Force and Torque

- For this hybrid locomotion robot, the motor has rotational speed of 60 rpm under load and with the wheel diameter of 0.1m, calculation for the velocity will be will be
  - Velocity = circumference × rpm = diameter × pi × rpm
    - V = 18.84 m/s
- For this hybrid locomotion robot, acceleration has to be about half to a third of the robots velocity, So the robot with V = 18.84 m/s, so the acceleration will be
  - Acceleration = 18.84 × 0.5
  - A = 9.42 m/sec²
- This means that it would take 2 seconds (18.84 / 9.42 = 2) to reach the maximum speed
- High force is required to push the robot forward and we need high acceleration. we can determine the force the robot is capable of by the following formula
  - Force = mass × acceleration = 47.1 kg-m/sec²
- The relation for the force and torque can be expressed by following formula that is given below
  - Torque = distance × force, = (0.1/2) × 47.1 = 2.355Nm

4. Weight Estimation

Table 1.

<table>
<thead>
<tr>
<th>S No</th>
<th>Name of the Components</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Outer Frame With Leg Assembly</td>
<td>2 kg</td>
</tr>
<tr>
<td>2</td>
<td>Inner Frame With Leg Assembly</td>
<td>1.50 kg</td>
</tr>
<tr>
<td>3</td>
<td>Motors</td>
<td>1 kg</td>
</tr>
<tr>
<td>4</td>
<td>Electronics Unit</td>
<td>.25 kg</td>
</tr>
<tr>
<td>5</td>
<td>Other Components</td>
<td>.25 kg</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td>5 kg</td>
</tr>
</tbody>
</table>

5. Analysis and Stimulation

The modal analysis is carried out for the inner frame and outer frame separately and visualized the maximum deformation that can occur when the robot is subjected to load in various points. The Figure 1 represents the modal analysis of the inner frame, when it is subjected to the deformation with respect to the z axis.

The Figure 3 represents the modal analysis of the outer frame when it subjected to the deformation with respect to the y axis.

6. Control Architecture

The architecture is adopted to suit the hybrid locomotion. The system follows behavioural approach with sensors to interpret the physical world, onboard microcontroller based control system to processing the collected data and for decision making and set of actuators to do the useful work.
6.1 Mode Selector

The mode selector constantly monitors the metal detection sensor output and the ultrasonic sensor output with the former having higher weightage than the latter. The metal detector’s digital output is tied to the RBO/INT pin of PIC 16F877A which is an external interrupt pin. Upon being interrupted the microcontroller calls the frame walking subroutine which involves a series of motor driving to negotiate the mine which in our case is a coin for experimental purpose. The metal detector also gives an alarm as soon as it detects a metal. When not interrupted through RBO, the mode selector authorizes wheeled mode which does navigation through ultrasonic sensor\(^1\).

6.2 Motion Planning

When in frame walking mode, the motion planning algorithm guides the robot to negotiate the coins.

The knowledge base has the set of possible cases the robot can be compatible with. By case we mean the possible patterns of coin distribution on the floor. The case verifier refers to the knowledge base and checks if the current case is present or not. If it gets positive reply it initiates the action execution to perform the corresponding actuation. A sample case is explained below\(^2\).

3 mines in our case coins are placed in line horizontally. The robot starts from START. As soon as it reaches 1\(^{st}\) coin the metal sensor gives high. Then the robot which is still now in wheel mode continues to be in it, retraces its path by travelling for ‘t1’ time. Makes a right turn which is its priority and travels ‘t2’ time, then takes a left turn and travels ‘t1’ time\(^3\). And now if the sensor gives high it understands the situation and repeats the same to check 3\(^{rd}\) one. If its positive it aligns itself straight to 2\(^{nd}\) and switches to frame walking and passes over. The above case will only hold if 2\(^{nd}\) coin is placed closer such that it robot requires ‘t2’ time to align to it. Otherwise the robot aligns it with 1\(^{st}\) coin and performs frame walking\(^4\).

![Figure 3. Control Architecture of Hybrid Locomotion Robot.](image)

![Figure 4. Motion planning.](image)

![Figure 5. Possible case of mine negotiation.](image)

![Figure 6. Robot encountering obstacle.](image)
6.3 Obstacle Avoidance

With an on board ultrasonic sensor the robot performs obstacle detection and avoidance scheme. The algorithm is devised to be so simple to reduce the computational load of the onboard 8 bit microcontroller. Upon detection of an obstacle the algorithm measures the distance ‘x’ to the obstacle. If x>x3, the robot takes 20° left and goes straight for ‘t1’ time and then takes 20° right and goes straight. If x<x3 and x>x2 the orientation angle is 45° and if x<x2 and x>x1 the angle is 90°.

7. Hardware Configuration

The Metal sensor model 1139 from Sunrom technologies is used. It has a sensing range of 7cm. It is fixed on an extended arm like structure in front of the robot. Apart from a logic 0 output via its out pin it also gives a buzzer and LED output upon detection of metal objects. Ping Ultrasonic sensor which has a range of 2 cm to 3 m is used. The PIC 16F877A microcontroller is used as the control centre. With its RISC architecture it offers high performance. L293D based motor drivers are used for driving 7 d.c motors to achieve both modes of locomotion.

8. Specification of the Robot

- Weight of the robot = 5kg
- Velocity of the robot = 18.84 m/sec

9. Conclusion

In this paper the design and development of hybrid locomotion mobile robot which mimics a mine detection robot is presented. The design evolved considering proper choice of material, hassle free locomotion scheme, reduced friction between moving parts, weight, size, seat for onboard control system. In the later part the hardware control architecture is discussed. It aimed at developing a robust system which centres around a RISC computing device solves the problems of metal sensing, locomotion, obstacle avoidance. Each individual problems are briefly discussed. Experiments are being carried out to validate the system and the future prospects include upgrading the system to encounter uneven terrains with tracked wheel, maintaining stability while moving in uneven terrains.

10. References

