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Global System for Mobile Communication (GSM) Based Robotic Control System

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ABSTRACT

This paper shows how the Global System for Mobile Communication (GSM) was deployed to implementing a wireless mobile robotic system which can be controlled from anywhere in the world by using mobile phone and Dual Tone Multi-Frequency (DMTF) technique which can move in forward, backward, left and right directions at the press of a button on the mobile phone. The Robotic Control System is able to scan environment and detect human presence and motion with the help of a Pyroelectric Infrared Sensor (PIR) and give a feedback via Short Message Service (SMS) to the user's mobile phone when it detects a human for the necessary action to be taken. In this design, the function of Pyroelectric Infrared Sensor (PIR) is to absorb the infrared radiation from the human body and create a corresponding signal. The detection range without a lens is about three feet but can be extended to up to 90 feet or more by placing an infrared Fresnel lens in front of the sensor. The wavelength of infrared radiation is 9.4 micro meter. This sensor can be used to find the human up to 3 meters to 90 meters distance. It also has a protection device that is Fresnel lenses. An application of this Global System for Mobile Communication (GSM) Robotic System with Pyroelectric Infrared Sensor (PIR) is used for rescuing persons during earthquake, building collapse and construction site collapse. This work is executed using a standard engineering software (Proteus) to design the circuit of the system with all its components and simulate its working and performance. The result shows that both the microcontroller and the motor driver circuit worked perfectly well and the motor was able to move the robotic system in different directions for its search. The test results also show that at a nominal speed value of 180 (cm/s), the robot which kept at tolerable stop distance to confirm human presence with an average breaking distance of 5.5cm. Future design should accommodate the provision of solar power supply for the control system in order to prevent the battery from running down completely. Another area of improvement is the addition of Bluetooth interface to the robotic system to enable the user use his/her smartphone to control the system instead of SMS to remove the cost of SMS charges. Finally, future design should also accommodate installation of surveillance camera which will provide visual feedback of environment and target in order to propel corresponding user response.

Key words: Robot, Pyroelectric Infrared Sensor, Short Message Service, Dual Tone Multi-Frequency

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INTRODUCTION

A robot is a mechanical or virtual agent, usually an electro-mechanical machine that is guided by a computer program or electronic circuitry. Robots can be autonomous or semi-autonomous intelligent machine. Robotics is a wide and vast research field that is growing day by day. Kerrow and Wesley [1], asserted that a networked robotic system refers to a group of robotic devices that are connected via a wired and/or wireless communication network. Networked robotics applications can be classified as either tele-operated robots or multi-robot systems. According to Mohammed [2], a mobile controlled Robot is a mobile device, which provides wide-range of wireless control ability to your robot unless your cell phone gets out of signal. A general concept of mobile controlled robot is that it can be controlled from any part of the world.

Acquiring the data for analysis and decision making is very important part of life; in the past, acquiring these data was done through wired media, but one of the clear limitations that wired communication requires cables and that has a significant difficulty in the longer destination. There is high degree of complexity and cost involved in

creating robotic control systems, that can be used in very large coverage areas thus the need for further research in this area to develop more cost effective versions. This project aims to create a control system that can use wireless communication over a large coverage area by using existing and accessible components, unique to this design is the Passive Infrared Sensor (PIR) sensor which makes the system more cost effective.

Until recently robots were mainly used by factories for automating production process. The appearance of robots in 1970 influences the rate of unemployment in Europe and USA. New robotics no longer concerns only factories application but has evolved to the used of robotics in automation in numerous human activities. The new robot is thus usually not a self-sufficient system as it's supported by network of information technologies.

Literature survey is the most important step in software and hardware development tool. Before developing the tool, it is necessary to determine the time factor and economy. Once these things are satisfied, the next step is to determine which operating system and language can be used for developing the tool. Once the programmers start building the tool the programmers need lot of external support. This support can be obtained from senior programmers, from book or from websites. Before building the system, the above consideration is taken into account for developing the proposed system. Ladwa [3] proposed a remote domestic system using DTMF. The proposed model was used to control home appliance using DTMF decode such as light ON and OFF, switching motor ON and OFF, Chen and Bu, (2010). Similarly, Kumar [4] proposed a robot controlled by DTMF and GSM. DTMF used to control the Robot and GSM is used to send and received sensors information and commands. Felix, [5], proposed a home automation using GSM. The proposed GSM model was better than Zig bee, RF, IR, etc. It was able to control sensors, switching, temperature controlling. Muhury, [6], proposed an application controlled by GSM modem. The GSM modem can able to send and receive data and information. GSM modem was used and the network is used in external device controlling.

