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An Effective Development and Analysis of a Mobile Robot

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ABSTRACT

This paper deals with the design of a battery operated Mobile Robot with various modes of its control. The Mobile Robot can be operated in three different modes, namely Dual Tone Multi Frequency (DTMF), Radio Frequency Input Devices (RFID) and laptop control with ZigBee technique, thereby enabling a multi- dimensional control system. The Mobile Robot is a single seated carrier and can also be used to transport substantial amount of physical load for short distances. It is a prototype of a multi-use robot having a wide range of applicability according to the requirement after suitable modifications. There are four microcontrollers used in this mobile robot. The input to microcontroller sent via the devices like cellphone, RFID and laptop. Thus it can be easily applied inside a hospital to carry patients, as a wheel chair for physically challenged people, to carry goods in large shopping malls, as golf cars, can also be used for industrial purposes with adequate modifications. It uses a DC power source and not any conventional energy sources. Hence it is ecofriendly and this Mobile Robot can be termed as an advancing step in the field of mobile robot.

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1. INTRODUCTION

Robotics is a very attention-grabbing field because once a robot is developed; it makes our work trouble-free. The word robot generates a fascinating imagination of a human-like structure. However a robot is a mechanical or virtual artificial agent, usually an electro-mechanical machine that is controlled by a computer program or electronic circuitry aimed at performing certain tasks. Mobile robots have the capability to move around in their environment while performing the given tasks and are not fixed to one location of installation. Mobile robots may be classified on basis of their functions, applications, output capacity etc. A manually operated robot is under complete control of the operator and is usually operated with a joystick or any similar control device. An automated robot has the ability to sense and avoid obstacles. The proposed Mobile Robot is a manual cum automated robot. It would be appropriate to call this vehicle a robot and not an automobile as it doesn't contain any components of traditional automobiles. Rather it possesses digital electronic circuits, wireless data transmission techniques, software programming skills, etc.

Aruna et al. [1] proposed a method for distant control of a device through the use of DTMF Technology. They used this technology to control a land rover by giving a call to a cell phone connected to it. Any key pressed during the call shall act as a command for the robot. Tuljappa M Ladwa et al. [2] proposed the use of DTMF signals to monitor and control household appliances. They used voice call facility to send signals to turn on and off various household appliances like bulbs, fan, etc. Jasmin Velagic et.al [3] designed a robust robot which was capable of storing its surround details and generates a virtual map so as to find a collision-free trajectory between the starting configuration and the goal configuration in its environment. The various soft computing methodologies used for this purpose were fuzzy logic, genetic algorithm and the Dempster–Shafer theory of evidence. X.J. Jing [4] proposed in his work that by modeling the dynamic process of the interaction between the robot and its local environment, we can formulate a dynamic motion-planning problem which can then be transformed into an optimization problem in the robot's acceleration space. The solution to this problem provides an optimal motion of the robot in the unknown environment. Guan-Chun Luh and Wei-Chong Cheng [5] reinforced the adaptive learning mechanism by combining knowledge regarding on-line adapting capabilities of immune system and applied it to some intelligent robots. As a result, the robot is now capable of taking decisions and modifying its properties. A real life case study was also performed by considering a food foraging work problem. Noureddine Ouadah et al. [6] in their work mentioned the use of fuzzy logic controllers in mobile robots. They used two controllers to enable the mobile robot to move along a fixed path and accomplish its specified task. The technique was also implemented on a car-like robot.

Krzysztof Tchoń et al. [7] derived an extended Jacobian inverse kinematics algorithm by generalizing the extended Jacobian method for stationary manipulators and applied it to nonholonomic mobile robots. They divided the entire space into a finite and an infinite region and modified them to form the map for extended kinematics. The truth of this technique was verified by simulation studies. Irfan Quazi et al. [8] proposed the use of AVR software in making energy measuring meters for household use. They programmed the 8-bit ATMega16 microcontroller so that metering of domestic power consumed could be accomplished. Mike Stilman [9] in his work described three algorithms regarding the unified representation for task space constraints in the context of joint space motion planning. After comparisons, the First-order Retraction was found to be faster than the others. Luca Iocchi and Daniele Nardi [10] stressed on locating the position of a robot in its environment with precision as the critical element in determining the efficiency in completing a specified task and for this they used the Hough transform for matching a geometric reference map with a representation of range information acquired by the robot's sensors. This technique proved useful in indoor areas where there are restrictions in motion. Kooktae Lee et al. [11] proposed various schemes for calibration of systematic errors and reduction of non-systematic errors in a car-like-mobile-robot. They found that systematis errors can be reduced by couple of test drives while the non-systematic errors can be reduced by use of extended kalman filters.

