Autonomous Mobile Robot Navigated by using DTMF Signaling

Firoz Mahmud, Al Arafat, Syed Tauhid Zuhori

Abstract—This paper illustrates on an approach to control a mobile robot using DTMF tone through the GSM network. DTMF tones to control a mobile robot are generated by pressing the keypad buttons of a GSM mobile which is counted as remote. The robot receives the tones using another GSM mobile stuck with it. The mobile robot perceives the control tone by using a DTMF decoder IC and a preprogrammed microprocessor takes decision on the basis of the received tone and navigates the robot accordingly. In order to transmit the DTMF tone through the GSM network, a phone call needs be on air between the two mobiles. This approach has been implemented on a toy car.

Index Terms— Autonomous Vehicle, DTMF Tones, DTMF Decoder, Mobile Robot, Mobile Navigation, Processing Unit, Robotics.

1. Introduction

CONTROLLING mobile robots precisely is the more desirable demands still today. As human mind always think of doing a job innovatively and more affordably, mobile controlled autonomous robotic vehicle system is an outcome of this thinking. The autonomous robotic vehicle system can be more robust and user friendly by making it capable of being controlled by mobile phone since mobile phone has become vastly available and of great importance in our everyday life.

Navigating a mobile robot is done in three distinct phases- Sensing, Processing and commanding. Several sensors and processes can be used to perform these tasks precisely. The actions to be performed also can be fed to the mobile robot in many ways either wirelessly or using wires.

Sensing can be carried out using several sensors to sense its surroundings. Camera, proximity sensor, laser range finder and several others are commonly used sensors for this purpose.

Processing Unit may be a laptop, a computer or a microcontroller. Processing unit is to make decisions based on the sensor's result. To process the sensor result and make decision, the processing unit is trained previously. The whole training process is done manually by a human prior to make it operative. The actions to be performed can be fed to the mobile robot either wirelessly or using wires. Navigating a robot wirelessly is a great challenging fact. Among many ways to do the job, using RF (Radio Frequency) signal and DTMF (Dual Tone Multi Frequency) signal are popular.

Mobile can be used as a sensor for an autonomous mobile robot while the decision making is carried out through using a microcontroller. Since, for some major drawbacks of RF signal like- short working range, limited working frequency and overall limited control, DTMF signal has become a great alternative of RF (Radio Frequency) communication. Because DTMF Signaling offers a wider distance communication than RF and is now a day widely used to communicate between robots or between robot and device. This brings a great inspiration in the field of automation of vehicle system.

In this paper we presented an approach to control and navigate an autonomous mobile robot using mobile phone that uses DTMF signaling.

2. Related Work

Extensive researches had been made through to navigate autonomous mobile robot precisely over decades. Myriad of algorithms and processes have been formed and experimented to do the job.

Mobile robot being controlled by mobile phone was implemented by P.Raghavendra Prasad and K. Susram Rahul successfully in 2008. In case of using computer vision to make decision, neural network, fuzzy network, background extraction and many other algorithms have been used over years to navigate autonomous mobile robot.

Path planning for an autonomous vehicle system based on visual system was first implemented by Pomerleau at Carnegie Mellon University, Pittsburgh, USA. The architecture was named as ALVINN (*Autonomous Land Vehicle in a Neural Network*).ALVINN is based on multilayer perceptron network. It was implemented on NAVLAB vehicle.

The same team under Pomerleau built MANIAC, an updated variant of ALVINN comprising several ALVINN networks.

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Several other algorithms have been used to perform the operation also. Like SVM, Fuzzy network have been used many times to navigate vehicle.

Similarly Satellite, sonar sensor, GPS have been also introduced by researchers to achieve the goal to navigate mobile robot precisely. All these have been done to achieve better performance with cost effectiveness, more over to achieve precision.

3. Some Basics on DTMF

DTMF (Dual Tone Multi Frequency) is a signaling tone composed of two different sine waves of different given frequencies. Individual different frequencies are used to ease the transmission and to be easily identified and decoded. The DTMF tones are intended to control signals.

With DTMF, when each mobile phone button is pressed, two different but unique tone frequencies are generated. One of the tones is generated from a high-frequency group of tones and the other is generated from a low-frequency group of tones. With DTMF, the different signals combination is like:

Frequencies	1209 Hz	1336 Hz	1477 Hz	1633 Hz
697 Hz	1	2	3	A
770 HZ	4	5	6	B
852 Hz	7	8	9	C
941 Hz	*	0	#	D

Fig 1: Frequency assignment in DTMF

The generated DTMF tones are just the arithmetic sum of the two different frequencies that is, the summation of two different sine waves for each specific key. The mechanism works as: pushing '1' will generate the frequency that is the resultant sum of the frequencies 697 Hz and 1209 Hz. And the DTMF encoder does this job automatically.

