Intelligent Autonomous Vehicle Navigated by using Artificial Neural Network and DTMF Signaling over GSM Network

Al Arafat
Department of Computer Science and Engineering
Rajshahi University of Engineering & Technology

Abstract:

This paper illustrates on an intelligent agent that can be navigated by using visual identification of road direction utilizing artificial neural network while simultaneously using DTMF signaling over GSM network. The system considers two individual approaches occurring concurrently. While navigating the vehicle by using artificial neural network, an artificial neural network, Kohonen Concurrent Self-Organizing Map (CSOM) is used to make correct identification of road direction by accessing the visual sensor's information. The road directions are classified into one of the three classes- left, straight & right, for each module an individual SOM module is used. The classified decision is then used to navigate the vehicle. While to control the robot using DTMF signaling DTMF tones 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. These two simultaneous operations work as alternatives to one another.

Keywords: autonomous vehicle, artificial neural network, visual road detection, concurrent self-organizing map, edge detection, DTMF Signaling.

1. Introduction:

Developing an efficient autonomous vehicle system is always a great challenge. Myriad of researches has been done over this contemporary topic. An autonomous vehicle system is an intelligent agent that should have the capability to control and run by its own. Precise automation of a system using Artificial Neural Network lies on two practical principle tasks- sensing and reasoning. Sensors make a system running more precisely by gathering information about the robot with respect to the surroundings. While the reasoning makes decisions in order to control the robot by applying appropriate algorithms on the information. Navigating this 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 command to be performed can be fed to the robot either wirelessly or using wires.

Precise controlling in real world environment is the main criterion in this case. Because automation of vehicle based on traditional vision based pattern recognition system may perform well but won't be precise, since path detection in autonomous vehicle system in real time is the main aspect of this system, which is a difficult task. It's because of noises and incessant changes in the surroundings.

Thus immaculate decision making is required to achieve precise controlling. And a perfect artificial neural network classifier can perform this task intelligently by making correct decision.

Artificial Neural Networks are relatively crude electronic models based on the neural structure of the brain. The brain basically learns from experience. It is natural proof that some problems that are beyond the scope of current computers are indeed solvable by small energy efficient packages. This brain modeling also promises a less technical way to develop machine solutions. This new approach to computing also provides a more graceful degradation during system overload than its more traditional counterparts.

Artificial neural network proved itself much more promising in doing jobs like pattern recognition, image processing, etc. Artificial neural network has done these dynamic tasks with a higher success rate. Self-organizing map, an unsupervised neural network widely used for exploratory data analysis, visualization of multidimensional data, segmentation of complex data etc. Self-organizing map is thus used in dynamic pattern recognition in different applications.

Giving alternative to this autonomous system may consolidate its capability in the field of autonomy. The autonomous robotic vehicle system becomes 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 illustrated an intelligent agent that has the ability to drive by using command selected automatically by Artificial Neural Network along with command from remote mobile. The system can run on the both approaches having synchronously.

II. APPROACH

The automated vehicle system runs on two different approaches.

To navigate vehicle on visual based automation system these steps are followed-

i. Input processing,
ii. Reasoning
    a. Feature selection,
    b. Classification.
iii. Feeding output.

To control the robot by mobile phone, the main task is to program the microcontroller properly.

For automated vehicle system using ANN

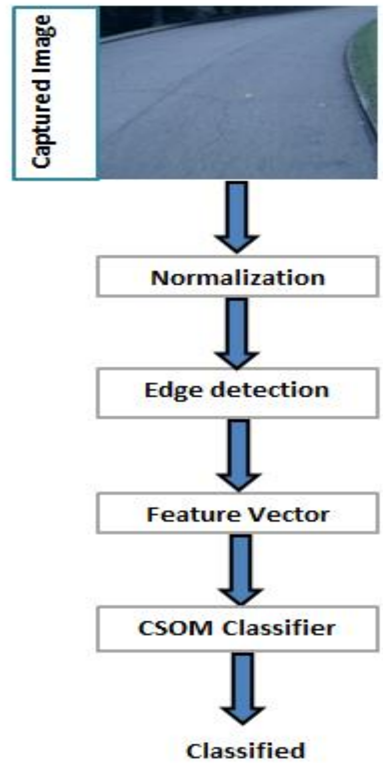

Figure 1: Tasks' sequence to navigate the vehicle using ANN

A. *Image Acquisition*

As this autonomous vehicle identifies road direction visually, it uses camera to take the surrounding images. After taking the surrounding images need to extract road images these images. We only concern the road images of our work. This autonomous vehicle only uses the road images to perform path detection and selection. To do so the images are fed to the processing portion as a vector matrix to make decisions.