Stephen Marsland et al. [12] provided with an algorithm that would help a mobile robot in navigation. Through this algorithm, it would be able to generate a map of its locality by choosing an ideal landmark as its reference point. This algorithm can be used to make mapping mechanisms more efficient and reliable. Ilan Zohar et al. [13] presented in their work a control scheme for wheeled mobile robots whose model included both the kinematic and the dynamic effects. Firstly a controller was designed to track the trajectory of the robot and then it was employed in its control system so as to drive a group of vehicles in convoy. Simulations and lab experiments were done to evaluate the effectiveness of the proposed scheme.

2. METHODOLOGY

To design an advanced semi-automated Mobile Robot that can be controlled by a microcontroller this works on the operator's instructions. The input to microcontroller can be sent through very common devices like cellular phone, laptop. There is also provision for remote control using radio frequency signals. The sole purpose of the work is to build a prototype that can be used to predict the best mode of operation for control of an automated Mobile Robot. This Mobile Robot is capable of carrying a person or equivalent physical load and move with a speed of around 3km/hr. And the materials taken are mentioned Table 1. The main aim of designing the Mobile Robot is to carry a person or an equivalent physical load, that having multiple controlling system with a factor of safety of 2 or more. Apparent substantial load of 150 kg along with its own weight was assumed to be applied on it. To obtain this the material used should have a high tensile strength and bending strength as well as crushing strength. The structure of Mobile Robot must be stable, balanced, vibration free and light. The motor should be capable of providing necessary starting as well as the running and braking torques to provide necessary motion to the Robot. A strong and capable wheel is to be used to sustain the load and having a perfect friction for good control and driving. A reliable battery for energy source is also required that can deliver the required amount of power for a long period of time. A perfect logic is to be programmed on the Microcontrollers to have a firm control of the Robot. The electronic components should be held securely in positions of the Robot so that a perfect working condition is created without damage and heat.

This is the main skeleton of the Mobile Robot and thus should be given the most priority. Iron (MS angle 30) is used as to obtain required strength and stability. The lower part of base is a square of side 70cm and 30 mm thickness. The upper part is a shape of parallelogram having parallel sides of 70cm, 40cm and the non-parallel sides of 43cm each as shown in figure 1.

Table 1. Materials Required

Sl. No.	Components (Hardware)	Quantity
1	Chassis	-
	MS -30mm x 5mm angle, 30 ft.	
	ALUMINIUM sheet- 3mm thickness, 5ft x 3ft	
2	Wheels	2
	MATERIAL: HIGH DENSITY POLYMER	
	15cm diameter, 4 cm thickness	
3	FREEWHEEL	2
	7cm diameter: 2 in number.	
4	DC Stepper Motor with MOSFET and Motor Driver	2
	24V, 250rpm, 300kg load bearing capacity	
5	Dc Rechargeable Battery	1
	12V, 35A	
6	Dc Charging System(for the batteries)	3
7	Driver Chair	1

Electronic Components

	Software Components	Hardware Components
1	AVR Programmer Kit	ATMEGA 32
2	SINAPROG	RF module
	XICTE	DTMF DRIVER
3	PL232 Driver	ZigBee module
4	USBASP	USB programmer

