Remote Monitoring and Control of a Mobile Robot System with Obstacle Avoidance Capability

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***Abstract*—With the advancements in technology, the field of robotics and automation has gained tremendous popularity. Mobile Robots are being widely used in a number of places including production plants, warehouses, airports, agriculture, medical, military, and in hazardous environments to reduce human efforts. In this paper, we present the design and implementation of a mobile robot system with obstacle avoidance capability for remote sensing and monitoring. The proposed system enables the user (base station) to send necessary commands to the remote station (mobile robot) using Dual-Tone Multi-Frequency (DTMF) signals for robot teleoperation. Global Positioning System (GPS) and Global System for Mobile communication (GSM) technologies are used, which provide user with mobile robot location in the form of a Google map link. The system also provides the user with real time video monitoring of the remote area by using an internet enabled device. The user can also save the images and record the videos captured by the mobile robot IP webcam at the remote location, which can be stored in a public cloud for later use.**

Keywords—Mobile Robot; Global Positioning System; GSM Modem; DTMF decoder, Ultrasonic sensors; IP webcam

I. INTRODUCTION

There has been a tremendous increase of interest in mobile robots and their applications, although the notion of web-based robotics is relatively new and still it is in infancy, but it has captured huge interest of many researchers worldwide. One of the applications of wireless mobile robots is to sense several variables in the environment. Mobile robots equipped with sensors can be used to perform some dangerous and laborious human tasks, especially in hazardous environments, where human involvement is less, impossible or dangerous [1].

Wireless Communications is the most evolving fields of application in present scenario, where different technologies can be used so as to have automated systems with flexibility, accuracy and reliability. Today's advanced wireless technology provides a convenient way for us to develop a mobile robot system that takes an advantage of remote monitoring and controlling by using the GPRS. Conventionally, many mobile robots have equipped with different wireless technologies such as Bluetooth, Wi-Fi, Wireless LAN, RF technology, etc.

Yeong Che Fai et al [2] explores the implementation of Bluetooth technology in mobile robots, which gives robots the capability to move around autonomously with more complicated and powerful algorithm. Feng Cui et al [3] have proposed a system in which WLAN (wireless LAN) with high gain antenna is used to realize teleoperation function that operators can use the virtual robot to control the real robot several kilometres away. An innovative mobile robot navigation technique using radio frequency identification (RFID) technology is demonstrated in [4], in which the main idea was to exploit the ability of a mobile robot to navigate a priori unknown environments without a vision system and without building an approximate map of the robot workspace. Wireless robots based on RF technology, have several drawbacks such as limited working range, limited frequency range and limited control. Yi Jincong et al [5] proposed a mobile robot system with intelligent obstacle avoidance capacity by adopting multi-sensor data fusion technology and obstacle avoidance algorithm based on fuzzy control. Use of a mobile phone with Dual-Tone Multi-Frequency (DTMF) technology for robotic control can overcome limitations of existing systems and provides robust control, working range as large as the coverage area of the service provider, no interference with other controllers and up to twelve controls using DTMF. So this system will be a powerful and flexible tool that can provide service at any time, and from anywhere with the constraints of the technologies being applied [6].

The mobile robot navigation is obviously a major requirement for a mobile robot to survive in a given environment or to fulfill its mission to reach the destination. This localization / navigation issue can be solved by using the Global Positioning System (GPS). GPS has become an efficient positioning tool for numerous civilian and military applications. GPS technology works under different weather conditions across the world. If the user has a GPS receiver, he can track location of objects or individuals in outdoor locations.

General Packet Radio Service (GPRS) is a packet-based mobile communication service. It offers faster data transmission via a Global System for Mobile communication (GSM) network within a range from 56Kbps up to 114 Kbps and continuous connection to the internet for mobile phone and computer users. In this project, the GPRS technology is used for real-time remote monitoring and control of the mobile robot system. GSM and GPS technologies have been used for mobile robot navigation and positioning in outdoor locations.