B. *Reasoning*

Reasoning part of this system includes two vital processes of the operating algorithm. The first one performs the feature selection process and the second one includes the classification process.

1) Feature Selection: In the feature selection portion modification, normalization and edge detection of the input images are done.

Modification of the input image aggregates the conversion of the image RGB to gray scale and resizing. Conversion of the image from RGB to gray scale and resizing are required to make the computation fast and easy for the classifier.

Normalization is done to perform linear and logarithmic scaling and histogram equalization over the image data. Scaling has great importance because SOM measure Euclidean distance between vectors and thus greater valued variables will dominate over the measurement as they have greater impact.

Edge detection method discards the entire unwanted phenomenon from the image to do more smooth processing over the image. Canny Edge Detector is used as the edge detection algorithm as it is very popular in detecting optimal edge in an image and also gives precision [11]. When we use this algorithm to our work, a binary image of the same size as the input image is obtained, with the points belonging to edges marked as 1's and others marked as 0's. So all information stored in the system only 1's or 0's. That why a large amount of useless information will be out from the system and reducing the total amount of data to the further processed (by the classifier), while preserving the structural properties of the input image.

2) Classification: The processing unit (PU) of the system is the classification process, which makes decision for the system. Concurrent Self Organizing Map (CSOM) classifier is used as the classification model. Classification process evolves through two selection steps.

i) *Architecture:* Three SOM modules are used, each of which individually detects one direction (left, right or straight) class. Each SOM module is a two dimensional one layer neural network. In each SOM modules images are fed as inputs. The topology of a network can be square, circular or other quadrilateral form. Each input node is connected with every other node on the network. Each network identifies a winning neuron. Each module is trained individually with classified images in the training phase to detect one direction. The architecture of a SOM module is shown in fig. 2.

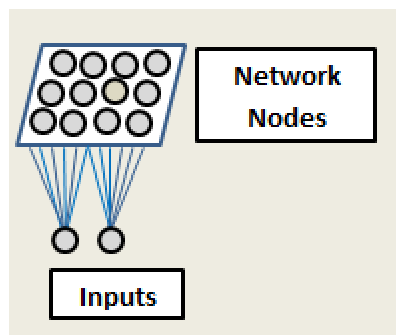

Figure 2: Basic Architecture of each SOM module.

ii) Training of the modules: Each SOM network is trained individually. To train each network, images of the corresponding class is used i.e. to train the SOM module that will recognize only left directed road, only the image subset that contains the left directed road images is used. Thus the other SOM networks are also trained. The training process steps as-

Input images are presented at the input nodes. How the images are presented at the network to train it is shown in fig 3.

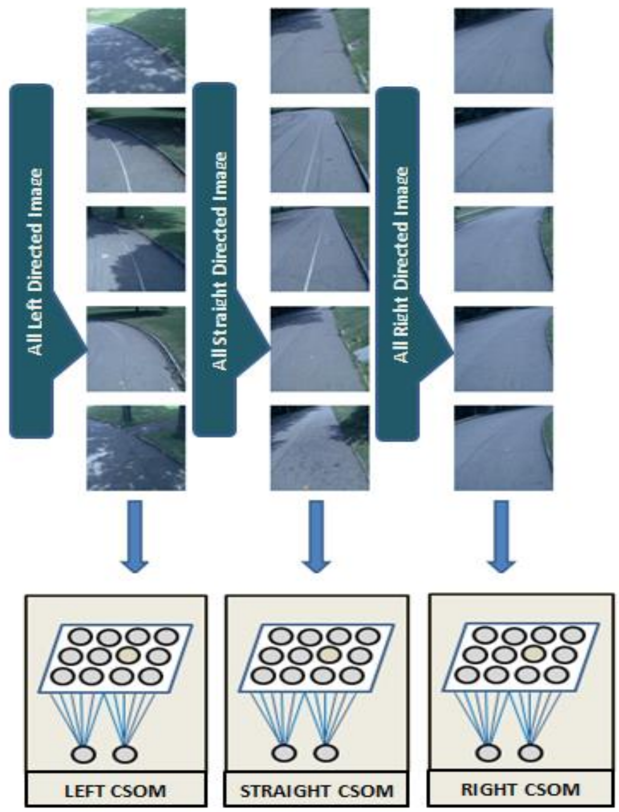

Fig 3: Training process of the CSOM classifier modules.

