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Implementation of Autonomous Metal Detection Robot with Image and Message Transmission using Cell Phone

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Abstract: ***This paper describes the implementation of autonomous robot prototype for metal detection. The robot scans predefined area strip by strip and detects metallic object. Two DC geared motors are used for controlling the movement of robot. The metallic objects are detected by simple R.F. based Colpitt's oscillator circuit using transistors and passive components. The robot has been provided with facility to avoid obstacles through LED sensor module. A novel feature of automatic transmission of image to user cell phone on metal object detection is incorporated. The usage of Multi-media Messaging Service (MMS) feature of cellular networks eliminates the constraints of range and cost of customized transmitter for message transmission. The system is based on AVR ATmega16 micro-controller. Any cell phone with camera and MMS facility can be used with the system. The other applications which can be developed based on similar concepts are also discussed.***

Keywords: Metal detection, remote scanning, micro-controller, MMS, cell phone.

1. Introduction

Metals are widely used in applications ranging from automobiles, electrical conductors, to rockets and space shuttles. In order to cope up with increasing demand, there is need to carry out rapid explorations of mines to locate this material. Many companies have developed metal detector models to meet the requirements. Large portable metal detectors are used by archaeologists and treasure hunters to locate metallic items such as jewelry, coins, bullets, and other various artifacts buried shallowly underground. An autonomous robot based system is envisaged to carry out remote scanning of mines for metal detection without presence of human beings and alert along with image transmission whenever metallic object is detected.

Remote monitoring of processes, machines, etc. is popular due to advances in technology and reduction in hardware cost. Internet based monitoring [1, 2]; Short Messaging Service (SMS) and Multimedia Messaging Service (MMS) offered by cellular networks [3-6] and Wireless sensor networks (WSN) [7] are popular approaches for remote monitoring.

Due to widespread coverage of cellular networks and availability of cheap cell phone models, it was decided to use an appropriate cell phone model with camera and MMS facility to capture image and send it to the user cell phone.

2. System Description

The objective of the work is to develop prototype robot which scans the predefined area and detects metallic (ferromagnetic) objects. Two DC geared motors are used for controlling the movement of the robot. Whenever metal is detected, the system captures the image of the object using cell phone and transmits it to the user cell phone. The robot then deviates around the object and continues scanning of the area. The obstacles are detected by the LED sensor. For non-metallic obstacles, the image is not captured. The entire system‟s operation is controlled by using Atmel's AVR ATmega16 microcontroller.

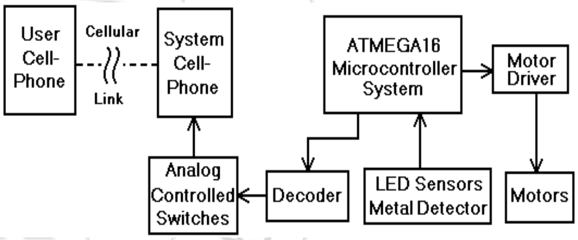

Figure 1: System Block Diagram

The Block diagram of the system is shown in Figure 1. Nokia C1-01 model is used as system cell phone [8]. Four port bits of microcontroller are used to control the soft keys and command keys of cell phone through decoder and analog controlled switches to send images and messages to user cell phone based on certain conditions. LED sensor module is used to detect obstacles in left, right and front regions of the robot. Metal Detector circuit is used to detect metallic objects. The microcontroller controls the selection of DC motors through L293D driver IC and direction of movement of robot depends on motor's state. If both motors are in ON states, the robot moves straight in forward or reverse direction depending on connections. However, if only one motor is energized, then robot takes right or left turn depending on position of motor currently in ON state. The adjustable field coil presets are provided in series with dc motors to balance out minor differences in the speeds of the two motors.

2.1 Mechanical Aspects

The chassis of robot provides support for motors, batteries, sensors, circuit PCBs, cell phone and the controller. The board of 12 × 15 cm. dimensions was chosen. Two gear head DC motors of 12V, 60 rpm are attached at the bottom of the board using clampers. The front wheel consists of a small iron ball rotating on sliding arrangement. The two side wheels are chosen of 5 cm diameter and thickness of 1.5 cm. These side wheels are mechanically coupled to DC motor shaft through gear assembly to improve the torque.