The gap filled by this research is majorly in the application of PIR sensor in GSM controlled Robotic system, previous research work in the field of Robotics have made use of Sensors that are not as cost effective as the PIR. Also, the PIR sensors are called simply "PIR", or sometimes "PID", for "passive infrared detector". The term passive refers to the fact that PIR devices do not radiate energy for detection purposes. They work entirely by detecting infrared radiation (radiant heat) emitted by or reflected from objects, hence the energy consumption is far less than the consumption rate in other sensors, these results to a significant advantage in this era where energy conservation is of utmost importance. This prototype employs the PIR (Passive infrared) sensors which can detect moving objects even in the dark with high level of accuracy, detect objects without coming in contact with them and are very easy to install and do not require much wiring as such less energy consumption is required for running the system.

GLOBAL SYSTEM FOR MOBILE COMMUNICATION

Global System for Mobile Communication (GSM) is a digital mobile telephone system that is widely used in Europe and other parts of the world. It uses a variation of Time Division Multiple Access (TDMA) and is the most widely used of the three digital wireless telephone technologies (TDMA, GSM, and CDMA). GSM digitizes and compresses data, then sends it down a channel with two other streams of user data, each in its own time slot. It operates at either the 900 MHz or 1,800 MHz frequency band [7]. GSM is an international digital cellular telecommunication. The GSM standard was released by ETSI (European Standard Telecommunication Standard) back in 1989. In less than ten years since the first GSM network was commercially launched, it became, the world's leading and fastest growing mobile standard, spanning over 190 countries.

GSM is a second-generation cellular standard developed to deliver high quality and secure mobile voice and data services (such as SMS/ Text Messaging) with full roaming capabilities across the world using digital modulation. It is known as 2G digital which has a maximum data speed of 9.6Kbps and is based on circuit switched technology and provides short message service (SMS). The GSM network can be divided into three broad parts. The subscriber carries the Mobile Station. The Base Station Subsystem controls the radio link with the Mobile Station. The Network Subsystem, the main part of which is the Mobile services Switching Centre (MSC), performs the switching of calls between the mobile users, and between mobile and fixed network users. The MSC also handles the mobility management operations. The Mobile Station and the Base Station Subsystem communicate across the Um interface, also known as the air interface or radio link. The Base Station Subsystem communicates with the Mobile services Switching Center across the A interface [7].

Table -1 GSM Characteristics [7]

Specification	Value
Mobile Frequency Range	RX:925-960; TX: 880-915
Multiple Access Method	TDMA/FDMA
Duplex Method	FDD
Number of Channels	124 (8 users per channel)
Channel Spacing	200kHz
Modulation	GMSK (0.3 Gaussian Filter)
Channel Bit Rate	270.833Kb

The GSM standard provides a common set of compatible services and capabilities to all mobile users across Europe and several million customers worldwide. The basic requirements of GSM have been described in five aspects.

Basic Requirements of GSM

Services

The system provides service portability, i.e., mobile stations or mobile phones can be used in all participating countries. The system shall offer services that exist in the wire line network as well as services specific to mobile communications. In addition to vehicle- mounted stations, the system shall provide service to MSS used by pedestrians and /or on-board ships.

Quality of Services and Security

The quality for voice telephony of GSM shall be at least as good as the previous analog systems over the practical operating range. The system shall be capable of offering information encryption without significantly affecting the costs to users who do not require such facility.

Radio Frequency Utilization

The system shall permit a high level of spectrum efficiency and state-of-the-art subscriber facilities. The system shall be capable of operating in the entire allocated frequency band, and co-exist with the earlier systems in the same frequency band.

Network

The identification and numbering plans shall be based on relevant ITU recommendations. An international standardized signaling system shall be used for switching and mobility management. The existing fixed public networks should not be significantly modified. Cost of the system parameters shall be chosen with a view to limiting the cost of the complete system.