4. Approach

The main approaches to navigate this mobile based autonomous vehicle system are-

i. A phone call
ii. Press buttons to give command
iii. Processing Unit takes decision based on the command.

Here, two mobiles are required. While one mobile works as a remote to command the robot, another to receive the command to the processing unit.

The processing unit consists of a DTMF decoder IC that decodes the received tone and a microprocessor that has preprogrammed to take decision based on the command.

The whole approach can be stated as-

First, a mobile has been attached with the mobile robot. Then a phone call has been made to the attached mobile. While the phone call is on air, the predefined buttons, like 2, 4,6,8,5 to steer the robot straight, left, right, backward & stop respectively, are pressed on the remote mobile.

Every time a button is pressed, a corresponding DTMF tone is heard at the receivers end.

And then the DTMF decoder decodes the tone and the microcontroller takes decision based on the decoder's result and navigates the mobile robot accordingly.

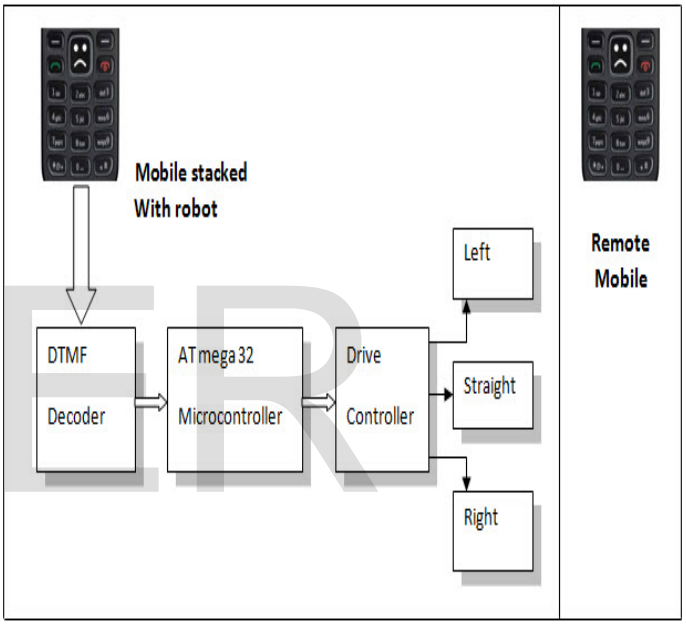

Fig 2: Mobile controlled paradigm.

5. Operational Structure

5.1 Operational Circuit Diagram

The operational structure of the mobile robot is as following (Figure 3)-

The circuit is counted as processing unit of the mobile robot. In this circuit MT8870 IC is the DTMF decoder IC. This IC takes input from the mobile phone attached with the robot through earpiece and produces 4-bit binary equivalent output. The resultant output of the MT8870 IC is then inverted using the 74LS04 IC, which is then fed to the ATMega16 microcontroller.

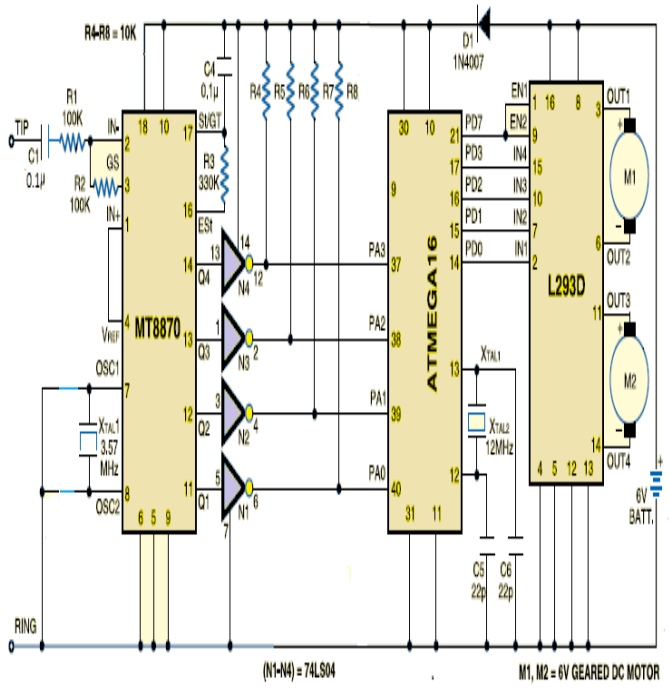

Fig 3: Circuit diagram of the processing unit

F_{LOW}	F_{HIGH}	DIGIT	D_3	D_2	D_1	D_0
697	1209	1	0	0	0	1
697	1336	2	0	0	1	0
697	1477	3	0	0	1	1
770	1209	4	0	1	0	0
770	1336	5	0	1	0	1
770	1477	6	0	1	1	0
852	1209	7	0	1	1	1
852	1336	8	1	0	0	0
852	1477	9	1	0	0	1
941	1336	0	1	0	1	0
941	1209	*	1	0	1	1
941	1477	#	1	1	0	0
697	1633	A	1	1	0	1
770	1633	B	1	1	1	0
852	1633	C	1	1	1	1
941	1633	D	0	0	0	0

0= LOGIC LOW, 1= LOGIC HIGH

Fig 4: DTMF decoder data output [3].