The training process then advances following the below algorithm

Initialize the weight of network as w_{ij}, where w_{ij} be the weight between input node i and network node j.

The initial radius of the network are set to N_j..

The distances between the nodes are adjusted as following

$$d_j = \sum_{i=1}^{n-1} \left(x_i(t) - w_{ij}(t)\right)^2$$

The minimum distance is selected from them.

Then the weights are updated as the following

$$W_{ij}(t+1) = w_{ij}(t) + \eta(t)(x_i(t) - w_{ij}(t))$$

All the neurons' weights are updated that are in the neighborhood radius. Here $\eta(t)$ is the learning rate factor. The learning rate factor is updated with time as

$$\eta(t) = \alpha(t)\times\exp(-(d_{ij}^2)/2\sigma^2(t)).$$

Here, both $\alpha(t)$ & $\sigma(t)$ are monotonically decreasing factor, where $0<\alpha(t)<1$ and $\sigma(t)$ defines the width of the network.

iii) *Recognition Phase:* The road image to be classified is fed to all three SOM modules at the same time (Fig 3). Then the distance between the input vector and the neurons of the modules are calculated. All the possible distances are then calculated and hence the minimum distance between input vector and the neurons of the module are found. As "Winner takes all" is the working principle of the CSOM classifier, the nearest neuron from the input vector is selected as the winner and the module containing the neuron is assigned to the image (input vector) and the robot is thus directed.

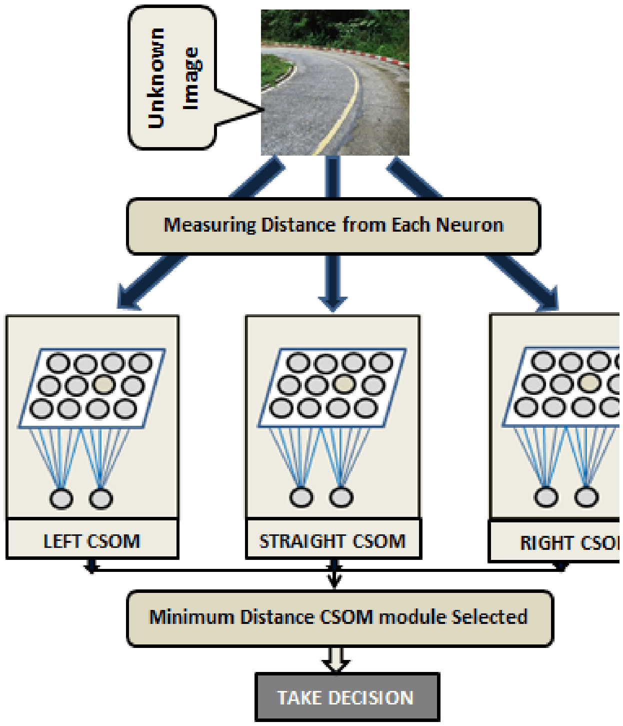

Fig 4: Classification of CSOM model.