Overview of DTMF Technology Used

The technology used in this paper is DTMF. DTMF stands for Dual Tone Multiple Frequencies. DTMF is a term which used in telephone industry. The robot receives this DTMF tone with the help of the phone stacked with the robotic system. The received tone is processed by the microcontroller (ATMega 2560) with the help of DTMF decoder (MT8870), which decodes the DTMF tone in to its equivalent binary digit and this binary numbers are then sent to the microcontroller. The microcontroller is pre- programmed to take a decision for any given input and outputs it decisions to the motor drivers in order to drive the motors for forward or backward motion or a turn right or left. The version of DTMF used for telephone dialing is called touch tone. The project uses MT8870 DTMF decoder IC which decodes tone generated by the keypad of cell phone. These tones are based on the DTMF technology. Data is transmitted in terms of pair of tones. The receiver detects the valid frequency pair and gives the appropriate BCD code as the output of the DTMF decoder IC. The tones are decoded by the switching centered to determine the keys pressed by the user.

Table -2 Frequency assignment in DTMF system [7]

Frequencies	1209Hz	1336Hz	1477Hz	1633Hz
697Hz	1	2	3	A
779Hz	4	5	6	B
852Hz	7	8	9	C
941Hz	*	0	#	D

MATERIALS AND METHOD

The materials or equipment employed in the development of the prototype system include Arduino Mega, GSM Module (SIM 900D), DC Motor, PIR Sensor, Power Supply (LM7805), Liquid Crystal Display (LCD). Figure 1 below denotes the block diagram of proposed GSM robotic control system. The main hardware components are microcontroller, level converter, LCD, DC motor and driver, GSM module and power supply. The main scope of project is to send commands from one cell phone to be received by another cell phone mounted on the robot. The

controller also connected to the GSM module, which sends information to rescue person about the dangerous area where robot is climbing or running.

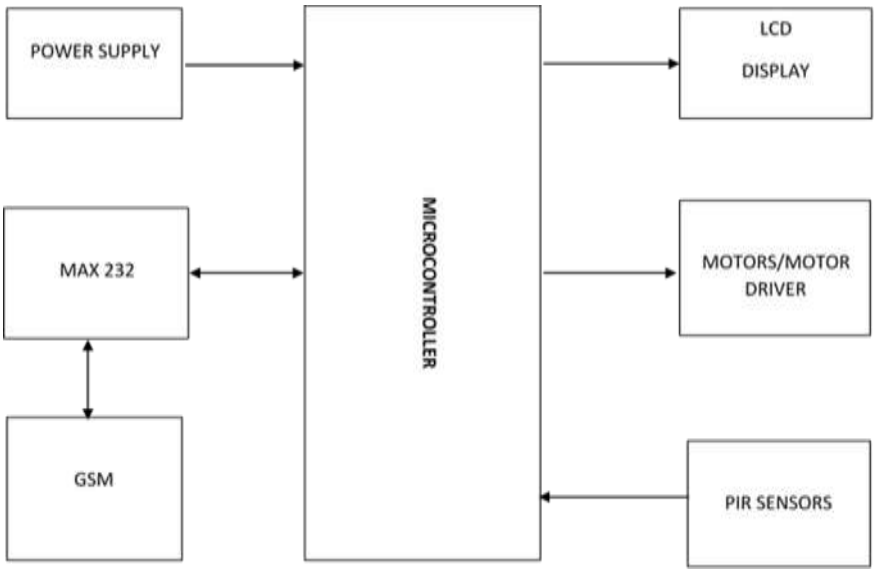

Fig. 1 Block Diagram of the GSM Robotic Control System

The methodology used in this paper is Dual Tone Multi-Frequency (DTMF). Our robotic system is controlled by a cell phone, through this we can make our robot communicate on a large scale over a large distance even from any place of the world. In the course of a call, if any pre-programmed button is pressed, corresponding tone will get generated. The generated tone will get receive by a mobile device which is attached with the robot. This tone is called DTMF tone. The robot perceives this DTMF tone with the help of the phone stacked on the robot. Here after receiving the DTMF tone, ATMega 2560 microcontroller is coming in to picture. The received tone is processed by the ATMega microcontroller with the help of DTMF decoder MT8870. The decoder decodes the DTMF tone in to its equivalent binary digits and this binary digit will be sent to the microcontroller which are pre-programmed to take a decision and give command to motor drivers in order to drive the motors in forward or backward motion or a turn to left or right. The microcontroller then transmits the signal to the motor driver ICs to operate the motors and our robot starts moving accordingly. Cell phone operated robotic system is a robot whose movement can be controlled by pressing the number of cell phone.