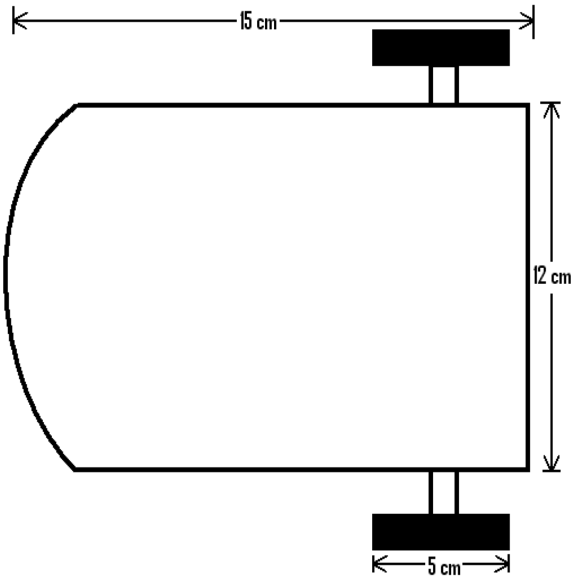

Figure 2: Chassis Dimensions

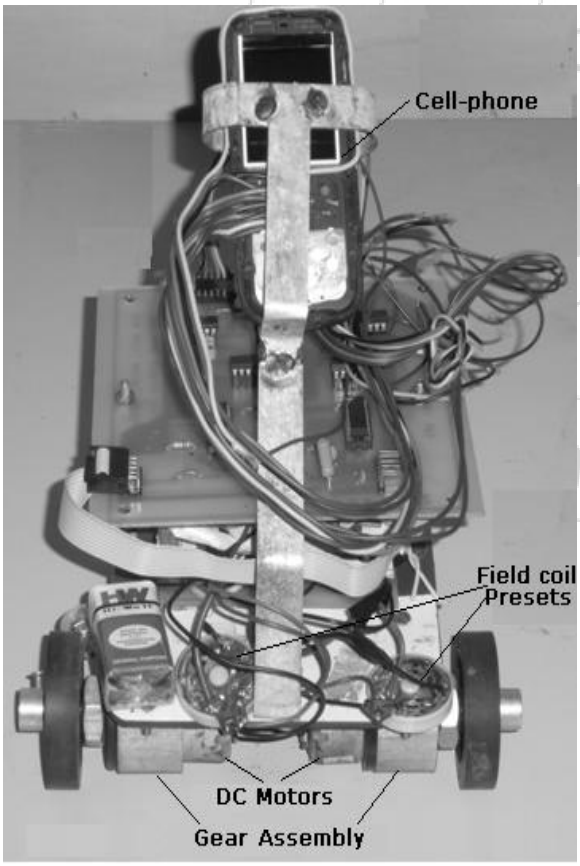

Figure 3: Back-end view of robot prototype

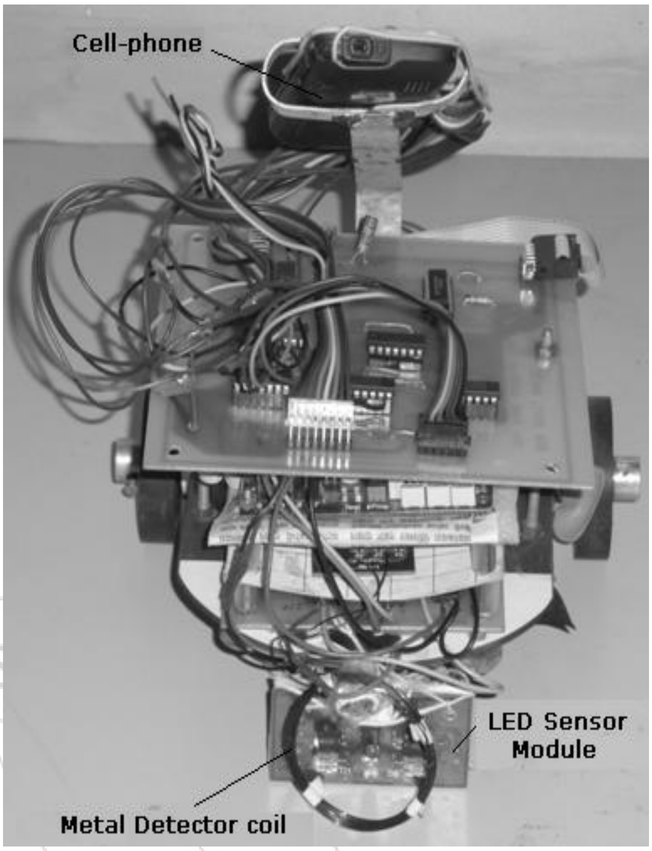

Figure 4: Front-end view of robot prototype

Figure 2 shows the basic dimensions of the chassis of the prototype robot. Figures 3 and 4 show the front side and back side image of entire robot prototype with cell phone, circuit PCB, sensors and DC motors.

2.2 LED Sensor Module

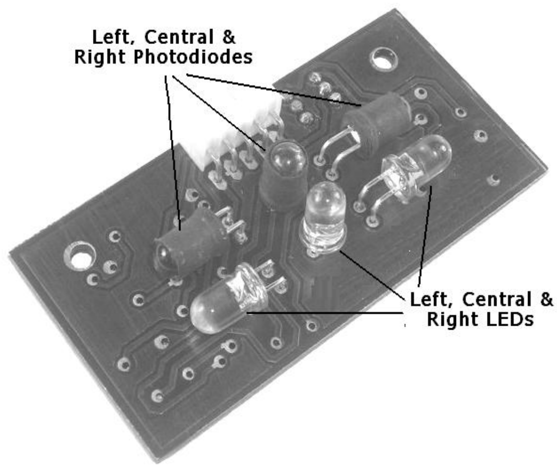

Figure 5: LED Sensor Module

The sensor has a compact size with front, left and right LEDs along with its photodiode pair. The LED sensor is modulated at 10 kHz. It has active filter to protect against ambient light. Whenever there is no obstacle, the light emitted by LED is not reflected and hence the outputs corresponding to current state of photodiode are at relatively higher voltage. However if any obstacle is present, the reflecting light from obstacle changes the corresponding photodiode current resulting in lower output voltage depending on direction of obstacle. The intensity of light reflected is proportional to distance between obstacle and emitting LED. Sensor produces analog output in the range of 0.5V to 1.3V. The sensor module is shown in Figure 5. The output of the sensor is sensitive for distance range between 3 and 15 cm.

2.3 Metal Detector Circuit

A simple metal detecting circuit using transistors and passive components was implemented. It consists of weak Colpitt‟s R.F. range oscillator in the input stage. The oscillator circuit is connected to transistor through capacitors and coil making up the oscillator‟s tuned circuit. Changing any combination of these components will vary the oscillator‟s operating frequency. When sensing coil is brought near a metallic object, magnetic energy is absorbed and oscillator loses its capacity to produce sustained oscillations. As a result, output stage transistor conducts and buzzer is activated. The coil is externally mounted at front end of robot prototype to detect metallic obstacles (Figure 4).

3. Microcontroller System

ATMega16 microcontroller has RISC architecture with 16 kB of in-system programmable Flash, 1k E^2PROM, 2 kB SRAM, 32-bit multi-function General purpose I/O, 8 channel 10-bit ADC, TWI, USART, SPI, JTAG interface support, etc. [9, 10] Ponyprog software was used for flash programming [11]. The software was developed in C language using GCC compiler.