II. Operational Details of Mobile Robot System

The proposed system is divided in two sections: viz. Remote station (Mobile Robot) and Base station (User's side). Figures 1 and 2 show the block diagrams of Remote station (Mobile Robot) and Base station (User's side). The implemented mobile robot is a four wheeled vehicle prototype. DC motors are used for driving and steering, the prototype provides support to the batteries, camera and all elements related to the proposed design. Mobile robot consists of an ARM7 LPC2148 microcontroller and it is controlled by a mobile phone using DTMF technology by user. During a call, if any button is pressed, a tone corresponding to the button pressed is converted into binary code at the remote station by using the DTMF decoder. The microcontroller is preprogrammed to take decisions for any given input and generates its decision to drive circuits of the driving and steering motors; mobile robot reacts directly to the user's commands. Ultrasonic sensors are used to detect an obstacle in the mobile robot path. If any obstacle is found within 20 cms, the robot will be stopped. A GPS receiver connected to the robot system provides latitude and longitude position of the robot. The location of the robot is sent to the user in the form of a Google map link through GSM of mobile robot, which enables user to navigate the robot.

After this, user at base station monitors the obstacle and remote area environment by using the IP address of the IP webcam attached to the mobile robot, by using any internet enabled device. The user can then control the mobile robot to move forward, backward, turn left or turn right to avoid the obstacles using the mobile phone. User can also take images and record videos and store them in a public cloud such as Google Drive for future use by accessing internet.

III. Implementation Details

The mobile robot system is built using ARM7 LPC2148 microcontroller. For proper navigation and teleoperation of the mobile robot, the major components used in the system are GPS, GSM, DC motors, two ultrasonic sensors (front and back), IP webcam and DTMF decoder. Brief discussion of these components is given in this section.

A. *Features of ARM 7 LPC2148 microcontroller*

LPC2148 microcontroller board consists of ARM7 processor. It is based on Reduced Instruction Set Computer (RISC) architecture, and the instruction set and related decode mechanisms are much simpler as compared to micro-programmed Complex Instruction Set Computers (CISC). The LPC2148 microcontroller uses a 32-bit ARM7TDMI-S CPU with real-time emulation and embedded trace support.

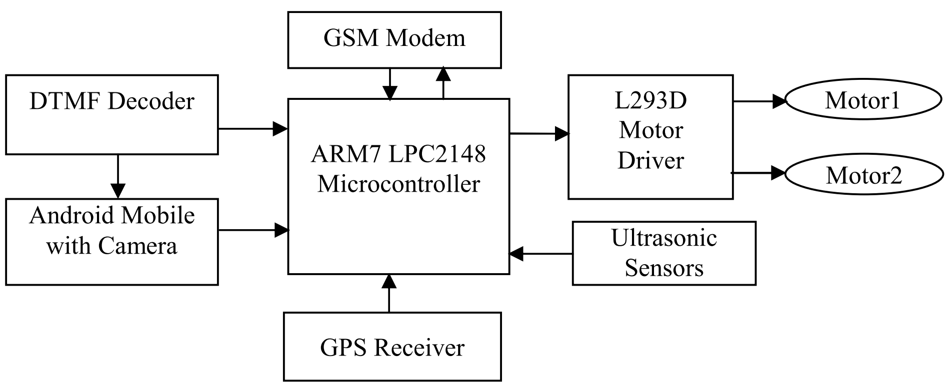

Fig. 1 Block diagram of Remote station (Mobile Robot)

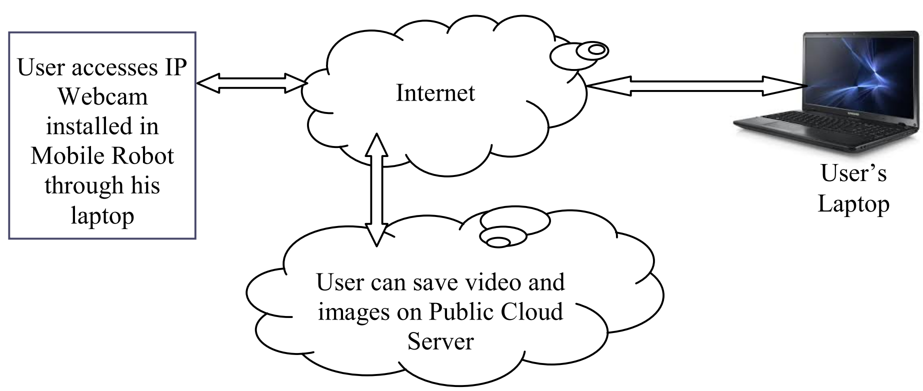

Fig. 2 Block diagram of Base station (User's side)

It has various features such as high speed flash memory of 512 KB, on-chip SRAM of 40 KB, two 32-bit timers, two 10-bit analog to digital converters, 10-bit digital to analog converter, PWM channels and 45 fast GPIO lines [7]. Due to its tiny size and low power consumption, LPC2148 is well suited for this system.