The robot can move forward, backward, right or left which depends on the numbers which you are pressing. This system makes use of GSM technologies. The robot has an LCD screen for the display of pictures, image sequences, multimedia presentations or any other information. The desire of making life better and easier is part of human nature. Before live implementation, testing of the developed technique is required. Most of the time, testing and evaluating the protocols or theories proposed is not practically feasible through real experiments as it would be more complex, time consuming and even costly. So, to overcome this problem, “SIMULATORS and TESTBEDS are effective tools to test and analyze the performance of protocols and algorithms proposed [8].

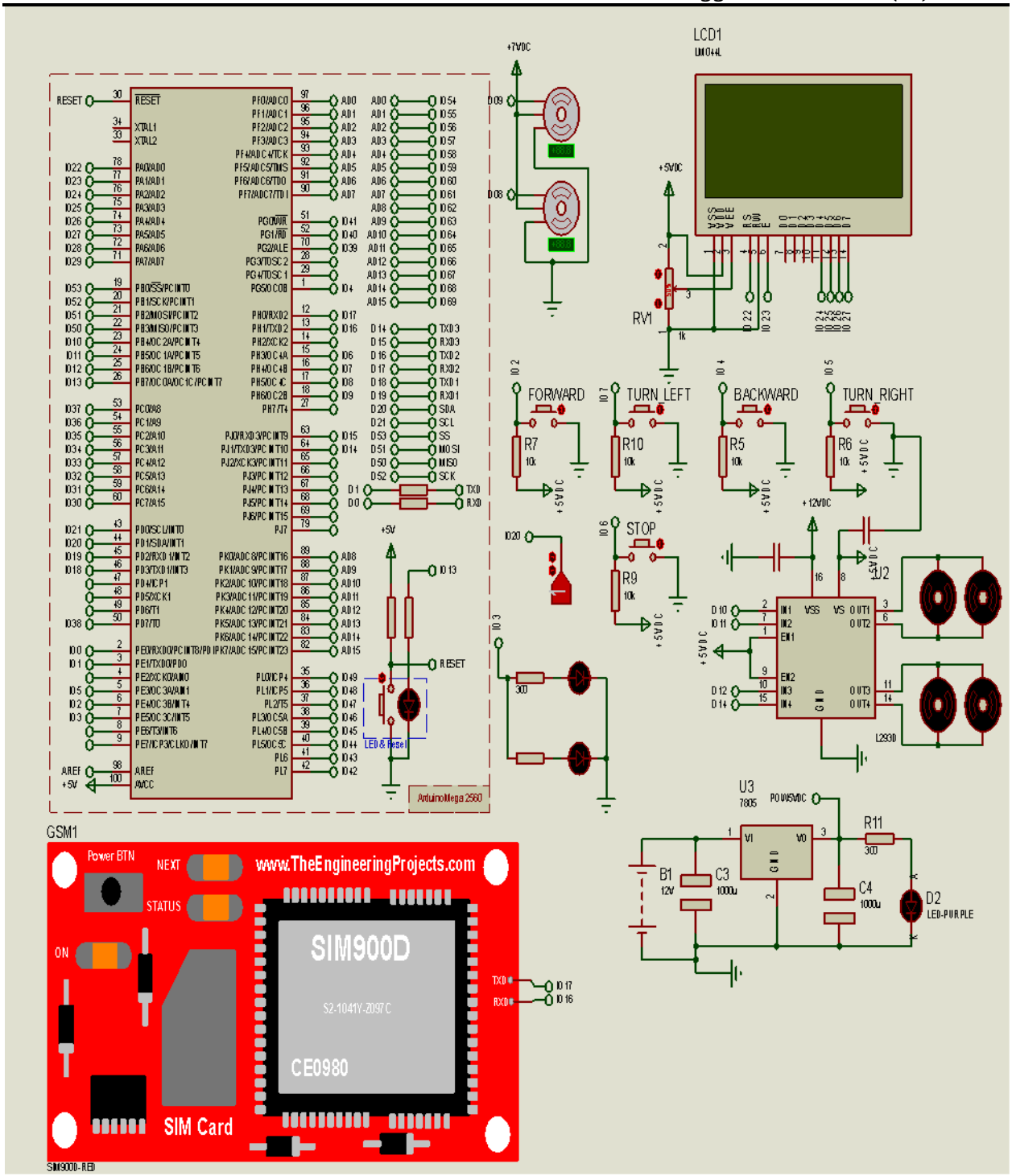