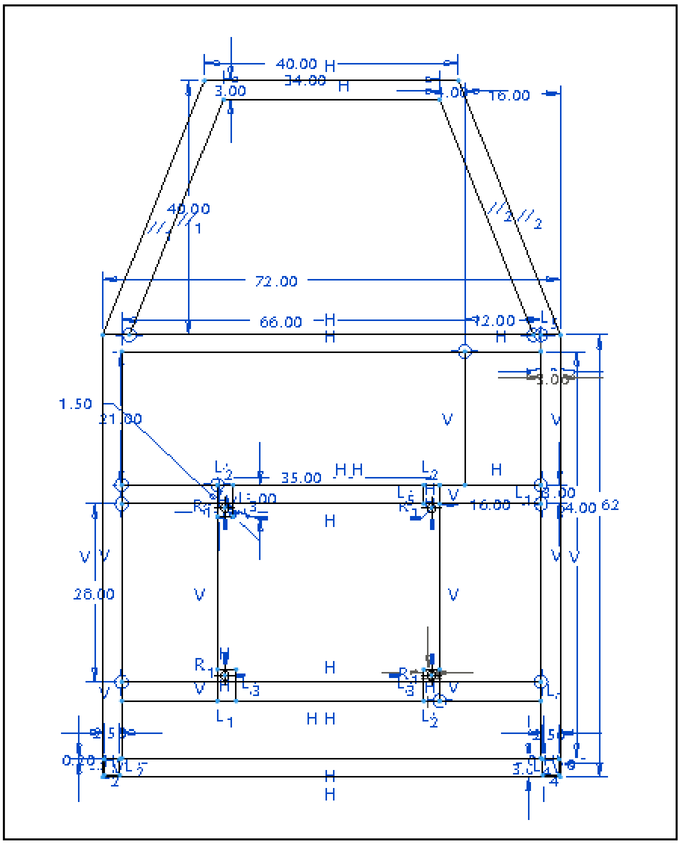

Figure 1. Dimensional view of mobile Robot

Each parts of base were cut and polished so that each part matches perfectly. A butt joint technique is used to provide a perfect plane shape of the base. Then parts were assembled together by welding at the joints by using 2.5mm weld rod with common arc welding method. The Two parallel beams in middle of frame provide the support to the base plywood, chair and battery. Separate bar supports hold the battery in position firmly. All the parts welded by single side butt joint. The slags were removed and the parts were polished. Two clamps of 10cm have been welded on both the sides at a distance of 10cm from the back side of the frame. Motors are placed in between the clamps. Rubber packing layer of 5mm provides the necessary friction to hold the motor and provides damping. Two holes of 6 mm diameter were bored on square part of clamps. Two strips of 5cm X 15cm with two holes of 6mm at 14cm distance were made and aligned with the clamp to fix the motors. The packing strips of 3cm X 2cm X 0.5cm also used to obtain a good motor clearance from the ground.

The selection of the motors is based on the desired load to be applied on the Mobile Robot. The average load is taken to be 400kg. The actual working load applied is taken is an average of 200kg. Hence two motors each of 300kg-cm load bearing capacity motor have been used. The motor is 3cm in diameter and its height is 8cm. It has an angular speed of 250 rpm and provides a constant torque of 300 kg-cm. The gearbox is a cuboid having dimensions of 12cm X 8cm X 3cm. A sketch of the motor is given below in figure 2. Each motor weighed 1.28 kg. Motors were held at their position firmly with rubber packing. Rubber restricts jerk, vibration and provides suspension for the motor. The motor has a rating of 24V, 60Amp. 12V, 35Amp current is provided from battery used considering the ease of controlling its speed. Battery used for Mobile Robot is dry cell rechargeable battery. The motor rotates at 250rpm at rated speed. Motor shaft is made up of high-speed steel having 1cm radius and 3cm length. A key way is bored to hold the wheel in position on the shaft. Holes of 3mm diameter and 2mm depth are made on motor to hold the set screw in position. Set pin are also provided to keep the motor in position. A ground clearance of 12cm is maintained.

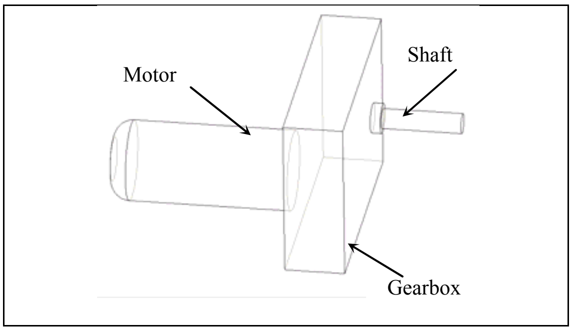

Figure 2. DC Motor with gearbox

Vehicle floor is made up of plywood. For rectangular pieces, dimensions are 70cm X 21cm. The trapezium was cut in dimensions of 70cm X 28cm. The parallel sides were maintained at 70cm and 40cm, while the other two sides were 43cm long. Rectangular parts were made of 5mm thick plywood while trapezium was made from 10mm thick plywood. The front part of floor provided with 1cm thickness plywood to resist extra fore during a person getting in to the Mobile Robot. Extra link is provided on main base to support the weight of plywood. The Mobile Robot floor thus forms a best platform to carry a person.

- *Wheel design*

Rear wheel:
At rated voltage of 24V,
The speed of motor N = 250 rpm.
The diameter of wheel D= 0.165 m
Hence speed of Mobile Robot is $v = \pi DN/60$
$= \pi \times 0.165 \times 250 / 60$
$= 2.159$ m/s
$= 7.77$km/hr

For a 16.5cm wheel, speed of Mobile Robot is 7.77km/hr. The width of the wheel is 3cm having hole diameter of 1.6cm at the center. Two 5mm 45° set key screw are used to hold the wheel tightly without any vibration. The crushing load of wheel chosen is 1KN. The wheel is made up of high density polymer. V type tire track were used around the wheel for making the grip of Mobile Robot stronger. The length of tire used is 53cm and width of 3.5cm. Weight of wheel is 1.08kg each. Wheels are fitted in position such that the clearance between ground and Mobile Robot base is 12cm.

