International Journal of Scientific Engineering and Technology (ISSN : 2277-1581)
Volume No.3 Issue No.8, pp : 1065-1070 1 Aug 2014

Accelerometer Based Direction Controlled Wheelchair Using Gesture Technology

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Abstract*— *This paper presents a model for Gesture controlled user interface (GCUI), and identifies trends in technology, application and usability. We present an integrated approach to real time detection, gesture based data glove technique which controls the wheelchair using hand movements. The paper proposed a low-cost and small 3-axis wireless accelerometers based system to control the wheelchair using microcontroller. The system is divided into two main components: Gesture recognition module with Micro-electromechanical systems (MEMS) sensor and wheelchair control. In the gesture recognition module the heart of the system is microcontroller. The MEMS sensor which is connected to hand, is an 3-axis accelerometer with digital output (I2C) that senses the angle of the hand, i.e. according to the tilt of hand it gives voltages to microcontroller. The wheelchair control unit is controlled using PC89C52 controller. The four proposed movements that achieved: are stop, backward, forward, left and right. Finally, the results of some tests performed with the controlled system are presented and discussed. Experimental results show that the system can recognize input gestures quickly with a reliable recognition rate. The users are able to perform most of the typical interaction tasks in virtual environment by this accelerometer-based device.

Keywords— Hand gesture recognition, GCUI, posture, MEMS Sensor, Microcontroller, GRS, Human Robot Interface.

I. Introduction

The increase in human-machine interactions in our daily lives has made user interface technology progressively more important. Physical gestures as intuitive expressions will greatly ease the interaction process and enable humans to more naturally command computers or machines. For example, in tele robotics, slave robots have been demonstrated to follow the master's hand motions remotely. Other proposed applications of recognizing hand gestures include character-recognition in 3-D space using inertial sensors, gesture recognition to control a television set remotely [4], enabling a hand as a 3-D mouse, and using hand gestures as a control mechanism in virtual reality.

In today's fast world, everyone is busy and there are less people to care for the increasing number of elderly and the physically challenged people. Also these people find it tough to even navigate inside the home without external aids. The elderly people find automated wheelchairs as an easy way for locomotion. Having known about these facts, our aim was to bring an automated control system which can be used by both the elderly and the physically challenged people in a user friendly manner using hand gestures for operation.

In biomedical sector, a wheelchair is an important device because of the recent shift in the industrial populations. The demand of the physically handicapped and the aged are ever rising. The present wheelchairs do not have integration of technologies for their working. It either requires constant monitoring by the helper or hence lot of effort. Traditional wheelchairs have some limitations in context ton flexibility, bulkiness and limited functions [1]. The recent developments in the robotics artificial intelligence or sensor technology promises enormous scope for developing an advanced wheelchair. Some existing wheelchairs are fitted with pc for the gesture recognition or voice recognition [2]. But making use of the pc along with the chair makes it bulkier and increases complexity. This complexity is reduced by making use of the MEMS accelerometer [3-4], due to very compact and can be placed on the fingertip of the patients. And some other systems, which based on the same technique and use of similar kind of sensors are wired, which again increases the complexity of the system. They also limit the long range communication. This complexity is removed by using the RF transmission with high range frequency. Our approach allows the users to use human gestures of movement like hands and synchronize them with the movement of the wheelchair so that they can use it with comfort and ease on all kinds of terrains without the hurdle or cardiovascular problems or fatigue. In this project we are trying to include some sensors to develop an automated wheelchair which can help the patient to control the direction of the wheelchair based on gesture [5].

II. Analysis

The objective of this project is to use the concept of gesture recognition to control a wheelchair (robot). The primary emphasis laid on the mechanism of GR Technology which is achieved by the help of accelerometer and its proposed mechanism. For gesture recognition the accelerometer data is calibrated and filtered. The accelerometers can measure the magnitude and direction of gravity in addition to movement induced acceleration. In order to calibrate the accelerometers, we rotate the device's sensitive axis with respect to gravity and use the resultant signal as an absolute measurement. The four proposed movements that will be tried to achieve are backward, forward, stop, left and right.