The ATMega16 microcontroller then takes decision as it is preprogrammed. And the L293D motor driver IC takes decision from the microcontroller and rotates the motors accordingly which in turns navigates the robot.

5.2 DTMF Decoder

MT-8870DE is the DTMF decoder IC used here. This decoder IC takes the received tone through earphone as input and produces 4-bit binary equivalent representation as output.

The MT-8870DE decoder uses a digital counting technique to determine the frequencies of the limited tones and to verify that they correspond to standard DTMF frequencies. A complex averaging algorithm is used to protect against tone simulation by extraneous signals (such as voice) while tolerating small frequency variations [3].

What the MT8870DE outputs after performing the decode is shown in the following table (Figure 4)-

5.3 ATMega 16 Microprocessor

ATmega 16 microcontroller manufactured by ATMEL is used here. It is an 8 bit, low power Microcontroller with two eight bit counters, two sixteen bit counters with pre-scale feature and 16Kb of non-volatile programmable memory and data memory, up to 64 Kb of extendable memory with many other features and modules. The microprocessor has been burnt with the hex code compiled by WinAVR software.

5.4 Motor Driver

As motor driver IC, L293D has been used. The two motors, one to steer left-right and another to steer straight-backward, have been commanded by this driver IC.

The L293D is a quadruple high-current half H driver. The L293D is designed to provide bidirectional drive currents of up to 600-mA at voltages from 4.5 V to 36 V. The device is designed to drive inductive loads such as relays, solenoids, dc and bipolar stepping motors, as well as other high-current/high-voltage loads in positive-supply applications [4].

6. Working Maneuver

The operation, which has performed to navigate the robot using mobile phone, can be stated in some steps-

i. A phone call from a mobile phone has made to the mobile stuck with the robot while the mobile phone stuck with the robot has set to 'auto answer' mode.
ii. When the phone call is on air, selected buttons has pressed.
iii. As a result corresponding DTMF tone has heard at the receiver's end.
iv. The DTMF tone has been decoded by the MT8870, DTMF decoder. Then the decoder has generated 4-bit binary numbers and sent them to the microcontroller.
v. The microcontroller has taken decision based on the decoder's output and directed the robot accordingly.

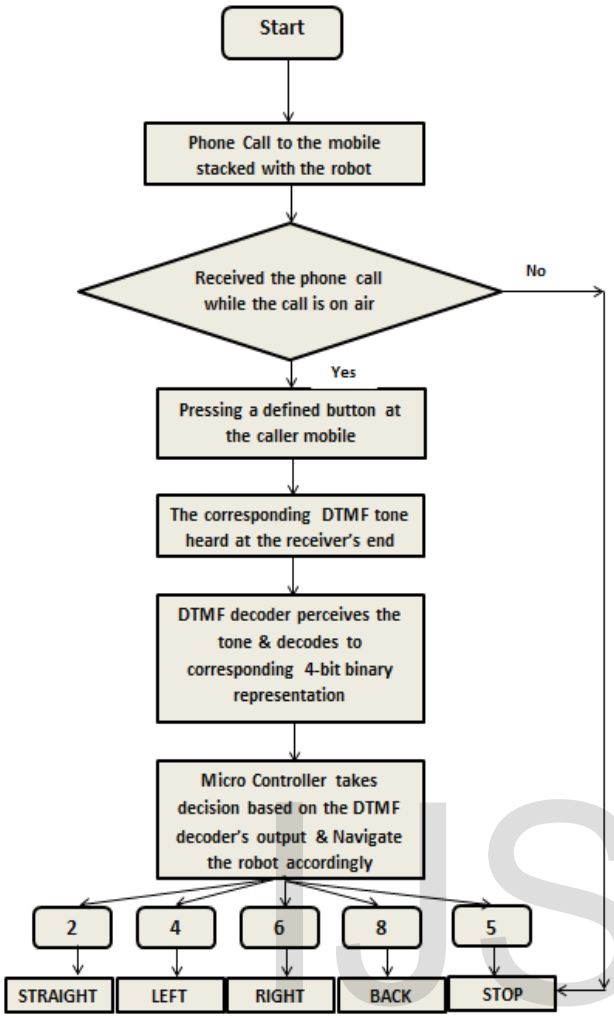

Fig 5: Flow chart of whole process.