- Front wheel

Two free wheels are used in the Mobile Robot to provide proper control of it by using two rear wheels. The diameter of wheel is 4 cm. The wheel is connected with a shaft to wheel holder. Wheel holder has a bearing mechanism which provides axial rotation and making the wheel to orient in desired direction. Greasing was done properly to provide smooth operation of wheel. The angle of rotation of front wheel is kept about 52°. Wheels are fitted to the main base through two 10M bolts. Holder piece have welded in frame to hold the wheels in position. The clearance of Mobile Robot base from ground was maintained 12cm. A tie rod of dimensions 40cmX3cmX0.2cm is connected between the two front wheels. The tie rod is bolted loosely with a M6 bolt at the upper cover. Proper clearance between the front wheel tires and the nut is maintained. Tie rod provides a liner functional relation between the front wheels. Hence the angle turned by one of the wheel is equivalent to the angle turned by the other wheel. This helps to obtain directional stability and the robot is able to move in a single direction uniformly. Seat of the Mobile Robot is placed in middle of the Mobile Robot base. Seat is having a dimension 40cm X 40cm. It is placed 52 cm from ground level. Height of back side is 101cm from ground. Four L clamp has been wound with bending wire are attached to legs of chair. 3mm diameter holes were made on clamps and holders to set the chair firmly with Mobile Robot base. 7M bolts are used to hold the chair in position. Extra foam with silk cover is provided to seat that helps comfort seating. Gape distance from dash board is kept 35cm enabling user to get in and out easily. Chair is made up of square pipe of cross section 1.5cm X 1.5cm. The crushing strength of similar chair is found to be 5 KN. The battery used in Mobile Robot is a general car battery manufactured by Exide. Voltage supplied by it is 12 volts and the current is 35 amperes. The battery is 20cm long, 15cm wide and 30cm high. It is kept at a height 35cm from ground. It is fixed to Mobile Robot base with 3 guided pins and a side. It is placed on right side at a distance of 30cm from back side of frame. Weight of battery is 11.29kg. It is placed in this position such that the whole weight is distributed properly on wheels.

Two MS angle30 of height 45cm were welded to the Mobile Robot base. A top parallel MSangle30 of 50cm was joined to make a frame for front dash board. Two 3cm hinge clamp were used to hold the dashboard. Dashboard is made up of 0.5cm thick plywood having dimensions 48cm X 30cm. The microcontroller board is attached to it by means of screws. The dash board has a single degree of freedom of rotation about breadth side. Electronic components are place on dashboard and floor of Mobile Robot below the seat. Plastic foam of 1.5cm thickness is used to hold the electronic components in position without any vibration and jerk. Electronic components required more safety and careful handling. PCB boards are bolted to a plastic board of dimension 15mm X 30mm X 0.5 mm. Plastic board was fitted to dashboard by 4 3mm head and 3.5cm long screws. Battery charger, relay board and MOSFETs are attached to the Mobile Robot base firmly. The Mobile Robot body is made up of 0.5mm thickness aluminum sheet and 1.5cm square iron pipes. The sheet used for this purpose has a 160cm length 75cm width. A frame of roof is made up of 5mm diameter iron rods. Aluminum sheet is riveted at each side with 6mm head rivet. Four pipes were fitted firmly to the Mobile Robot base around the 5mm thickness rods. The sheet is bent around the pipes and clamped. Front side of Mobile Robot head is made up of sheet of .5mm thickness sheet and 76cm X 45cm cross section. Head of Mobile Robot is located at 49cm from ground. Height of head is 37cm having a thickness 11cm. the head is filled with plastic foam as filler material. The shape of front head is shown in figure 3.

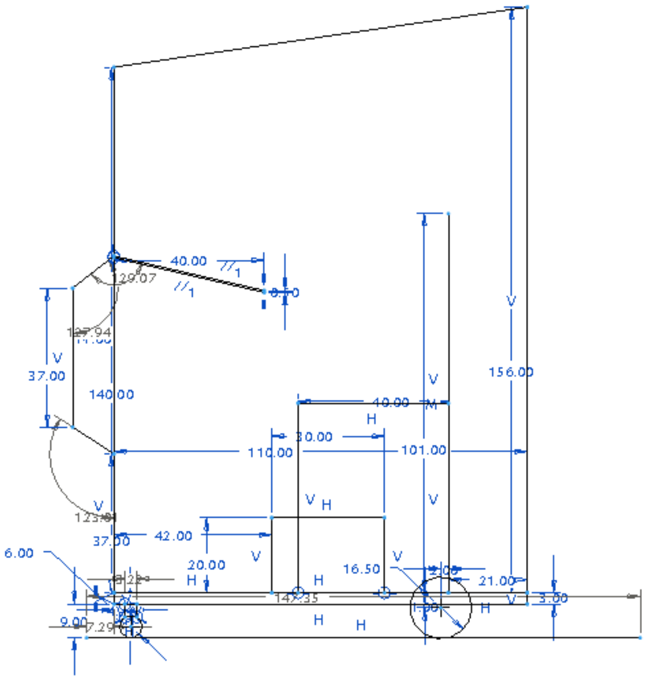

Figure 3. Side view of Mobile Robot

Frame of Mobile Robot is painted with black colour oil paint. Plywood used in Mobile Robot floor is reddish yellow. Blue colour seat and electronic components enhances the beauty of Mobile Robot to a great level. Front side is lowered by 5cm than the rear side. It increases aerodynamic resistance and improve the looks. Top part is made up of white coloured aluminum sheet and it completes the Mobile Robot. Hence the overall look of Mobile Robot is more attractive.