III. Related Work

Gesture recognition based on data from an accelerometer is an emerging technique for gesture-based interaction after the rapid development of the MEMS technology. Accelerometers are embedded in most of the new generation personal electronic devices such as Apple iPhone , Nintendo wiimote which provide new possibilities for interaction in a wide range of applications, such as home appliances, in offices, in video games and most important in medical Centre. Gesture recognition has been extensively investigated . The majority of the past work has focused on detecting the contour of hand movement. Computer vision techniques in different forms have been extensively explored in this direction. As a recent example, the Wii remote has a "camera" (IR sensor) inside the

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remote and detects motion by tracking the relative movement of IR transmitters mounted on the display. It basically translates a “gesture” into “handwriting”, lending itself to a rich set of handwriting recognition techniques. In paper [6] by J.S. Kim, C.S. Lee, K.J. Song, B. Min, Z. Bien, a pattern recognizing algorithm has been used to study the features of hand. There are many papers where training of hands using a large database of near about 5000-10000 positive and negative images are considered. But this procedure is very tiring and time taking. In Paper [7] by Francisco Arce, José Mario García Valdez a three axis accelerometer has been used to read different types of hand gestures. But carrying extra circuitry on the hand involves attaching a number of accelerometers with the hand, this causes irritation to the user, there may be loose connection in the system which may result in abnormal outcomes. Hand gesture recognition using image processing algorithms many time involve use of color gloves. By tracking this color glove different hand gestures can be interpreted as described by Luigi Lamberti1 and Francesco Camastra in their paper [8].Here they have modeled a color classifier performed by Learning Vector Quantization. In Paper [9] by Anala Pandit, Dhairya Dand , Sisil Mehta , Shashank Sabesan , Ankit Daftery used a combination of accelerometer and gyroscope and the readings are taken into for analyzing the gesture. Here accelerometer is dedicated for collecting translational dynamic and static change in positional vector of hand and infer it to the movement of mouse whereas gyroscope has been used for rotation of virtual object. There are many papers where gestures are being analyzed using color gloves [10]. A data glove is a type of glove that contains fiber optics sensor embedded in it to recognize the fingers movement.

IV. Working Model

Implementation of this proposed problem mainly involves two steps. They are gesture recognition and controlling direction of wheelchair using microcontroller based on the received gesture commands. The block diagram of the system is shown in Figure 1(a) Transmitter Block Diagram, (b) Receiver Block Diagram.

As overviewed in the block diagram the hand gesture is sensed by accelerometer using the instrumented glove approach. The ADXL 330 accelerometer which convert the hand position into 3-Dimensional Output. The values obtained from the accelerometer are analog values which should be further converted into digital values so they can be used by the microcontroller. The accelerometer analog outputs are converted into digital with the help of ADC 0809. ADC converts the data from sensor and proceeds to the microcontroller (P89V51RD2) for further conversion and calibration. Microcontroller gets the data from the accelerometer and converted into ASCII code for LCD display. LCD display the X—Y—Z values and display the values on the LCD.

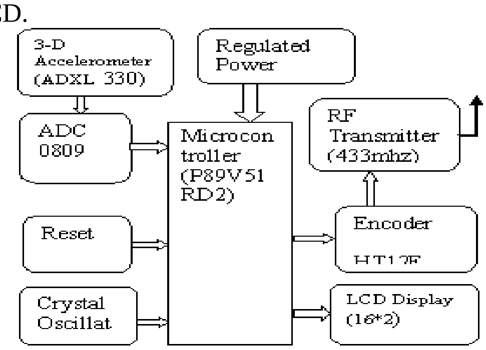

Fig 1(a) Block Diagram of Transmitter

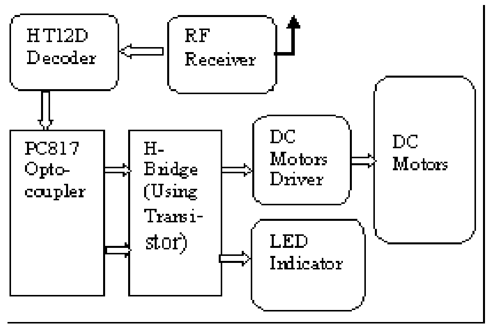

Fig 1(b) Block Diagram of Receiver

We use the readings obtained from accelerometer for wheel Chair movements. As the position of the hand changes, data from the accelerometer and microcontroller also changes automatically. We use HT12E encoder for serial communication. Data from the microcontroller is connected to the input pins of encoder and transmits via output pins of the encoder. Output from the encoder is connected to the RF transmitter module and transmit with frequency 433 Mhz. The RF receiver module sends it to the decoder which further decodes the signal and gives the signal to the optocoupler and H-Bridge circuitry which drives the motors of wheel chair based on the hand gesture and same result shown by the LCD.