Fig. 2 Full Circuit Diagram for the Design

RESULTS AND DISCUSSION

Proteus 8.10 SP3 Professional program was used for simulating components and writing the code. Below are the simulation diagrams at different stages showing the different capabilities of the design.

The circuit uses keypad buttons to send commands through the MCU to the Motors driver circuit and LCD to display the message sent by the GSM module. Keypad buttons forward, backward, left, right and stop buttons were labeled accordingly for the purpose of this simulation. In actual construction, these can be assigned buttons (2, 8, 4, 6, 0) respectively on a mobile phone.

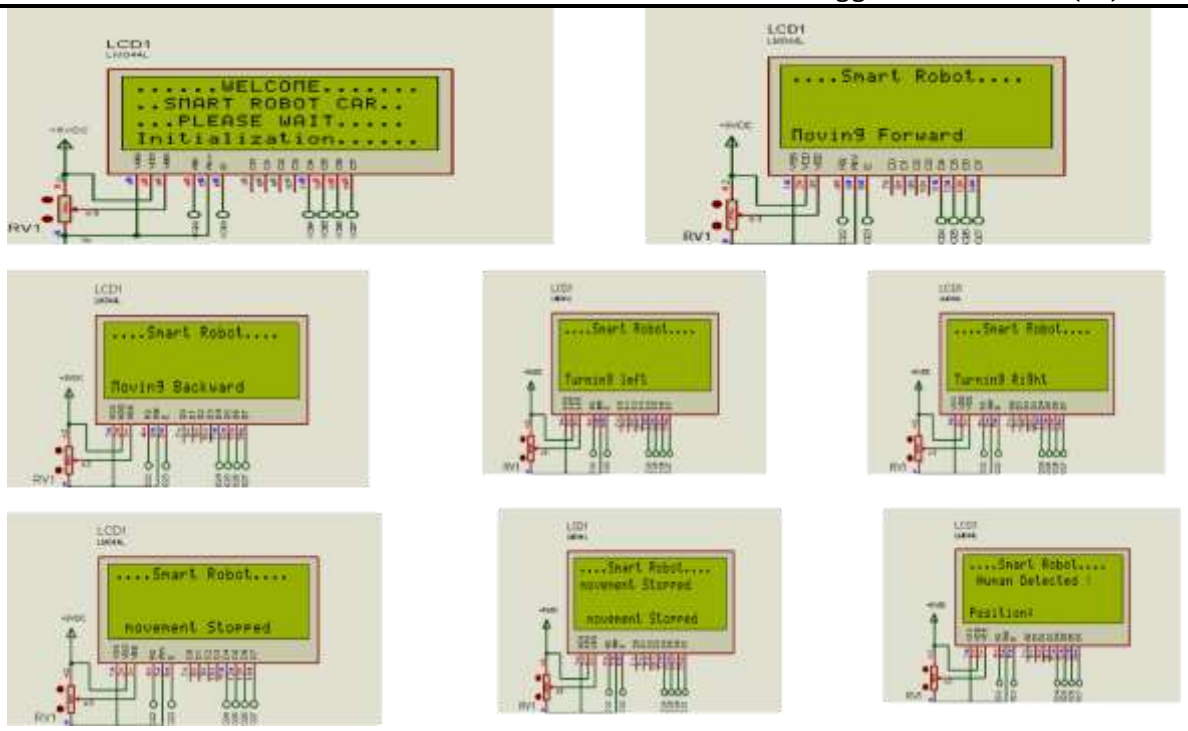

Fig. 3 Simulation of LCD display when the Robot is in different modes of Operation