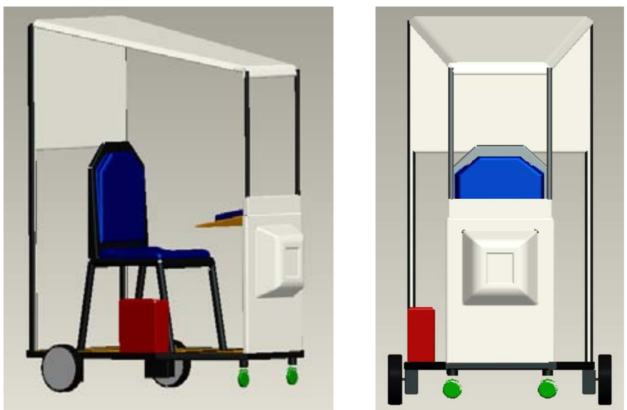

Figure 4. Side and Front view of the Robot

AVR trainer board consists of a microcontroller that receives the input signal, processes it and provides output which controls the Mobile Robot. The microcontroller used is ATMEGA32. It is a 32 bit microcontroller having 40 pins. The various ports are named as PORT A, PORT B, PORT C and PORT D respectively for pin 0-7, 16-23, 24-31 and 32-40. Pin 8-15 is used for power, ground, and enablement purposes of the microcontroller IC. The microcontroller possesses a RAM that stores the logic programs. The programs stay in the memory till a new program replaces it in the microcontroller memory. All the ports are similar and thus use any of them as input or output terminals in the circuit. However if one port is chosen as input then have to use the others as output. The same port can't be used as both input and output simultaneously. After program is loaded into the micro controller successfully, inputs and outputs can then be connected to microcontroller through any of the ports. Microcontroller processes the signal and gives the desired output in corresponding port/s. It also has provisions for displaying the output on LCD display and LED bulbs. Signals are discrete in nature with upper saturation set at 5V and lower limit at 0V represented by logic 1 or 0 respectively. These signal values are then transferred to the motor driver whose output enables the motion of the motors and hence the Mobile Robot. The display used here is 16X2 Liquid Crystal Display (LCD). It shows 16 characters per line in two rows. A standard matrix of numbers exists which allows the operator to communicate with the vast majority of LCDs regardless of their manufacturer. The standard is referred to as HD44780U, which is the name of the controller chip which receives data from an external source. The Atmega32 microcontroller communicates directly with the LCD through a separate set of pins fixed as its LCD outputs. The modern 44780 standard requires 3 control lines and 4 or 8 I/O lines for the data bus. In the concerned case, the 8-bit mode of LCD is used by using 8-bit data bus in order to widen the data capacity. USBasp is a USB programmer for Atmel AVR microcontroller circuits. It consists of ATMega48, ATMega88 or an ATMega8 and a couple of passive components. The programmer uses a USBasp driver to load the error-free compiled program onto the microcontroller circuit. Only then the circuit is capable of performing tasks desired of it. The USBasp driver is a freeware available on the web. It works under multiple platforms like Linux, Mac OS and Windows and Programming speed is up to 5 kbps. Here a 2 channel relay board has been used which gets enabled with the application of a 5V supply across its input terminals. It is used to convert the energy of the 12V battery (which is required to move the motors) to an appropriate level so as to meet the low voltage requirements of the PWM circuit (which generates the signals for motion of the motors). The board uses high quality relays, which are capable of handling a maximum of 40A/24 V DC during transient disturbances. Each relay has all three connections i.e. Common, Open and Close brought out to 3 pin terminals which are welded to printed circuit board. The board has a LED to show the status of the relay (ON/OFF). The board can accept inputs within a wide range of voltages from 4V to 12V. Power inputs and relay control signals are brought to corresponding terminal pins on the board. Output of 24V is drawn from output pin terminals. This relay board is responsible for a nose free operation of the entire assembly owing to the magnetic coupling present in it which eliminates any imbalance when found on its both sides.

A battery is used to supply power to both the robot and the electronic circuitry. A 12V, 35A automobile car battery is used to drive the robot. Its charging is done by a 4A DC charger with input of a 230V, 50Hz supply. Three 6V, 3A dry cell rechargeable batteries are connected in series to supply power to microcontroller circuit. They are charged by a parallel 175mA charger much similar to a cellular phone charging system. The chargers are attached to the Mobile Robot shown in figure 4 and hence the Mobile Robot can be charged at any place wherever proper supplies can be provided.

To control the motion of the robot, required signals may be given through any of the following devices:

i. Cellular phones:

Any cellular phone with a 3.5mm audio jack output can be used as the input device for the Mobile Robot. The key tone of the phone should be standard one and kept on at highest level during its interface with the Mobile Robot in order to get the best results.

ii. Laptop:

Windows operated (98 onwards) laptop with X-CTU software installed in it can be used as input device for the Mobile Robot. The signals are sent through various keys set before as per the program to perform various movements of the robot enabling the user to control it from a distance. Is this mode of operation there is nop need of a human being to sit inside the robot to drive it along the route as with the case of a cellular phone. Thus, this mode has vast scope of work in various practical scenarios where it is difficult for a human being to go physically in order to complete a task. We can simply engage the robot and guide it all the way and it can be programmed accordingly so as to perform the job.

iii. RF control remote:

A programmable RF control remote is required to operate the RF control system. The various movements can be set on the joystick through appropriate programming and the user can use the remote to control the robot from a distance. Here also no driver is required to be present inside the robot.