VI. Technology

Gestures have recently become attractive for interaction with consumer electronics and mobile devices block diagram in fig. 1(a) by the use of gesture recognition technique via the accelerometer the movement of the wheel chair will be controlled. The primary goal of gesture recognition research is to create a system which can identify specific human gestures and use them to convey information or for device control. Gesture Recognition is the act of interpreting motions to determine such intent. There are different types of gestures such as hand, face (emotion), body gestures etc. To identify and recognize these gestures there are different ways of gesture recognition such as:

1)hand and arm gestures: recognition of hand poses, sign languages, and entertainment applications (allowing children to play and interact in virtual environ ments).

2)head and face gestures: Some examples are a) nodding or head shaking, b) direction of eye gaze, c) raising the eyebrows, d) opening and closing the mouth, e) winking, f) flaring the nostrils, e) looks of surprise, happiness, disgust, fear, sadness, and many others represent head and face gestures.

3)body gestures: involvement of full body motion, as in a) tracking movements of two people having a conversation, b) analyzing movements of a dancer against the music being played and the rhythm, c) recognizing human gaits for medical rehabilitation and athletic training.

VII. Gesture Recognition Approach

For any system the first step is to collect the data necessary to accomplish a specific task. For hand posture and gesture recognition system different technologies are used for acquiring input data. Present technologies for recognizing gestures can be divided into vision based, instrumented (data) glove.

(i)Vision Based approaches

In vision based methods the system requires only camera(s) to capture the image required for the natural interaction between human and computers and no extra devices are needed. Although these approaches are simple but a lot of gesture challenges are raised such as the complex background, lighting variation, and other skin colour objects with the hand object, besides system requirements such as velocity, recognition time, robustness, and computational efficiency .[11]

(ii) Instrumented Glove approaches

Instrumented data glove approaches use sensor devices for capturing hand position, and motion. These approaches can easily provide exact coordinates of palm and finger's location and orientation, and hand configurations .however these approaches require the user to be connected with the computer physically , which obstacle the ease of interaction between users and computers, besides the price of these devices are quite expensive it is inefficient for working in virtual reality .[12] Instrumented Glove based (smart glove) solutions can recognize very fine gestures, e.g., the finger movement and conformation but require the user to wear a glove tagged with multiple sensors to capture finger and hand motions in fine granularity. As a result, they are unfit for spontaneous interaction due to the high overhead of engagement.

Parameters	**Data-Glove based**	**Vision based**
Computing Power	computational power not an issue(less)	more computing power
User Comfort	quite cumbersome(wear a tracking device, glove)	complete freedom
Hand Size	problem with glove-based solutions(due to different hand sizes)	not an issue
Calibration	more critical	Simple
Portability	Freely available (hand tracking is not involved)	difficult (due to camera
Cost	Expensive(tracking device)	Inexpensive
Noise	bounded with data	Minimal
Accuracy	high level	high level

Table 1 Vision v/s Instrument Glove

VIII. Sensing Device

(I)Accelerometer

Accelerometer-based gesture recognition has become increasingly popular over the last decade. The low-moderate cost and relative small size of the accelerometers make it an effective tool to detect and recognize human body gesture. We are using the Instrumented Glove based approach or Smart Glove using Accelerometer sensor for interfacing between Transmitter and Robot (GRS). Micro Electro Mechanical Systems (MEMS) is the integration of mechanical elements, sensors, actuators, and electronics on a common silicon substrate through micro fabrication technology. MEMS is an enabling technology allowing the development of smart products, augmenting the computational ability of microelectronics In most cases, the physics behind the behavior of MEMS devices can be expressed by mathematical expressions. MEMS works by creating a mathematical model of the system and generates analytical solutions to explain the behavior of the MEMS device. The user just has to enter the input parameters like length and width of the beam for example in a user friendly GUI, and the software will immediately calculate the relevant results and plot graphs that fully explain the MEMS device or part of it.

The ADXL330 is a small, thin, low power, complete 3-axis accelerometer with signal conditioned voltage outputs, all on a single monolithic IC. The product measures acceleration with a minimum full-scale range of ±3 *g*. It can measure the static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from motion, shock, or vibration.