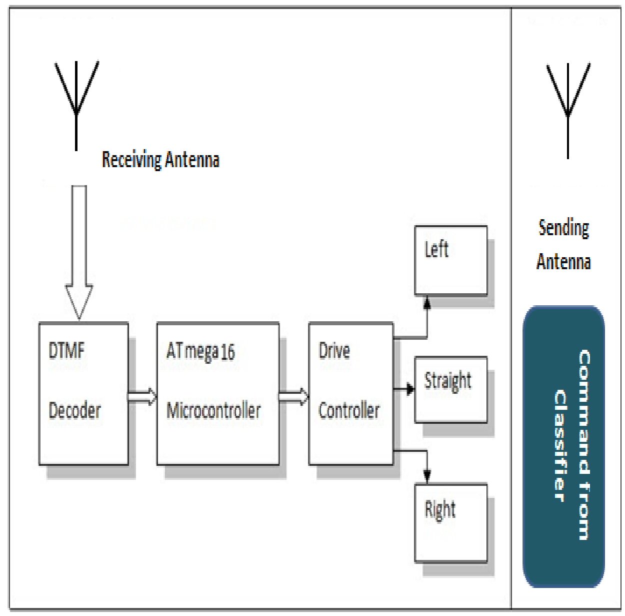

Fig 5: Block diagram of the process of sending the output to the vehicle

C. *Feed The Output To The Device*

The decision taken by the classifier is then sent to the vehicle as DTMF tone using RF transmitter. DTMF stands for Dual Tone Multi Frequency, which is intended for controlling purpose, is composed of two different sine waves of different given frequencies. After receiving the DTMF tone, a DTMF decoder at the receiver's end perceives the tone and generates 4-bit binary equivalent representation. The result is then fed to a preconfigured microcontroller. The micro controller then navigates the vehicle according to the command. The whole process works like-

For navigating the vehicle using DTMF Signaling

The main steps 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.

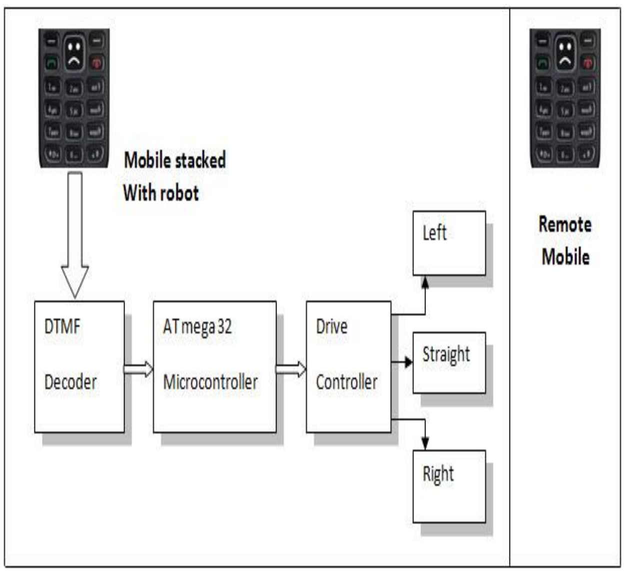

Fig 2: Mobile controlled paradigm

I. OPERATIONAL STRUCTURE

A. *Operational Circuit Diagram*

The operational structure of the mobile robot is as following-

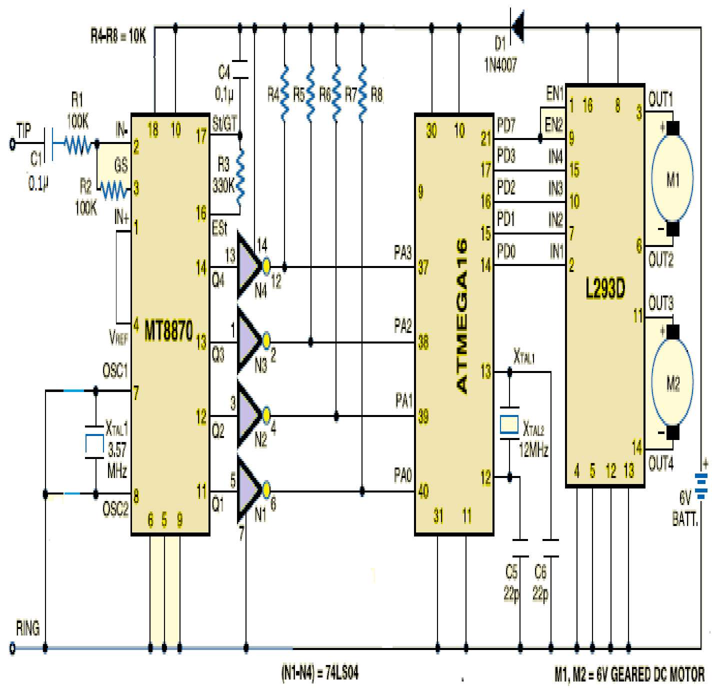

Fig 4: Circuit diagram of the processing unit

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.
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.