3.1 Interfacing Diagram

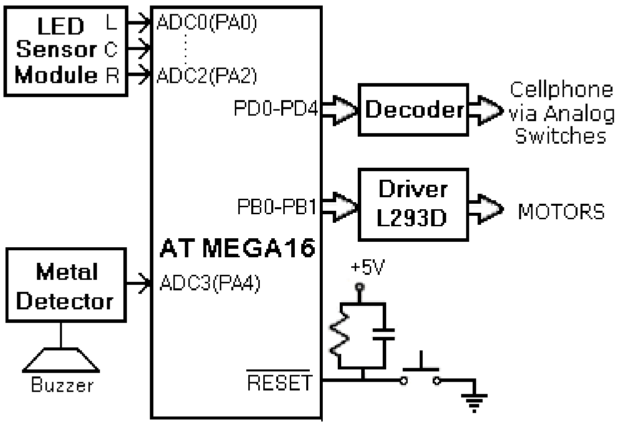

Figure 6: Microcontroller System Interfacing

Interfacing diagram of micro-controller system is shown in Figure 6. The eight bits of Port A are configured as analog inputs ports. The analog inputs PA0-PA2 are connected to right (R), Central (C) and Left (L) outputs of LED sensor module. The metal detector circuit output is connected to PA3 analog port bit. Lower two bits of Port B are used to control the ON-OFF states of two DC motors through half H Bridge driver IC L293D. The five port bits of Port D are connected to BCD to decimal decoder. The outputs of decoders are interfaced to control inputs of analog controlled switch IC. The inputs and outputs of controlled switches are connected to key matrix of cell phone through connector.

3.2 Algorithm

The prototype system sends message to user cell phone indicating start of scanning through sequence of commands to system cell phone. The analog inputs are continuously checked and both the motors are switched ON to move in straight path. Whenever non-metallic obstacle is detected through change in input magnitude of central output of LED sensor, the prototype system gradually turns itself around the obstacle by controlling the selection of motors and continues in straight path. When it reaches boundary of scanned region, it makes gradual U turn and start scanning the next strip. Whenever metal object is detected during scanning, the robot stops and captures the image through system cell phone and transmits MMS to user cell phone and continues its scanning process. When it reaches the end of predefined area indicated by presence of obstacles on all three sides, the robot prototype stops and sends message indicating end of scanning process.

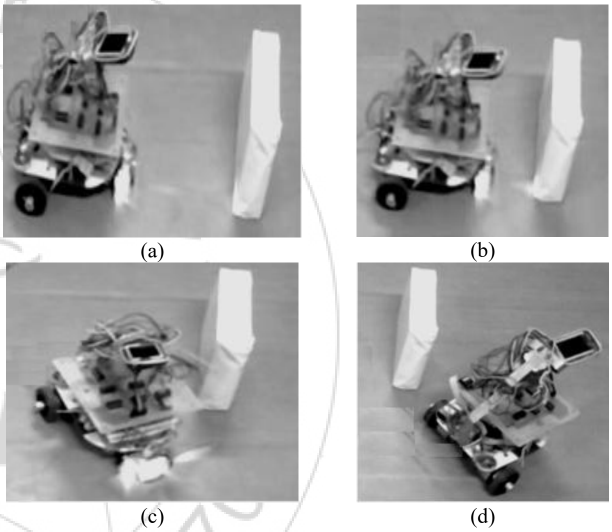

Figure 7(a) to (d): Maneuvering of prototype robot across non-metallic obstacle

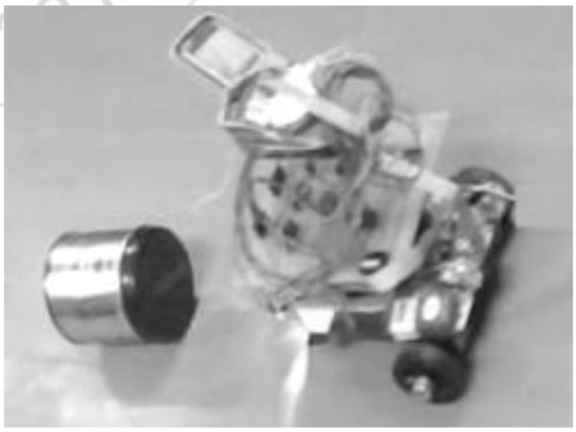

Figure 8(a): Detection of metal obstacle (cell phone activated)

