Robot Rangers

High Level Design Document

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Table of Contents

1 Introduction

According to the UNICEF, almost 10 000 people per year are killed by land mines, most of whom are civilians. Thousands more people lose limbs, livelihoods or loved ones[1]. In many cases, the conflict is long over but the danger remains due to the difficulty of finding and destroying the mines. Yet, destroying them is imperative for long term safety, and with over one hundred million planted world wide it is a daunting task[1]. Substantial action is required, but one must disarm a hundred million deathtraps.

2 Problem Statement and Proposed Solution

The problem is the minefield itself: a large area where a large number of explosive devices are randomly hidden. They cannot be spotted visually, since many are buried or designed to be difficult to detect. Disarming them personally would be extraordinarily hazardous, especially without knowing where the mines are buried.

Our proposed solution is a wirelessly controlled robot capable of locating the mines and marking them for future removal. The main goal is keeping humans out of danger, and by remotely locating the mines, disposing of them becomes much easier. Even if a mine is triggered during the marking process, the loss of a robot is a small price to pay.

3 System Description and Block Diagram

The Mine Detecting Robot system will consist of two main parts: the robot itself and the remote control system used to drive the robot and display information about the metal detectors to the user. The two parts will communicate with each other through a wireless connection that will send control information to the robot and return sensor information to display on the remote.

The core of the robot system will be a microcontroller. The microcontroller will receive input from the metal detecting sensors as well as from the wireless transceiver. The output will be sent to the motor driver circuits and also through the wireless transceiver back to the remote. Our current choice of wireless technology, Zigbee (which is discussed more in section 6), will communicate to the microcontroller through an SPI interface. A rough block diagram of the robot system is shown below.

Robot Block Diagram

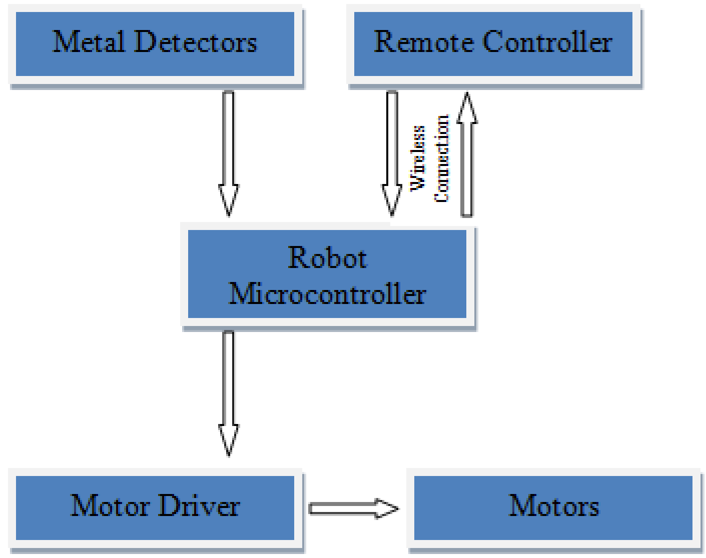

Figure 1

The core of the remote control system is also a microcontroller. This microcontroller will receive inputs from joysticks mounted on the remote control board. Joysticks function as analog potentiometers and will connect to the micro controller through an analog-to-digital converter, which our current choice of microcontroller (section 5.1) supports. The remote control microcontroller will also have a wireless transceiver used to communicate with the robot system. It will send control information to the robot and display information about the metal detector array in an LED configuration on the remote controller board. A rough block diagram of the remote controller system is shown below.

Remote Controller Block Diagram

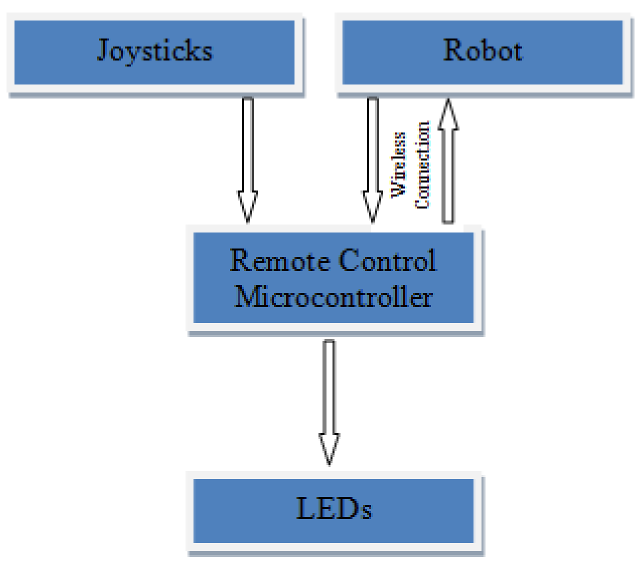

Figure 2

4 System Requirements

4.1 Overall System

-Must maintain a wireless connection out to 50 meters.
-Must have a battery life of at least 30 minutes when in normal operation.
-Must have a battery life of at least 2 hours when in standby mode.
-Must detect and mark mines.
-Must not cause mines to detonate.