Input modules:

The various controlling signals are loaded to microcontroller through these input modules. The input modules used in the proposed mobile robot are:

i. DTMF:

Dual tone multi frequency (DTMF) board is required to convert the input signal generated from a cell phone so that it can be loaded on to the microcontroller. A L293D chip is used for this purpose. The

DTMF circuit assembly has a provision to display the input signal on the LED bulbs present on it so that any wrong signal (if generated) can be easily detected.

ii. ZigBee:

ZigBee transmitter and receiver modules are provided with the robot. They are used to transfer data signals between the robot and a laptop. Transmitter module is connected to the laptop through a USB port. A character typed in the X-CTU software window is converted intoits equivalent signal as per the programming done earlier and is sent to the receiver module which is located in the microcontroller board located on the dashboard of the Mobile Robot.

iii. RF module:

Similar to ZigBee module, the RF module also contains a transmitter and a receiver circuit. Signal generated in the remote (transmitter) is sent to the receiver which is located in the Mobile Robot as a radio wave.

3. WORKING PROCEDURE

An input signal generated in the various input devices mentioned earlier can be fed to its corresponding microcontroller circuit in its own unique channel. However it is important to remember here that at any instant only one mode can be enabled. The other modes remain inactive during the whole duration. The input signal is processed by respective microcontroller (1 out of 3) and is then sent to the 4^{th} microcontroller for generation of PWM signals to be sent to MOSFET circuit. The MOSFET activates the relay board which in turn closes the motor circuit. After that power is drawn from 12V battery and the motor runs. This is how the whole electronic circuit closes resulting in the various movements of the robot. This entire procedure may be expressed in a simpler manner through the following block diagram.

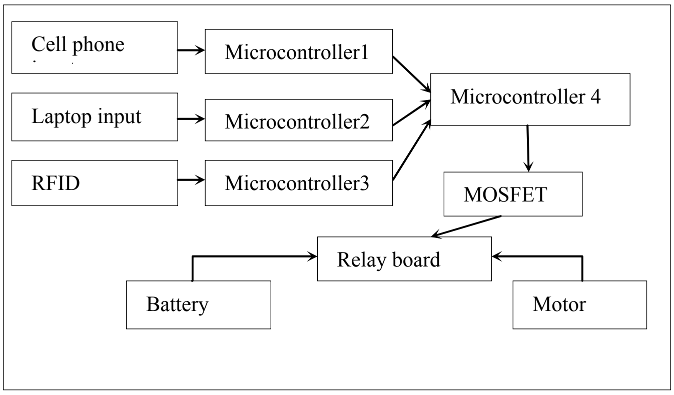

Figure 5. Working principle of Mobile Robot

- *Mobile interface:*

In the mobile interface, a tone which is generated on pressing a key in a cell phone is used to produce the required input signal. Signal generation in the cell phone is done by DTMF (Dual Tone Multi Frequency) principle. It has been successfully used for purposes like voice mail, electronic mail and telephone banking, etc. A DTMF signal is a signal produced by the algebraic summation of two sinusoidal frequencies, which belong to two mutually exclusive groups. These frequencies are used to differentiate one signal from the other. Each tone contains one frequency of the lower row (697 Hz, 770 Hz, 852 Hz, 941 Hz) and one frequency of the higher row (1209 Hz, 1336 Hz, 1477Hz) and is summed together to represent a unique signal (DTMF signal). The frequencies that are allocated to the push-buttons of the typical cellular phone's keypad are shown below in the Table 2. To control the mobile robot by a cellular phone, each key has been assigned with an action. When a button is pressed on the mobile phone or in the course of a call, the DTMF tone corresponding to that button is generated. It acts as the input signal for the microcontroller. As a result, the robot moves based on the program fed in it.

Table 2. Dual Tone Multiple-Frequency

	1209 Hz	1336 Hz	1477 Hz
697 Hz	1	2	3
770 Hz	4	5	6
852 Hz	7	8	9
941 Hz	*	0	#

- *Laptop interface:*

ZigBee is a wireless data transfer technology which was designed with the original idea of creating a low cost low power consuming but highly efficient data transmission medium. To some extent it has been successful in achieving its initial objective. It can transmit data over a range of 10-75 meters depending on the power consumption of the circuit at a speed of 250 kbps when operated at a frequency of 2.4 GHz. This wonderful technology is a product of the combined efforts of the ZigBee Alliance and the IEEE 802.15.4 committee. It is similar to Bluetooth in understanding but lot better as far as operation is concerned. Its range of data transmission as well as the pairing strength of the connected devices is much better than with Bluetooth. A ZigBee network may be of any of the three topologies- star, peer-to-peer and cluster tree. However here the peer-to-peer topology has been implemented considering the simplicity and the requirement of the system. In this model, there exists a master node and a slave node. The master sends the data over a wireless medium while the slave receives it and performs the required operations. In the concerned project, the master is connected to a laptop and it transmits the wireless data in digital form to the slave which is connected to the ZigBee panel in the electronic circuit of the robot. The panel consists of various components which receive the signal, decode it, amplify it and sends it to the signal generator circuit which generates signals for the required motion of the robot.