B. Data Acquisition using GPS Receiver

The Global Positioning System (GPS) is a satellite based system widely used for position estimation and navigation. The GPS satellites broadcast ranging signals and navigation data on L-band frequencies. The user GPS receiver converts signal information into position, velocity and time estimates using the principle of trilateration. A single frequency GPS receiver shown in Fig. 3 is used with the mobile robot system. It provides data in a variety of formats. National Marine Electronics Association (NMEA) is a standard format that can be used to download information from a GPS receiver in real-time.

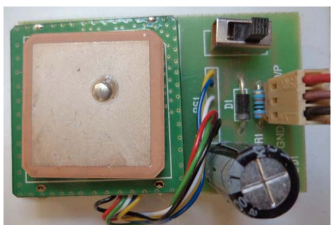

Fig. 3 Single Frequency GPS Receiver module

Most of the GPS receivers provide NMEA information called sentences. One of the most important NMEA sentence is the GGA sentence. This sentence provides various parameters such as latitude, longitude, time, number of visible satellites, dilution of precision (DOP) of the calculated position fix. The microcontroller inputs the latitude and longitude coordinates of the mobile robot from the GPGGA data [8].

C. GSM Module

Global System for Mobile communications (GSM) is the most popular wireless standard for mobile phones around the world which provides worldwide wireless communication by using TDMA technology. GSM modem works like a mobile phone, it accepts a SIM card, and operates over a subscription to a mobile operator. It operates on various AT commands. SIM900A GSM module is used in this design, which is used to send Google map link consisting position information of mobile robot such as latitude and longitude to the user's mobile whenever mobile robot stops due to an obstacle.

D. Ultrasonic sensors

Ultrasonic sensor provides precise, non-contact distance measurements from about 2cm to 400cm. Two ultrasonic sensors (type HC-SR04) are used on Mobile Robot to detect the route and avoid any obstacle in the working environment (Fig. 4). Two sensors are distributed forward and backward to detect the route. The ultrasonic sensor consists of an ultrasonic transmitter, receiver, and a simple control circuit [9]. It is easy to connect as only one pin is required to connect it to microcontroller.

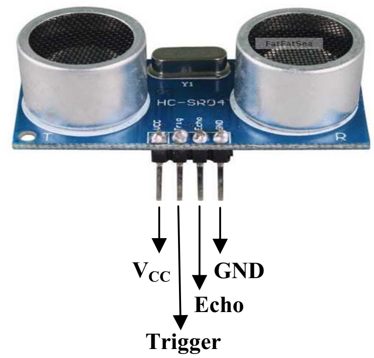

Fig. 4 HC-SR04 Ultrasonic Sensor

E. Interfacing of DC motor

The implemented mobile robot is a four wheeled vehicle prototype. DC motors are used for driving and steering, the first DC motor is used for driving both rear wheels via a differential box, while the second DC motor is used for combined steering of both front wheels. When a DC motor is supplied with DC power, it generates torque by using internal commutation, stationary permanent magnets, and rotating electrical magnets. In this project, controlling of the DC motor is done by using DTMF tone of the user mobile phone.

DC motors are commonly used in mobile robots, since they are clean; quiet, easy controlled, and can produce sufficient power. A motor driver acts as a current amplifier since it takes a low-current control signal and provides a higher current signal. This higher current signal is used to drive the motors [10]. L293D is a dual H-bridge motor driver integrated circuit that contains two in-built H-bridge driver circuits to drive the DC motors forward and backward. Four output lines from the microcontroller are connected to the H-bridge to drive the DC motors as shown in Fig. 5.

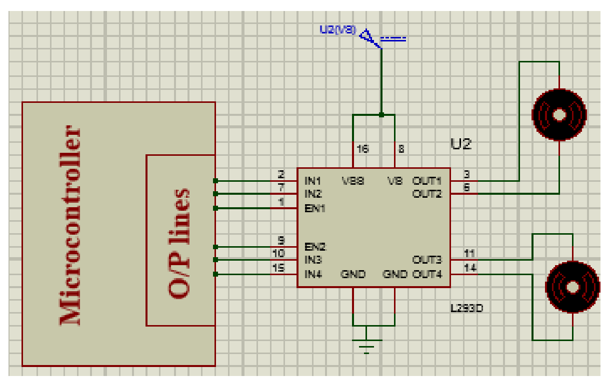

Fig. 5 Interfacing of DC motors

F. Relay

A relay is an electrical switch that has an electromagnet to shift the switch from OFF to ON position. Small amount of power is required to turn on a relay but it can control something which needs much more power. In this paper, relay has been used as a switch by pressing keys of the DTMF keypad.