Due to the absence of linear and rotational velocity feedbacks, the stoppage distance is not exact in the event the robot detects a person on motion and it's further required to stop and confirm the person's location the robot stops at distance few centimeters ahead due to inertia. This happens at several speeds, we require a safe speed or PWM (Pulse Width Modulation) value that ensures the robot moves steadily and stops at the detection of obstacle with some allowable Gaussian noise. The figure shown below shows the test results for a speed or PWM value of 200, 180, and 150 (cm/s) we found 180 (cm/s) to be a nominal speed value which kept the robot at tolerable stop distance to confirm human presence.

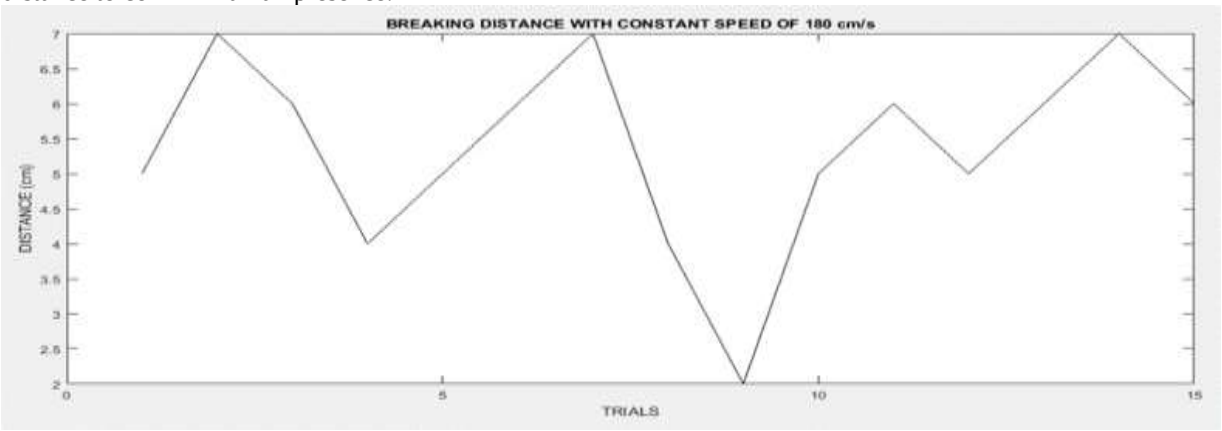

Fig. 4 Graph of breaking distance of the robot at constant speed of 180cm/s

Figure 4 is the graph of different trials for the breaking of the robot when it senses a human being moving with a speed of 180. Due to slippage and inertia it couldn't be predicted. The graph shows an average breaking distance of 5.5cm