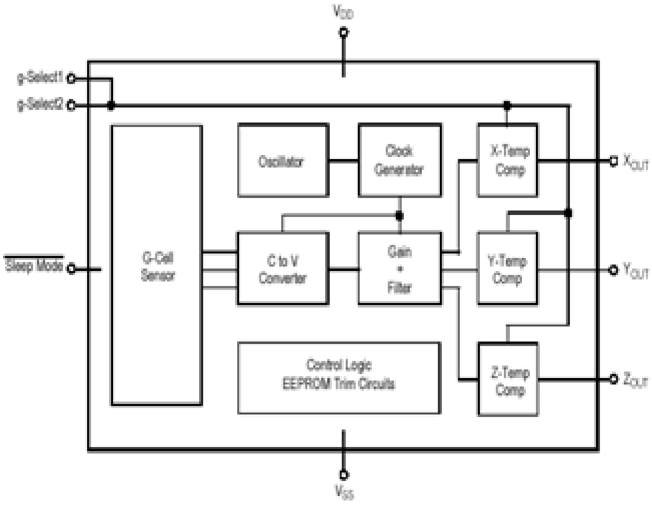

Fig 2 MEMS Accelerometer

The user selects the bandwidth of the accelerometer using the C_X, C_Y, and C_Z capacitors at the X_{OUT}, Y_{OUT}, and Z_{OUT} pins. Bandwidths can be selected to suit the application, with a range of 0.5 Hz to 1600 Hz for X and Y axes, and a range of 0.5 Hz to 550 Hz for the Z axis.

The sensor can be modelled as a movable beam that moves between two mechanically fixed beams. Two gaps are formed; one being between the movable beam and the first stationary beam and the second between the movable beam and the second stationary beam. The ASIC uses switched capacitor techniques to measure the g-cell capacitors and extract the acceleration data from the difference between the two capacitors.

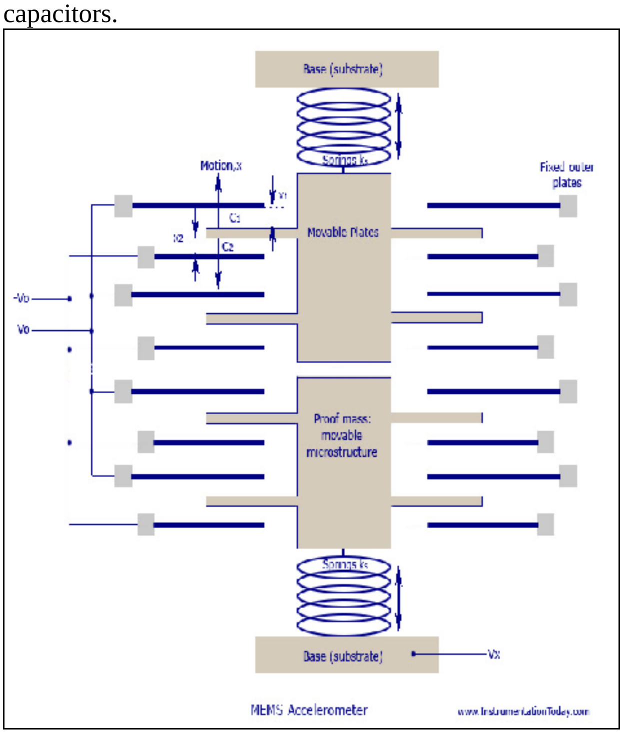

Fig 3 G-cell Accelerometer Structure

(i) Features

1. Gesture input for straight motion: 60 ms
2. Gesture input for directional motion (left or right): 95ms
3. Processing speed is 100kbps
4. Power consumption
Active mode: 47-294 Micro amperes.
Off mode: .4 Micro Amperes
Standby mode: 3 Micro Amperes
5. Cross axis Sensitivity (ability to reject an acc applied 90 deg from true axis) is ± 1%
6. Operating voltage = 5V DC
7. Min Voltage = 19.53 mVIn most micromachining technologies no or minimal additional processing is needed.
8. Max Voltage = 5 V
9. Current for x axis = 350 Micro Amperes
10. Max distance between TX and RX: 100 m
11. Speed and distance of wheelchair depends upon thebattery used
12. Noise = ±1 count
13. I2C interface speed = 400 KHz
14. Input leakage current = .025 Micro Amperes

The MEMS sensor has inbuilt I2C protocol using which the processing speed of the system is increased. Another advantage of I2C is, by using its two lines we can connect up to 128 devices to the controller. The I2C bus was designed by Philips in the early ‘80s to allow easy communication between components which reside on the same circuit board. The name I2C translates into “Inter IC”. It is sometimes written as I2C. Simplicity and flexibility are the key characteristics that make this bus attractive to many applications.