G. DTMF decoder

DTMF is a scheme of representing digits with tone frequencies so as to transmit them over an analog communication channel. This process works when the user mobile phone initiates a call to the SIM on the GSM modem of the robot with the receiver end connected in auto answer mode. During this outgoing call, when a key is pressed, the associated key generates a DTMF tone at the other end. The DTMF decoder (IC MT8870) processes the received tone. It produces two distinct frequencies corresponding to the lower and upper band frequencies. For example, if the user press key'6' it will send a tone having 770 Hz and 1447 Hz to the other end (Fig. 6). The decoder then produces an equivalent binary digit after decoding the DTMF tone [11].

1	2	3	697 Hz
4	5	6	770 Hz
7	8	9	852 Hz
*	0	#	941 Hz
1209 Hz	1336 Hz	1447 Hz	

Fig. 6 Frequency assignment in DTMF system

Any received DTMF code at mobile phone can be audible through speaker. So to decode this DTMF code, output of speaker is connected to IC MT8870. It gives 4-bit digital output Q1, Q2, Q3, and Q4 according to the received key as shown in Table I.

Table I Digital Output generated for each key

Key	Q4	Q3	Q2	Q1
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
0	1	0	1	0
*	1	0	1	1
#	1	1	0	0

Table II shows the various controlling keys used by user to control the mobile robot direction to avoid obstacle.

Table II Various Keys Used to Control Direction

Key	Direction
2	Forward
4	Left turn
6	Right turn
8	Backward
5	Stop

H. IP Webcam

IP webcam is an android application which turns android mobile into a network camera and it is used for remote sensing of environment. It supports remote viewing and recording from anywhere anytime via web browser. It also provides user authentication with login id and password. By using the IP address of the IP webcam which is attached to the mobile robot, user at the base station can monitor remote area in real time.

I. LCD Display

The LCD display used is 2×16 character display. LCD is controlled by the microcontroller; it displays the GPS latitude and longitude values of mobile robot and distance between mobile robot and obstacle.

IV. SOFTWARE TOOLS

The various software tools used in the design of this system includes Keil µVision4 Integrated Development Environment (IDE), Flash Magic and Proteus.

A. Keil µVision4 IDE and Flash Magic

Keil µVision4 IDE is a Windows based front end for the 'C' Compiler and assembler. This software is used to write the embedded C code of different modules for various events of the system. The embedded C code is compiled and a Hex file is created. Flash magic software is used to dump the Hex code in LPC2148 microcontroller. It supports the microcontrollers of Philips and NXP only.

B. Proteus Software

Proteus is a simulator for digital systems simulation, schematic capture, and printed circuit board design. This software is used to design the schematics by interfacing the modules.

V. SOFTWARE FLOWCHARTS

The software flowcharts consist of two sections, viz. Remote station (Mobile robot) and Base station (User's side).

A. Remote station (Mobile Robot)

Figure 7 shows the flowchart indicating operation of mobile robot and various steps for controlling the mobile robot (remote station) system. It shows various events including initialization of various hardware such as GPIO ports, LCD, ultrasonic sensors, and UART0/1 ports.

B. Base station (User's side)

Figure 8 shows the flowchart for Base station (User's side). User can view robot location on Google map and can monitor the obstacles remotely by using the login id, password and IP address of IP webcam placed on mobile robot using any internet enabled device (laptop or mobile). The mobile robot is then controlled from the base station through user mobile keypad using DTMF signals. The user can also capture videos and images and can store the data in public cloud for future access.