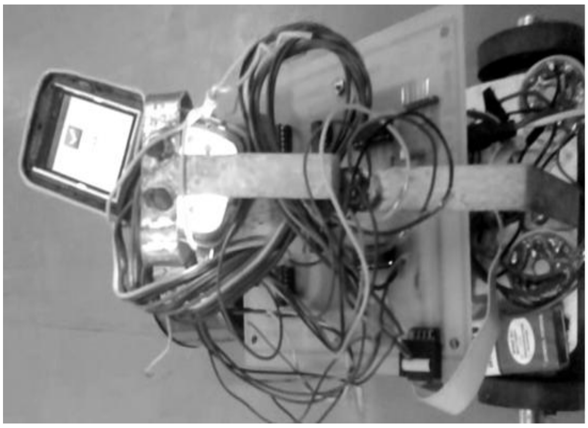

Figure 8(b): Capturing of image completed by cell phone

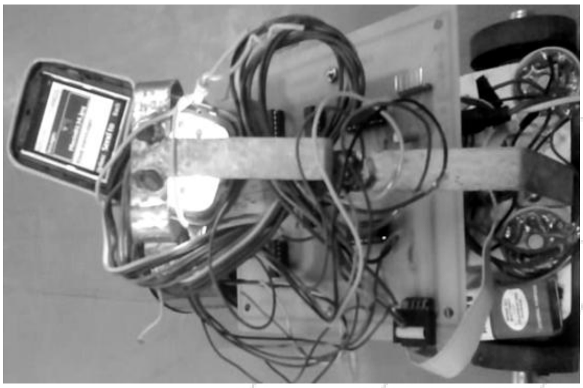

Figure 8(c): Stored Image file being sent through MMS

Figure 8(d): Robot prototype moving past metal obstacle

The screenshots of robot prototype maneuvering past the non-metallic obstacles are shown in Figures 7(a) to (d). The screenshots of processes involved during encounter of metal obstacle are shown in Figures 8(a) to 8(d).

4. Image and Message Transmission

After considering various possibilities for image capturing and transmission to remote user, it was observed that cellular phone offers best choice due to its low cost, single component solution and easy availability. However, the current cell phone models do not support RS232C serial communication protocols. Hence, simple micro-controller systems without USB connectivity cannot be directly connected to cell phone. The alternate options of USB to serial converters or Bluetooth Serial adapters are costly to implement [12]. Moreover, even if these adapters were used, there exists another difficulty of obviating the access permission levels for connectivity in Java ME as cell phone are basically designed for human interaction using key pads and touch screens and cannot be directly automated.

The various menu functions of cell-phone can also be operated by activating the key presses of right soft key, left soft key, 5-way navigation(4 arrows and selection key), call creation and termination keys (control keys) through ports of µc system using analog controlled switches [13]. Figure 9 shows the control keys for Nokia Cell phone model C1-01. Many powerful functions of cell phone like camera image capturing, sound recording, sending MMS, etc. can be called through sequence of control keys activation by microcontroller [14]. There is also set of short-cut keys provided by cell phone manufacturers to speed up the tasks e.g. pressing top scroll key after call termination key directly opens camera application in Nokia Models.

Figure 9: Control keys of Nokia C1-01 cell phone model

Four output port bits are connected to control pins of analog controlled switches through BCD to decimal decoder IC to ensure activation of single control key press. An additional port bit is used to enable/disable the decoder. Table 1 shows the code for activation of control keys based on decimal code received.

Table 1: Coding for Control Keys of Cell Phone

Decimal Code	*Control Key Activation*
'0'	Selection key - Navigation
'1'	← (Leftwards Arrow) - Navigation
'2'	↑(Upwards Arrow) - Navigation
'3'	→(Rightwards Arrow) - Navigation
'4'	↓(Downwards Arrow) - Navigation
'5'	Right Soft Key
'6'	Left Soft Key
'7'	Call Creation Key
'8'	Call Termination Key
any other code	No action

5. Conclusions and Further Recommendations

Thus robot prototype has been developed for remote scanning of mines for metal detection. This system is able to detect metallic objects without human presence and informs user with image transmission whenever metal is detected. The usage of cellular networks reduces the cost of establishment of wireless network and removes the constraints of range of the system. Any obsolete or unused cell phone model with camera and MMS facility can work as system cell phone. The concept can easily be extended for range of applications from security systems, automatic car parking to fire and gas leakage detection systems for unmanned or hazardous regions by choice of appropriate set of sensors. Presently unidirectional communication from system cell phone to user cell phone is supported. However, it is also possible to modify the system with use of serial port adaptors to provide facility to receive commands from cell phone by microcontroller system [12].

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