B. *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.

What the MT8870DE outputs after performing the decode is shown by this table-

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 3: DTMF decoder data output

C. ATMega16 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.

D. 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.

II. Experimental Results

Working Maneuver to control the robot using Artificial Neural Network

A. *Database*

CMU (Carnegie Mellon University) Vision and Autonomous Systems Centre's Image Database has been used as the database includes a large number of road images captured as part of the extensive research they conduct at their Robotics Institute, for the NAVLAB series of vehicles.

60 images (20 images for each module) have been used to train the network. And 30 images (10images for each module) from the CMU (Carnegie Mellon University) Vision and Autonomous Systems Centre's Image Database have been used to test the network. The test images are different from the images those were used to train the network.

B. *CSOM in real detection*

Three individual SOM modules each having square topology with 10 x 10 neurons has been used. A toy car as mobile robot has been used. A laptop was set on the vehicle. The webcam captured images at 3 seconds gap and sends those images to the computer through data cable. The images have been processed in the computer to take decision by following the approach.

The robot has first driven manually to get its network trained and the captured images during this time were stored. Then the classifier has made decision by selecting the closest neuron to the input image as output. Every direction (left, right or straight) have it own form. This input combination is used to select output direction, which lead to drive vehicle to a specific direction. The output formed as 0100 to define left, 0010 to define straight and 0110 to define right.

Input	Output/ Decision
010	left
001	straight
011	right

Table 1: Input form to output form for the vehicle.

Then the decision has been fed to the mobile robot using RF transmitter. And a microcontroller has been stacked on the robot to drive it according to the command from the computer. The microcontroller has been pre-programmed to drive the robot to left, right or straight. Camera has been set to take road images every 3second and same process is applied to the images to detect next the right path to drive the robot.

The CSOM algorithm gives 95% accuracy in detecting left directed road (can recognize 19 images from 20 images) and 100% accuracy in detecting straight and right directed road images (can recognizes 20 out of 20 images). The overall accuracy of the CSOM is 98.33% in detecting correct road images.

The whole process has been employed in MATLAB.

The block diagram of our working procedure is as following.

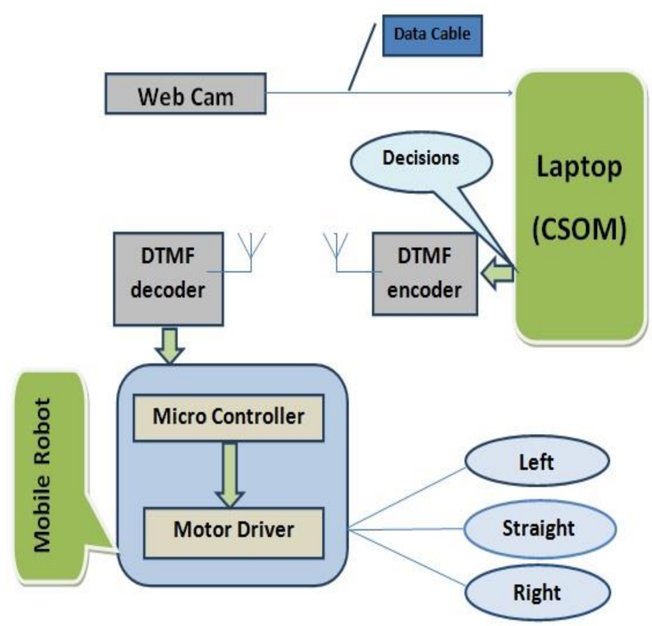

Fig 6: Block diagram of our working procedure.

Working Maneuver to control the robot using DTMF Signaling

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.