When a call is made from a mobile phone then callee mobile automatically received this call which is attached in the robot. Here, the callee mobile phone has acted as remote.

The relationship between the input DTMF tone and the decision is shown in the following figure (Fig 6).

7. Contribution & Implementation

The main contribution of this work than other works is apparent by its efficacy and preciseness. More over this mechanism can be implemented along with other navigating strategies in the same robot, operating simultaneously. In our work this whole process had been implemented as an alternative to navigate the vehicle intelligently using Artificial Neural Network. To accomplish this task, button '5' or call end button on the remote mobile had to be pressed and thus the whole system had been turned out to rely on the alternate system independent of DTMF controlling. To transfer the controlling from the alternative mechanism to DTMF signaling, the working maneuvers had been followed from first to last accordingly.

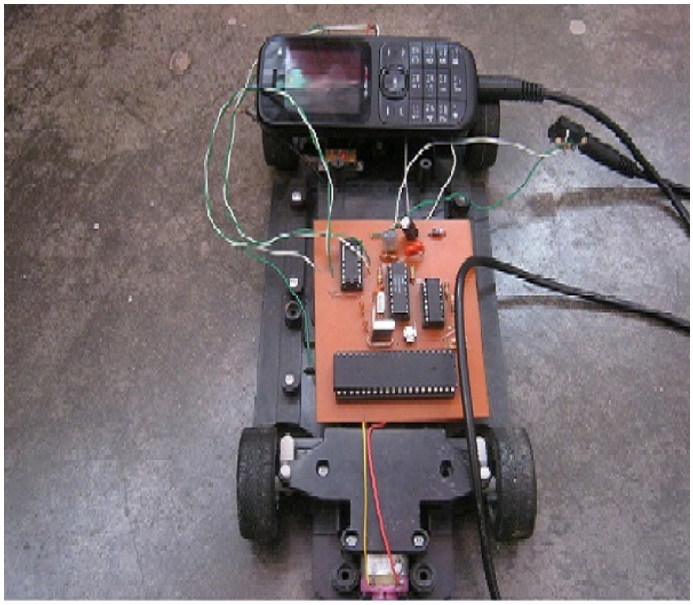

Fig 7: Implementation of the whole process

This would certainly allay the probability of occurring faults either by human or by machine in any one system and thus ameliorate the fault tolerance capabilities.

Number pressed by the user	Output of MT8870 DTMF decoder	Input to microcontroller	Output from microcontroller	Action performed
2	0X02 00000010	0xFD 11111101	0x89 10001001	Forward motion
4	0X04 00000100	0xFB 11111011	0x85 10000101	Left turn
6	0X06 00000110	0xF9 111111001	0x8A 10001010	Right turn
8	0X08 00001000	0xF7 11110111	0x86 10000110	Backward motion
5	0X05 00000101	0xFA 11111010	0X00 00000000	Stop

Fig 6: Relationship between DTMF tone and decision [1].

8. Conclusions

This paper has shown an approach to navigate a mobile robot using DTMF tone through 2G GSM network. Using mobile phone to control a mobile robot reduces the overall cost along with modest performance. DTMF tone signaling has given the robot a new dimension by allowing it to be

navigated in a wider range of area. The input to the DTMF decoder is of vital importance to get a success, demands to be connected accurately.

In future we would like to give this robot intelligence by controlling it through computer automatically and simultaneously. We would also like to add some means with the robot to observe its surroundings so that to operate it from a far.

REFERENCES

[1] Raghavendra, Rahul, *"Mobile phone operated land rover"*
[2] Tuljappa M Ladwa, Sanjay M Ladwa,R Sudharshan Kaarthik, Alok Ranjan Dhara, Nayan Dalei,*"Control of Remote Domestic System Using DTMF, ICICI-BME 2009 Bandung, Indonesia".*
[3]V.O.S. Olunloyo, M.K.O. Ayomoh, " *Autonomous Mobile Robot Navigation Using Hybrid Virtua", European journal of Scientific Research, ISSN 1450-216X Vol.31 No.2 (2009), pp.204-228, Force Field Concept.*
[4] Victor-Emil NEAGOE1, Cristian-Tudor TUDORAN2, *"A Neural Machine Vision Model For Road Detection In Autonomous Navigation"*, U.P.B. Sci. Bull., Series C, Vol. 73, Iss. 2, 2011
[5] Tho Nguyen and Linda G. Bushnell, *"Feasibility Study of DTMF Communication for Robots"*, UWEETR, 2004.
[6] Vamsi Mohan Peri, *"Fuzzy Logic Controller for an Autonomous Mobile Robot"*, 2005.
[7] MT8870DE Datasheet.
*www.ee.mut.ac.th/**datasheet**/doc/MT8870d.pdf*
[8] L293D Datasheet.
*www.zartronic.fr/doc/Z1/**L293D**_ST.pdf*