- *RF control system:*

Radio frequency (RF) control uses radio waves to transmit data over a wireless medium in between the remote controller and the robot. The remote transmits various signals to the electronic device connected to its receiver at the other end. RF remotes are nowadays used in remote controlled toys and remote car-entry key locks etc. A RF remote encodes the command signals in a binary notation. These signals are sent in form of radio waves to the device at the receiver end. There again signal conversion takes place before the signal is sent to the electronic circuit for evaluation. They can transmit signals over a range extending up to 100 feet (30.5 meters) and owing to its radio wave nature; the signals can pass through walls and furniture as well. In the given case study, the RF controller, i.e., the joystick generates a signal and transmits it to the RF receiver present in the microcontroller circuit board of the mobile robot. After required processing is done by the microcontroller circuit, the output signal is fed to the motor driver and the motor runs accordingly. Figure 5 shows with all controllers interfaced with each other.

SOFTWARE AND PROGRAMMING:

- *AVR studio4*

The AVR Studio4 is a modern simulator, associated with functions like compiling, building and debugging a program for microcontroller circuits. It consists of a set of keywords and its own unique programming syntax using which programs can be written. Programs written in common languages like C are also found to be compatible with its compiler. These program codes after complete error corrections are compiled and then only they can be loaded in the microcontroller circuit of the robot thereby creating an interface between the electronic components and the hardware of the mobile robot.

- *Sinaprog*

It is a freeware used to burn the hex file (program written for AVRStudio4 are in .hex format) onto the microcontroller. After successful building of the code in AVRstudio4, the program is loaded into ATMega32 microcontroller. It is done by selecting the proper path in Sinaprog interface window. The program is loaded in .hex format at a frequency of 1 MHz.

- *X-CTU*

X-CTU is a Windows-based application provided by Digi. This program was designed to interact with the firmware files found on Digi's RF products and to provide a simple-to-use graphical user interface to them. X-CTU is designed to function with all Windows-based computers running Microsoft Windows 98 SE and above. This software has a variety of options out of which this robot uses only the "terminal" tab for sending data to its receiver circuit placed on the microcontroller circuit board. When the terminal tab is pressed, a white window opens. It is this main white portion where most of the communications information occurs while using X-CTU as a terminal emulator. The text in blue is what has been typed in and directed out to the radio's serial port while the red text is the incoming data from the radio's serial port. As in this case the laptop is only an input device, one can find only blue letters on the screen. He letters that are typed on the screen are nothing but the input signals from the keyboard. These are sent through the ZigBee transmitter which is connected at the USB port of the laptop to the corresponding receiver fixed to the dashboard of the robot. Then the decoding process starts followed by proper movement of the robot.

4. RESULTS AND DISCUSSION

For obtaining a good control and stability the alignment of various parts is very important. The alignment tests are required to be conduct for different parts. The angle between the lower square parts is tested to be at 90° to obtain a perfect square. The top bar is aligned with the top part of the lower square to obtain the trapezium shape. The lower part of robot base is placed on a flat surface to test the planarity of the base. The wheels are tested to be at a clearance of 5cm from both side of the base frame. The clamps are tested to be parallel each other to hold the motor. The clamps are also tested to be at 90° to avoid the inclination of tires. All the wheels were aligned in a plane of ground. The horizontal distance is 72cm and vertical distance is 110cm. The acting load on wheel during no load condition is 61.3kg. During start up load applied on wheel is N. Hence frictional force acting on wheels is N. Wheels have been attached with rubber damping to the Mobile Robot base to restrict vibration, jerk and provides tight holding. Any Mobile Robot test always begins with the speed test. The average speed of this Mobile Robot is 2.5km/hr. It is equivalent to walking speed of a normal person. That is best suitable for its application and objective of work. This speed can be increased by increasing the motor capacity and the use of high volt battery. The speed test result for different mode of controlling system and percentage of full speed is tabled bellow and graphed. The

Table 3. Speed Test results

Sl no	% of speed	PWM voltage (V)	RPM	Speed km/h
1.	25	4	31	0.97
2.	50	6	62	1.93
3.	75	10	93	2.88
4.	100	12	125	3.89

Table 4. Weight distribution table

Sl no.	Component	Weight (kg)	Quantity	Total Weight (kg)
1.	Base	36.15	1	36.15
2.	Battery	11.270	1	11.270
3.	Motor	1.28	2	2.56
4.	Chair	5.07	1	5.07
5.	Body	2.50	1	2.50
8.	2^{nd} battery	1	3	3.00
9.	electronic parts	0.75	1	0.75
10.	Total			61.3

The speed test results are calculated and mentioned in Table 3. Table 4 shows the weight distribution of different parts. All the time calculated as per the distance through cellphone, RFID, Laptop and the standard time shown in Table 5.