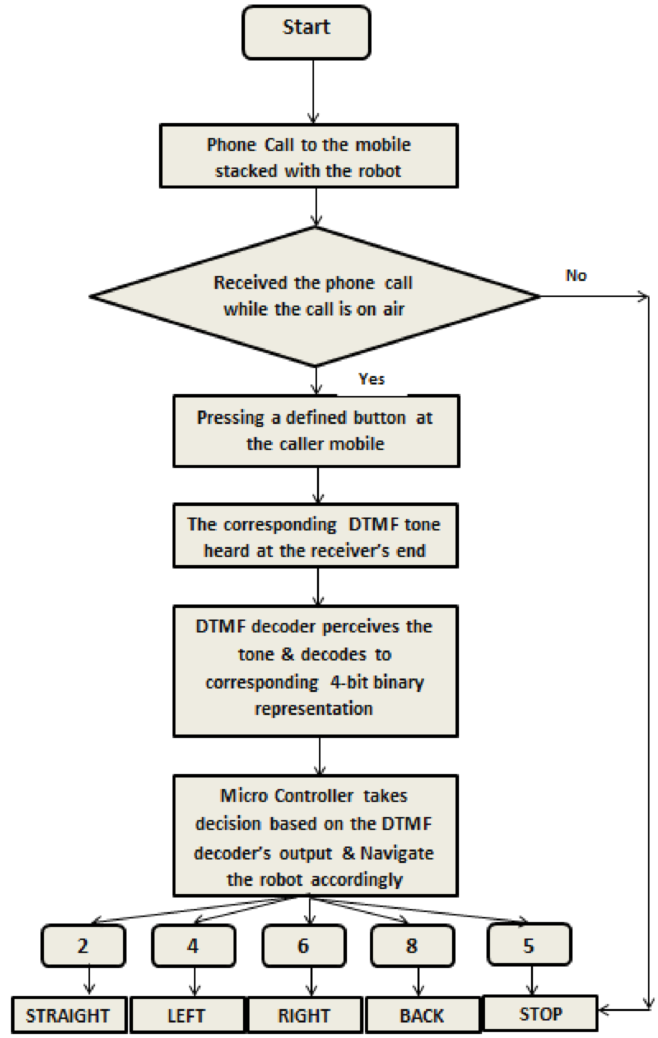

Fig 5: Flow chart of whole process.

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 below figure (Fig 6).

Number pressed by the user	Output of MT8870 DTMF decoder	Input to microcontroller	Output from microcontroller	Actio perfo
2	0x02 00000010	0xFD 11111101	0x89 10001001	Forwa motio
4	0x04 00000100	0xFB 11111011	0x85 10000101	Left tu
6	0x06 00000110	0xF9 111111001	0x8A 10001010	Right
8	0x08 00001000	0xF7 11110111	0x86 10000110	Backw motio
5	0x05 00000101	0xFA 11111010	0x00 00000000	Stop

Fig 6: Relationship between DTMF tone and decision

Synchronizing these two approaches

When the want to navigate the vehicle using DTMF signaling, we need to make a phone call to the mobile attached with the robot. At that time command from Artificial Neural Network doesn't come into action. When the call ends, the vehicle starts driving using the commands from Artificial Neural Network.

In our work this whole process had been implemented to give alternative to human error or mechanical error. 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. 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.