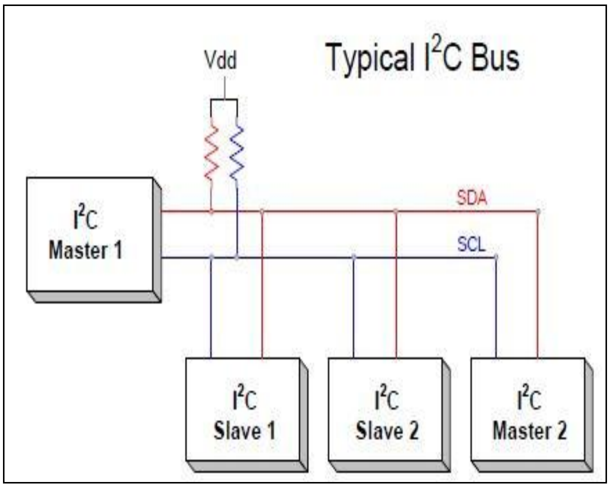

Fig 4 Digital Output

stops the CPU while allowing the RAM, timer/counters, serial port, and interrupt system to continue functioning. The Power-down mode saves the RAM con-tents but freezes the oscillator, disabling all other chip functions until the next interrupt or hardware reset.

IX. P89v51rd2

The AT89S52 is a low-power, high-performance CMOS 8-bit microcontroller with 8K bytes of in-system programmable Flash memory. The device is manufactured using Atmel’s high-density non-volatile memory technology and is compatible with the industry-standard 80C51 instruction set and pinout. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional non-volatile memory programmer. By combining a versatile 8-bit CPU with in-system programmable Flash on a monolithic chip, the Atmel AT89S52 is a powerful microcontroller which provides a highly-flexible and cost-effective solution to many embedded control applications. The AT89S52 provides the following standard features: 8K bytes of Flash, 256 bytes of RAM, 32 I/O lines, Watchdog timer, two data pointers, three 16-bit timer/counters, a six-vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator, and clock circuitry. In addition, the AT89S52 is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes. The Idle Mode stops the CPU while allowing the RAM, timer/counters, serial port, and interrupt system to continue functioning. The Power-down mode saves the RAM con-tents but freezes the oscillator, disabling all other chip functions until the next interrupt or hardware reset.

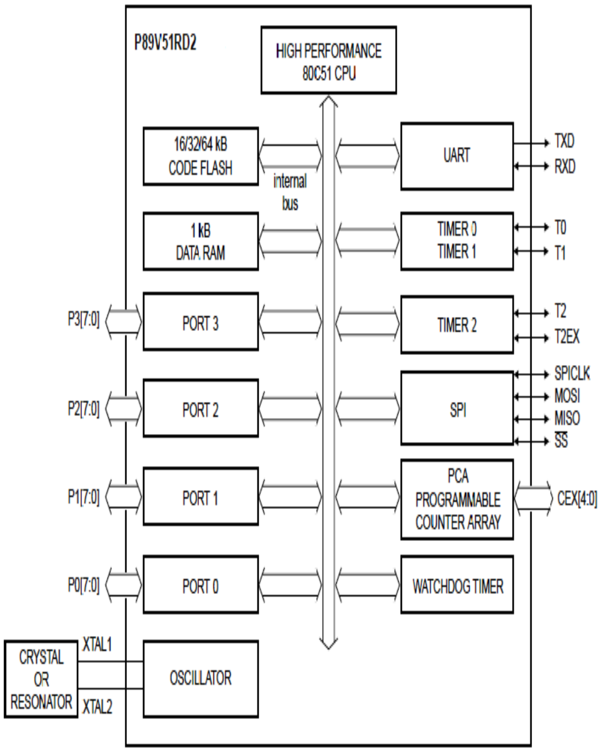

Fig 5 Microcontroller Block Diagram

A key feature of the P89V51RD2 is its X2 mode option. The design engineer can choose to run the application with the conventional 80C51 clock rate (12 clocks per machine cycle) or select the X2 mode (six clocks per machine cycle) to achieve twice the throughput at the same clock frequency. It has four 8-bit I/O ports with three high-current port 1 pins (16 MA each). Some other features are:

1) Three 16-bit timers/counters
2) Compatible with MCS-51™ Products
3) 8K Bytes of In-System Reprogrammable Flash Memory
4) Endurance: 1,000 Write/Erase Cycles
5) Fully Static Operation: 0 Hz to 24 MHz
6) Three-level Program Memory Lock
7) 256 x 8-bit Internal RAM
8) 32 Programmable I/O Lines
9) Three 16-bit Timer/Counters

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10) Eight Interrupt Sources
11) Programmable Serial Channel
12) Low-power Idle and Power-down Modes
13) Watchdog Timer present
14) Second DPTR register;
15) Low EMI mode (ALE inhibit);
16) TTL- and CMOS-compatible logic levels.

The Flash program memory supports both parallel programming and in serial In-System Programming (ISP). Parallel programming mode offers gang-programming at high speed, reducing programming costs and time to market. ISP allows a device to be reprogrammed in the end product under software control. The capability to field/update the application firmware makes a wide range of applications possible. The AT89C52 is also In-Application Programmable (IAP), allowing the Flash program memory to be reconfigured even while the application is running.

X. Proposed Model

There are two essential characteristics for any effective GSR system: accuracy and speed. In addition, to meeting these demands, GR systems face a number of additional challenges including the large variance that exists individual human hand patterns (e.g. tracking, motion, variation). A successful GR system requires extraordinary flexibility to accommodate these variances. The process of GRS typically follows these steps:
1. Hand gesture is captured by an Accelerometer sensor and undergoes analog-to-digital conversion.
2. Different Gestures are converted into signal features that can be used by microcontroller.
3. Series of different gestures are compared to saved information, the result shown on the LCD screen in the 3 Co-ordinates(X,Y,Z). LCD shows the numerical values which will be helpful to know about the position of hand.
4. For serial transmission the encoder is used and the RF Transmitting antenna is used with 433MHZ frequency.
5. At the receiver side the An H bridge is built with four switches (solid-state or mechanical). When the switches S1 and S4 (according to the first figure) are closed (and S2 and S3 are open) a positive voltage will be applied across the motor. By opening S1 and S4 switches and closing S2 and S3 switches, this voltage is reversed, allowing reverse operation of the motor.
6. The wheelchair is operated due to the Dc motor, the motor drives by the H-Bridge switching conditions. We need two H-Bridge and one H-Bridge has four Transistor for motor operation as shown in the receiver circuit Fig 7. The four conditions on which the motor movement based are

S1	S2	S3	S4	Result
1	0	0	1	Motor moves Right
0	1	1	0	Motor moves Left
0	0	0	0	Motor Stop
0	1	0	1	Motor Moves forward
1	0	1	0	Motor moves Back

Table 2 Switching Binary Conditions

The circuit diagram for both the phases of the system with all detail and the explanation of the component is discussed earlier.