4.2 Subsystem and Interface Requirements

4.2.1 Remote Control System

-Movement of the robot must be able to be controlled through a physical user input interface.
-Physical user interface must accept inputs based on user input and send outputs to the robot.
-Physical user interface must control the locomotion and turning of the robot via 2 joysticks.
-Physical user interface must send output (i.e. commands) to the robot via a wireless connection.
-Must have LED configuration to show output of metal detectors to the user.
-Physical user interface must be easily understood and operated without significant training.
-Must be powered by either a battery or a power brick connection.
-Battery life of the unit must last at least 2 hours.
-Physical user interface must send commands to the robot via a wireless connection.

4.2.2 Wireless Interface

-Must be able to transmit through solid objects such as trees and rocks.
-Must be able to communicate fast enough to ensure no more than 1 second of lag to the robot.
-Wireless connection must have a range of least 50 meters.
-Must not consume more power than the remote control unit can supply.

4.2.3 Mine Detection System

-Must detect mines within a wide area.
-Must mark location of mine accurately.
-Must be able to mark a large number of mines.
-Must not set off mines during scanning and marking process.

4.2.4 Robot Microcontroller

-Must have a separate input for each metal detector.
-Must have enough additional inputs to accommodate the number sensors needed for autonomous movement to allow for future enhancement.
-Must interface with a wireless transmitter.

4.2.5 Robot Power Management
-Must be capable of supplying power to robot for at least 30 minutes when in normal operation.
-Must be able to supply power for at least two hours when robot is in standby mode.

4.2.6 Movement System
-Must be able to move in response to user input.
-Must be able to turn in place.
-Must be able to vary speeds of both treads/sets of wheels.
-Must be able to move in forward and full reverse.
-Must be able to move on hard surfaces, grass, gravel, dirt, and slightly wet ground.

4.3 Future Enhancement Requirements
The robot would be even more effective if it did not require constant supervision and instruction from an operator, which would be accomplished through the addition of an autonomous mode. This would be difficult since the microcontroller would have to be able to independently sense it's environment and position itself over a detected mine in order to mark it.

Another future addition would be a digital copy of the locations of the mines, creating a map for future reference. This would require significant programming to accurately track the relative location of the robot and the location of the mines.

5 High Level Design Decisions

5.1 Remote Control System
The core of the remote control system will consist primarily of a circuit board with a microcontroller. The microcontroller will have to have enough output and input pins in order to handle the joystick input and LED output. The microcontroller will also have to have the capability to communicate with the wireless connection. The Zigbee wireless connection requires a Serial-Parallel serial interface (SPI). An example of a micro controller with such capabilities is the PIC18LF6723 microcontroller available from Digikey.

5.2 Wireless Interface
The wireless interface will require a Zigbee antenna and a Zigbee transceiver IC. One such RF transceiver circuit is AT86RF231 available from Digikey. This device can be controlled with an SPI interface, which our microcontroller can handle.

5.3 *Mine Detection System*
To minimize the number of passes needed to scan a given area, the robot will have five total metal detectors attached to it, four primaries and one secondary. The primaries will be arranged in a trapezoid around the front of the robot to maximize the detection area, with two on each side and two on the front corners of the robots aligned with the wheels or treads. These will be held in place using PVC pipe. Since each detector has a relatively small detection area, they should not interfere with each other. The fifth detector will lie beneath the robot centered

between the treads, and will be used for marking the mines. The goal for the operator is to align the mine underneath the robot using this detector, then activate the marking system.

Each metal detector outputs an analog signal, which needs to be processed and sent to the display on the controller. The information needed is the magnitude of the output, which is proportional to the proximity of metal to the detector. The signals will most likely need to be passed through an analogue to digital converter for processing.

The marking system needs to visibly mark the location of a detected mine. Spray paint will be used to give a lasting mark, centered on the location of the mine. The paint can will be aligned with the detector and activated with a small motor to depress the nozzle and paint the ground, marking the mine.