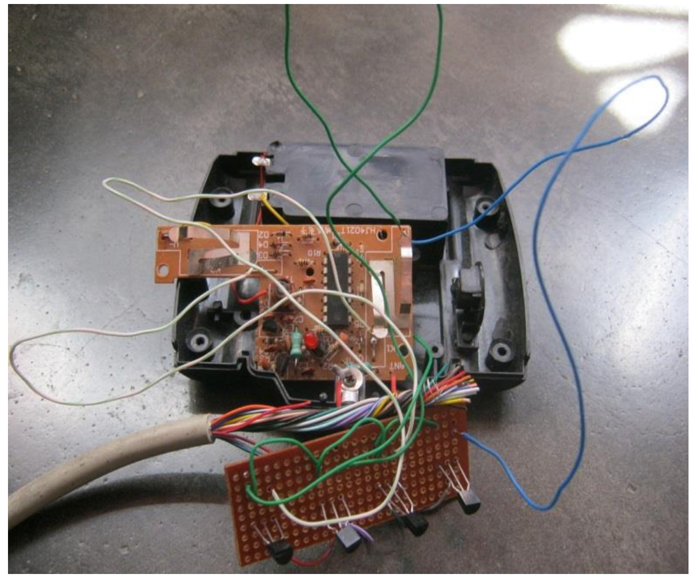

Fig 7.6: Interfacing mobile robot with computer through parallel port

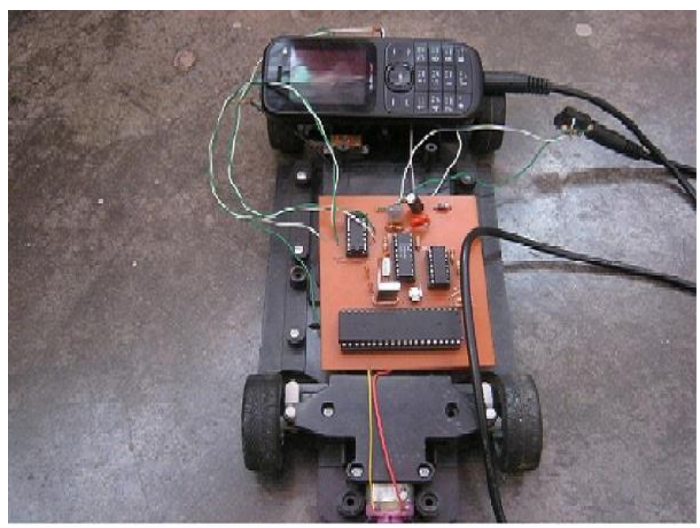

Fig 7: Implementation of the whole process

CONCLUSIONS

In this paper we have presented an approach to navigate a vehicle using alternative approaches. An artificial neural network classifier named CSOM was used to navigate it as one approach. The CSOM classifier gives much more precision and flexibility in classifying road directions. Feature selection method like normalization and edge detection brings better accuracy in classification process.

We demonstrated how we implemented the algorithm in software. We have run our simulation in MATLAB and our simulation result shows us the generalization and adaption capabilities of neural network.

Using mobile phone to control the 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.

By synchronizing these two approaches, we had the opportunity to give the robot better option to avoid mechanical or human errors. In future we would like to concentrate on to give this vehicle obstacle avoidance capability and make it more robust and dynamic. 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] *T. Kohonen*, Self-Organizing Maps, Springer-Verlag, 1995.

[2] *D.A. Pomerleau*, Efficient training of artificial neural networks for autonomous navigation, Neural Computation, vol. 3, no. 1, 1991, pp. 88-97.

[3] *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

[4] R. C. Gonzalez and R. E. Woods, Digital Image Processing, Third Edition, Prentice-Hall, Upper Saddle River, New Jersey, 2008.

[5] Dave Anderson and George McNeill, ARTIFICIAL NEURAL NETWORKS TECHNOLOGY, Kaman Sciences Corporation 258 Genesse Street, Utica, New York,1992,pp. 6.

[6] M. Bishop, Pattern Recognition and Machine Learning, Springer, New York, 2006.

[7] V. E Neagoe and C. T. Tudoran, Road following for autonomous vehicle navigation using a concurrent neural classifier, Proc. Int. Symp. Soft Computing in Industry (ISSCI'08), World Automation Congress, 2008 (WAC 2008), Sept. 28–Oct. 2, 2008, Hawaii, USA, ISBN: 978-1-889335-38-4.

[8] Matlab, Simulink User Guide, The Math Works Inc., 1997.

[9] D. A. Pomerleau, Defence and civilian applications of the ALVINN robot driving system, Proc. 1994 Government Microcircuit Applications Conference, San Diego, CA, Nov. 1994, pp. 358-362.

[10] M. Lützeler and S. Baten, “Road recognition for a tracked vehicle”, Proc. SPIE Conf. on Enhanced and Synthetic Vision, AeroSense 2000, Orlando, FL, USA, April 24-28, 2000.

[11] John Canny. A computational approach to edge detection. Pattern Analysis and Machine Intelligence, IEEE Transactions on, PAMI-8(6):679–698, Nov. 1986.

[12] Raghavendra, Rahul, ”Mobile phone operated land rover”

[13] 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".
[14] MT8870DE Datasheet. *www.ee.mut.ac.th/**datasheet**/doc/MT8870d.pdf*
[15] L293D Datasheet. *www.zartronic.fr/doc/Z1/**L293D**_ST.pdf*