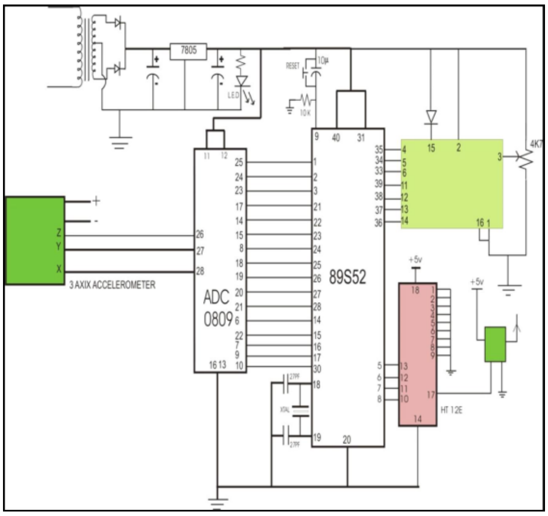

Fig 6 Transmitter Circuit

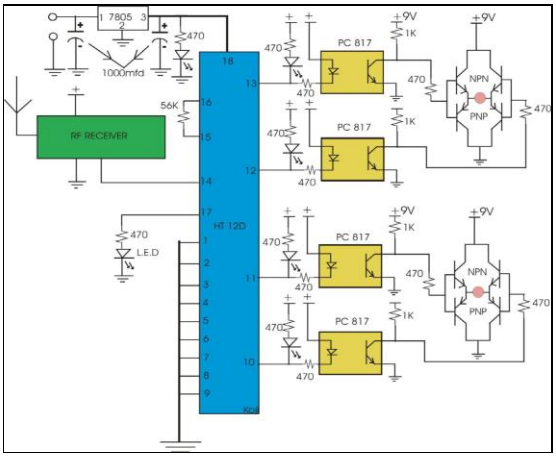

Fig 7 Receiver Circuit

XI. Results and Discussion

By using above procedure hardware setup is done figure 8 shows input part that is interfacing of gesture recognition module and accelerometer to CMOS 089C52 controller. A working model of Accelerometer based gesture recognition system was successfully made for the movement of the wheelchair .It was prepared with the help of 89C52 microcontroller (8051 family), two DC motors and other necessary equipments which resulted in the proper movement of the Wheelchair in all the four directions i.e. forward, backwards, right, left and stop.

Fig 8 Hand gesture and Co-ordinates value

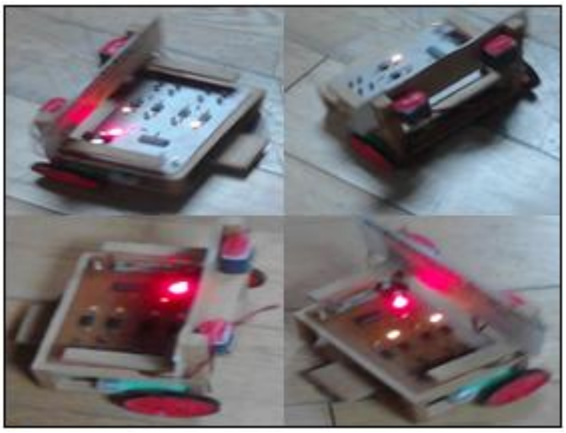

Fig 9 Hardware Setup Output Part
(a) Forward movement (b) Left movement (c) Back Direction (d) Right movement

A. Observations

Observation	No. of trials	No. of Successful Outcomes	Accuracy
Forward	15	14	96.67
Left	15	12	93.33
Right	15	13	93.33
Backward	15	14	96.67
Stop	15	14	96.67
		Overall Accuracy	**95.33**

IV. Future Work

As we all know, these days our nation is sick of massive health issues and most no. of people are suffering from malfun-ctioning of body. To avoid such health hazards issues technological power must exceed human power. Human life and time are priceless. So in this paper, we propose a model of a robot based on "Human Machine Interfacing Device" utilizing hand gestures to communicate with embedded systems for tracking of enemies. From this paper we can see the trends of gesture controlled communication systems. Easing of the technology use, affordability and familiarity indicate that gesture based user interface can open new opportunity for elderly and disable people. The older population (65+) numbered 36.3 million in 2004, an increase of 3.1 million or 9.3% since 1994 and it's growing over time. There will be more elderly people and fewer younger ones to care for them. So we need to invest much more heavily in Assistive Living solutions. The research 'A gesture controlled wheelchair for elderly and disabled people' can be a significant task for future**.** The two important aims of the research are to identify the different gestures of elderly and disabled people for communication and to design a rich augmented-reality interface for controlling via ubiquitous device such as a television set.

IV. Conclusion

Accelerometers have a secure place in the movement of equipment based on actions done. The system can be made free from challenges and will be cost effective in the near future. Calibration though at times is problem but with more introspection and research better calibration and performance can be achieved. The system developed by us despite calibration errors and problems still is able achieve accuracy of 88-95%, further improvements can used to achieve an accuracy of 95-99%. The system proves a very competitive performance computationally and in terms of recognition accuracy. Interesting topic to research is the problem of tilting. As mentioned earlier, tilting of the remote can lead to erroneous recognition if not taken into account. Therefore, in our proposed system, subjects were requested to hold the remote in a natural way while performing the gestures and to avoid any tilting of the remote as much as possible. However, this way of holding the remote can result in some inconvenience to users of the system. Consequently, a system which is immune to tilting of the accelerometer is definitely a desirable one.

Acknowledgement

The author wish to thank Mr. B.Anil Kumar for motivating me to do such an interesting work , Incharge and Prof. Shashi Kumar Singh , School of EEE, Lingaya's University, Faridabad for their moral support through the work.

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