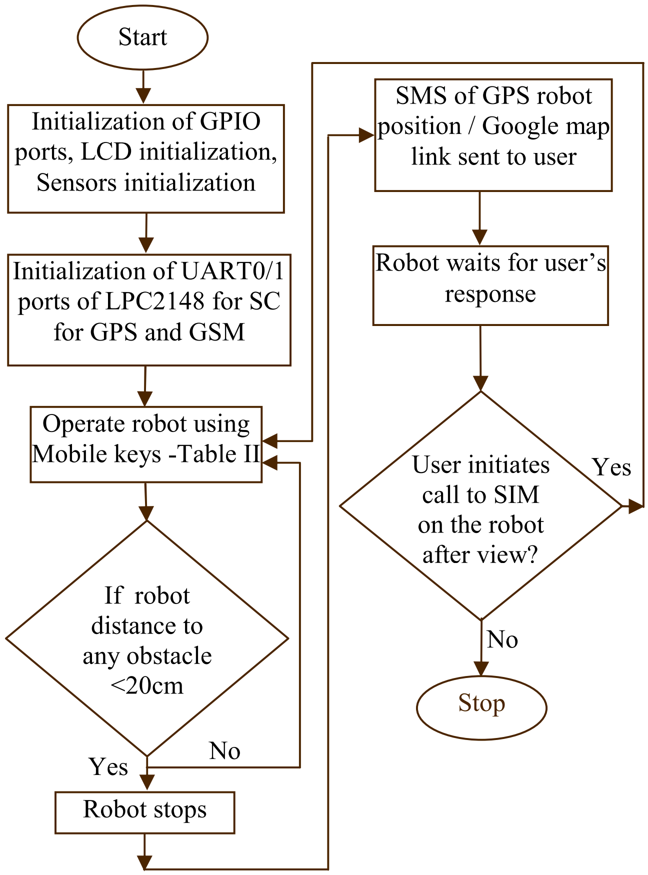

Fig. 7 Flowchart showing various events that occur at remote station

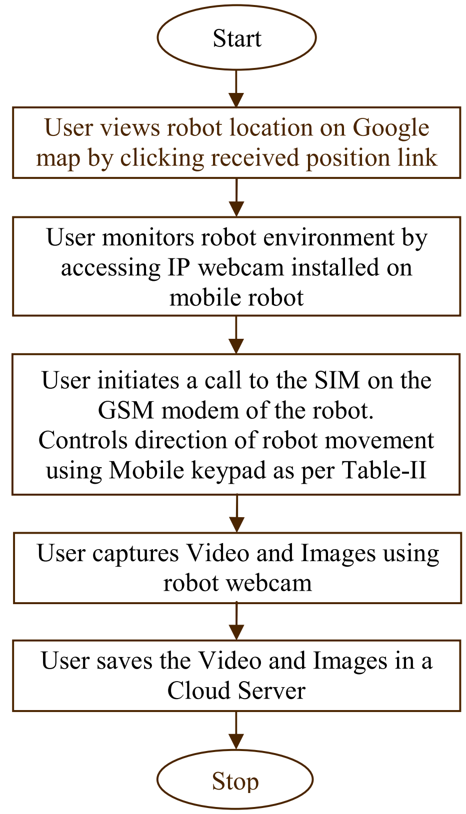

Fig. 8 Flowchart for Base station (User's side)

VI. Schematic and Experimental Results

Figure 9 shows schematic diagram of the system indicating various connections between components and the microcontroller.