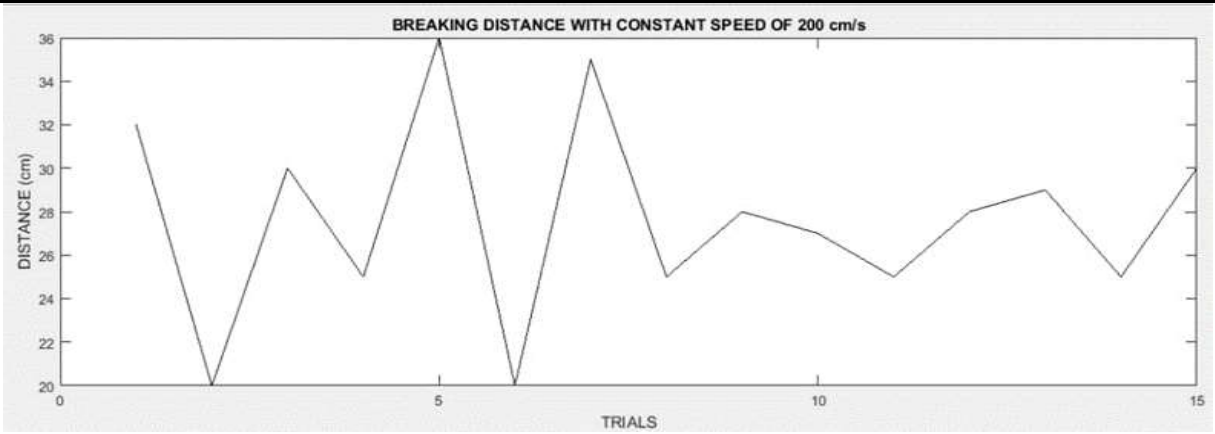

Fig. 5 Graph of breaking distance of the robot at constant speed of 200cm/s

Figure 5 is also a graph showing different test breaking distance point for the robot when it suddenly senses. The graph shows average distance of 27cm away from the point it starts breaking. A careful observation of the angular rotational speed of the robot was also taken. Data were taken to fit a formula for the stoppage errors of the robot. To get the robot to turn angles with inertia measurement unit (IMU), the robot has to be tested for different turn angles and the time it took to stop turning. The data were collected and mapped using Microsoft Excel to generate the quadratic below:

$$\boldsymbol{y} = 0.037x^2 + 3.231x + 8.395 \quad (1)$$

Equation (1) gives the time it will take the robot to turn given a desired angle; y represents the angle (degrees) on the vertical axis and x represents the time (seconds) on the horizontal axis. The figure 6 shows the turn angles of the robot.

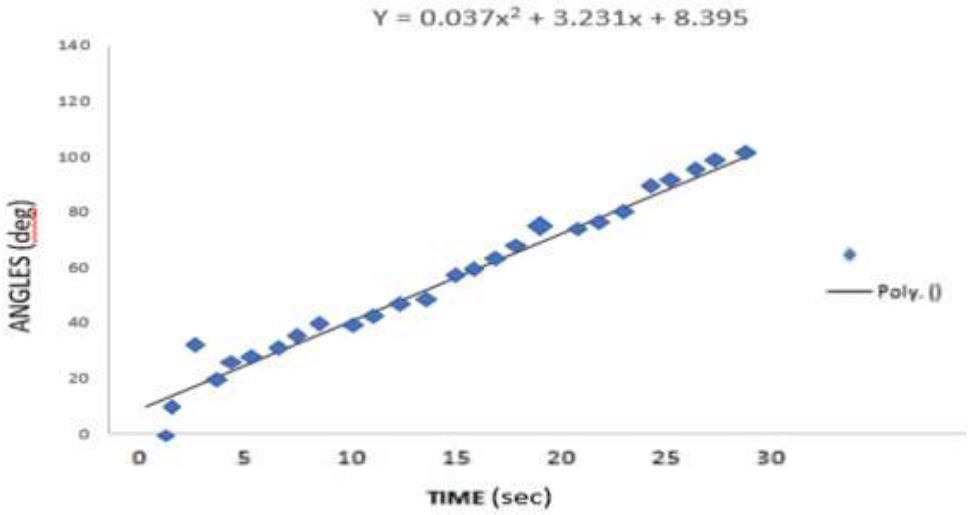

Fig. 6 Graph of turn angles of the robot

CONCLUSION

This work has presented a low-cost approach to improved microcontroller based robotic system. Dual Tone Multi-Frequency (DTMF) technology and Global System for Mobile Communication (GSM) are used. With the help of these technologies, we can control the robotic system from any location of the world. Global System for Mobile Communication (GSM) has been deployed in this design in controlling and sending instructions to the robotic system. This is achieved with the use of the GSM SIM900D module. GSM is used instead of CDMA because it is highly secured and cannot be easily jammed or tapped. Passive Infrared Sensor (PIR) is deployed in this design to serve as a unique feature to previous designs as it is cost effective, energy conservative and highly reliable in situations that needs high sensitivity. The developed system also gives us the LCD display at any point for any direction of the robotic system. It also displays automatically the position and direction for any human presence detected. To improve the efficiency as well as the interconnectivity and interoperability of the prototype system, the project schematic has been developed with Proteus 8 Professional Software. Significantly, this research work has shown that the PIR sensor will prove a preferable sensor on a robot that is to be used for rescuing persons during landslides, earth quakes and other recuse operations. Hence using PIR sensor is cheaper as well as reliable than

most sensors. Finally, this research eliminates the challenge of designing an effective and reliable robotic controlled system of low cost using accessible and reliable components.

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