Table 5. Results with all controllers

Distance	standard time	Cellphone	RFID	laptop
1	1.5	1.5	1.5	1.5
6	9	9	9	10
12	18	19	18	19
18	27	28	28	30
24	36	37	38	39
30	45	46	47	48
36	54	55	56	57
42	63	64	65	66
48	72	73	74	75
54	81	83	84	85
60	90	91	93	94
66	99	100	103	103
72	108	109	110	111
78	117	119	120	122
84	126	127	129	131

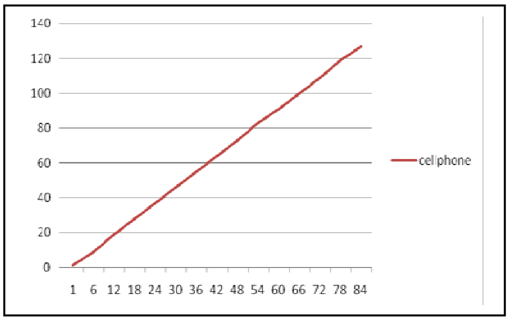

Figure 6. Results with cellphone

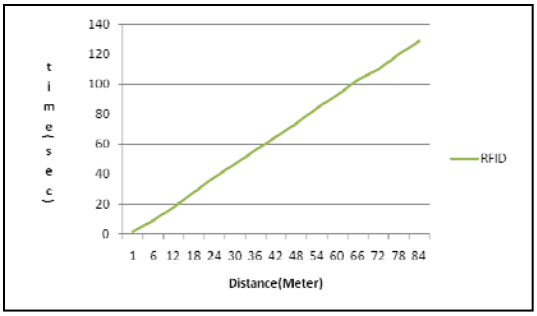

Figure 7. Results with RFID control

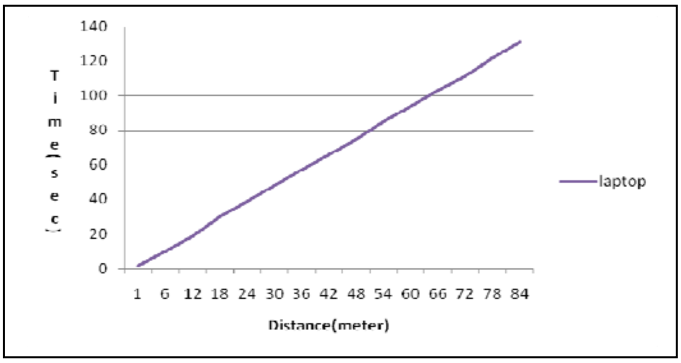

Figure 8. Results with Laptop control

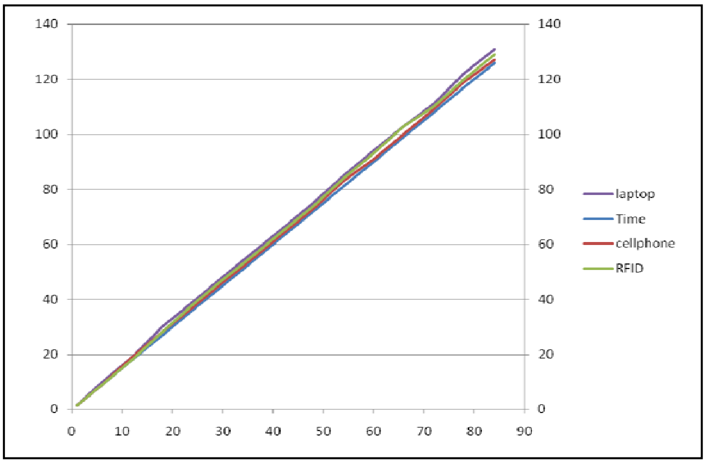

Figure 9. Comparison with all techniques

5. CONCLUSION

A mobile robot is built using the above mentioned technologies. Analyses of various control schemes were conducted mentioned in figure 6, figure 7 and figure 8 and it is found that DTMF mode is very accurate and had fastest response as comparison to the standard time shown in figure 9. Although it is designed for manual control of the robot through a cellular phone, there is provision for wireless control also via voice call. However it is not cost-effective as standard call rates are charged. For wireless control, two methods are incorporated namely ZigBee and RF. On experimentation, it is found that ZigBee mode is almost as accurate as DTMF and provided vast control of the robot. It is worth mentioning here that the robot is still under development and there are several plans for expansion including installation of camera for remote viewing.

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