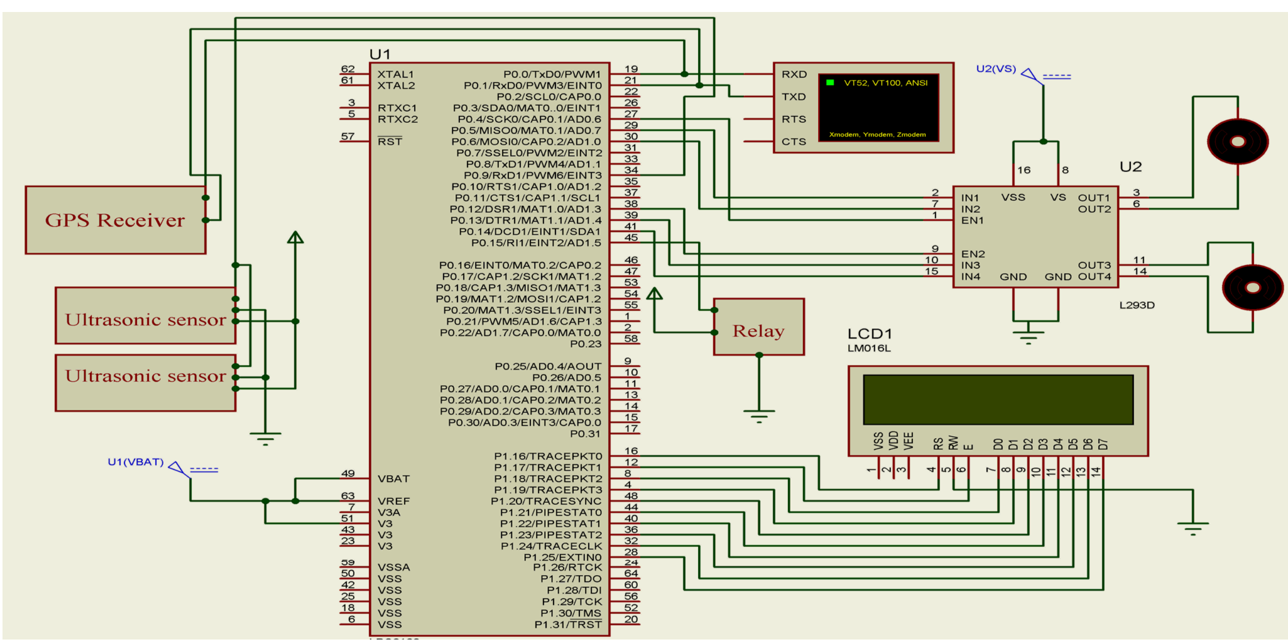

Fig. 9 Complete Schematic Diagram of the Proposed Mobile Robot System

The EN1, IN1, IN2, EN2, IN3, and IN4 pins of L293D motor driver IC are connected to P0.4, P0.5, P0.6, P0.12, P0.13, and P0.14 pins of LPC2148 microcontroller (labeled as U1) respectively. OUT1 and OUT2 of L293D IC drive motor1, whereas OUT3 and OUT4 drive motor2. Three pins from each ultrasonic sensor are connected to P0.9 pin of LPC2148, 5V power supply and ground respectively. One relay is used which is connected to P0.15 of microcontroller. In this system, 2×16 LCD display is used. We have grounded R/W pin of LCD. P1.16 and P1.17 are connected to RS and Enable pin of LCD respectively. Data pins (D0-D7) of LCD are connected to P1.18-P1.25 port pins of microcontroller, UART0 pins P0.0 and P0.1 (TxD0 and RxD0) of microcontroller are connected to RxD and TxD pins of GSM module and GPS module respectively. Two rechargeable batteries of 12V are used for powering the Mobile robot. Figure 10 shows the front view of mobile robot system. It depicts the ARM7 LPC2148 microcontroller board, ultrasonic sensor, DTMF decoder, LCD, power supply and relay.

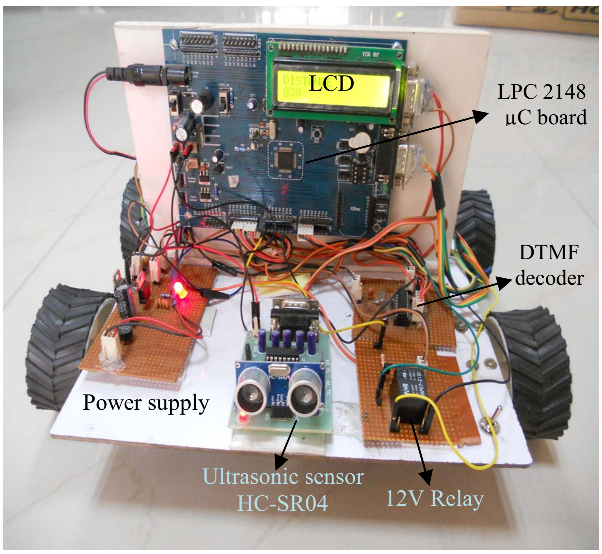

Fig. 10 Experimental Setup of Mobile Robot System (Front view)

Figure 11 shows the back view of mobile robot system.