5.4 *Microcontroller System*

The microcontroller in the robot will need to communicate with a wireless transmitter, send output to control the motor, receive input from the metal detectors, and be able to handle an upgrade to autonomous functionality. To communicate with the wireless transmitter, the microcontroller must support SPI protocol. To perform the other functionalities, the microcontroller needs to have a sufficient number of pins communicating with the motor, providing each metal detector with a separate pin, and providing enough pins for upgrade to autonomous functionality. The PIC18LF6723 could be used as a microcontroller as it supports SPI and has 54 I/O pins.

To provide power to the microcontroller, a battery separate from the main power supply to the motor will be used. Using the PIC18LF6723, the battery will need to be able to supply between 4.2V and 5.5V for at least 30 minutes while the robot is operating normally, and for at least one hour while the robot is in low-power mode. This can be provided using a generic radio control hobby battery pack.

5.5 Movement System

The movement subsystem will receive data from the microcontroller about the desire movement received from user input through the remote control system. In order to vary speed, Pulse Width Modulation (PWM) can be used to vary the amount of power that is delivered to the motors. DC motors will be used because they provide a relatively simple implementation as well as variable speeds. The selection of a specific DC motor will depend on the overall size of the robot, the maximum speed desired, and the amount of torque needed.

In order for the robot to turn in place, we will implement Tank Drive, which uses two DC motors to control the movement of the robot. One motor will control the wheels on one side of the robot, while the other motor will control the wheels on the other side. Each motor will require a separate output from the microcontroller. To turn the robot in place, one motor must be turned in full forward while the other one turns in full reverse. This can be achieved because another requirement states that the robot must be able to move in full forward and full reverse. In order to allow the same motor to turn in both directions, a simple circuit known as an H-bridge will be used. It is basically a set of four switches, which when certain ones are closed, allows current to go forward or backwards through the motor. This change in current drives the motor either forwards or backwards. Such a circuit can be implemented through discrete components, but there are integrated circuits that can also handle the task.

For the robot to be able to traverse various surfaces such as pavement, grass, gravel, dirt, and slightly wet ground, we will build a robot that can utilize either wheels or treads, with further testing on the various surfaces determining which method will be used in the final design.

6 Open Questions

The following is a description of the elements in this design which we are unsure will be ultimately successful and which will need to be tested and possibly replaced with alternative solutions.

One of the primary goals of this design is to have a robot capable of accurately detecting mines in a sufficiently wide path as it moves across the mine field. In order to do this, we have designed to have a trapezoidal positioning of five detectors as previously described. The detectors will need to be tested to determine how far they can be spaced apart while still accurately detecting mines in the space between them. Depending on how far the detectors can be spaced, we may need to add more detectors to cover a reasonably wide path. The factors that would limit the number of detectors we can add would be the weight of the detectors, the power needed to move the robot, and the size of the overall robot.

The wireless connection between the robot and the remote controller will also require testing before we can commit to any particular system. We are currently planning to use the remote controller to send motor control information from the remote to the robot and to send information about the detection of a mine from the robot to the remote. The system we have currently designed uses an SPI interface to connect to a ZigBee transceiver; however, this will need to be tested to see if it is functional out to our target 50 meter range, and to see if the data transmission rate is enough to control the robot in real time.

Lastly, the robot must be able to navigate the terrain where the mines are located. This will be accomplished by using either treads or wheels; however, we are unsure which option will be the easiest to implement and most effective. To decide between the options we will need to take into account the physical layout of the robot and the relative complexities of using treads versus wheels.

7 Major Component Costs

Component	Price Each ($)	Total Price ($)
5 Metal Detector Heads	20	100
Spray paint can	15	15
Spray can motor	3	3
PVC Pipe and glue	25	25
Boards for robot unit and remote controller	75	75
2 Movement Motors	30	60
H-Bridge IC	20	20
Microcontrollers	4.50	9
2 ZigBee Transceivers	4.75	9.50
Framing and Wheels	80	80
Total		**396.50**

8 Conclusions

The persistence of land mines is the greatest threat; long after the war is over the nightmare remains. Our robot will take the first step to ending the danger. Using metal detectors to find them and spray paint to mark them, we can take the first step towards removal. Even without disarming the mines this is already an improvement; everyone will know where the danger lies. The components, while not trivial, are well within our ability to build and program. Finally, there is plenty of room for expansion into autonomous detection, and disarmament. Our robot is the first step towards making the world safer for both ourselves and our children.

References:
[1]Unicef State of the World's Children 1996. Accessed at:
http://www.unicef.org/sowc96pk/hidekill.htm on November 7, 2010