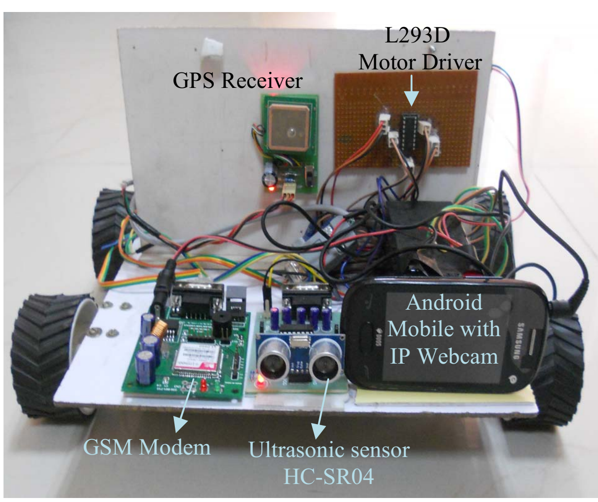

Fig. 11 Experimental Setup of Mobile Robot System (Back view)

It depicts the ultrasonic sensor, L293D IC, GPS receiver, GSM modem and android mobile with IP webcam.

Figure 12 shows the Google map location of the mobile robot on the user's android mobile, after clicking on the Google map link received through the GSM modem on the mobile robot. Figure 13 shows the sample view of the image observed on user's laptop that is captured by the IP webcam at the remote location. The mobile robot has been tested satisfactorily for obstacle avoidance capability in both forward and reverse directions. The robot stops whenever an obstacle is detected within 20 cms. The robot can be navigated in all four directions from the remote base station (user) by using the mobile keypad. The availability of GPS signals and GSM network is necessary for proper functioning of this mobile robot system.

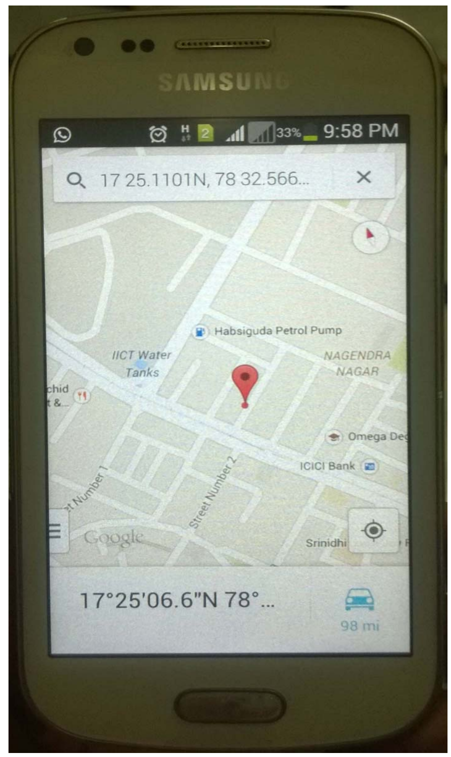

Fig. 12 Google map location of Mobile robot on User's Android Mobile

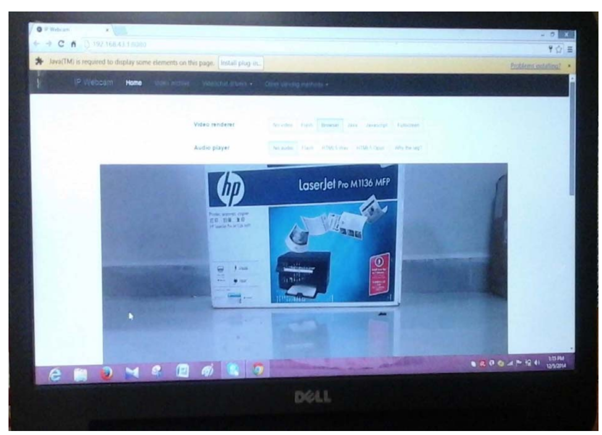

Fig. 13 Sample laptop view of image captured on Mobile robot camera

VII. Conclusions and Future Scope

We have designed and implemented an ARM7 microcontroller based prototype of a mobile robot for remote monitoring and control. This paper focuses on the use of popular and well known wireless technologies and integration of communication and navigation technologies such as GSM, GPRS, DTMF and GPS. The use of IP Webcam for remote area monitoring makes the system cost effective; this system also makes use of the cloud network to store the recoded videos and images of remote area in the Google Drive. With the rapid growth of the Internet, more and more intelligent devices or systems have been embedded into it for service, security and entertainment, including distributed computer systems, surveillance cameras, telescopes, manipulators and mobile robots. We can improve the system in future by allowing mobile robot to overcome unexpected obstacles by itself whenever possible. Also we can add ultrasonic sensors at right and left side of mobile robot, which could help to avoid obstacles from left and right sides. We can also integrate multiple mobile robots into a telerobotics system to achieve redundancy and robustness for getting good results.

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