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Gesture Recognition Based Device Control Using MEMS Accelerometer

*Kalyan Kasturi[1], K. Sri Mourya[2], I. Mahendra[2] and Vikas Maheshwari[1]
[1] Bharat Institute of Engineering and Technology, Hyderabad – 501510, India
[2] R.M.D. Engineering College, Chennai-601206, India
Email: kalyankasturi@hotmail.com

Abstract: *Gesture recognition is one form of human interaction that can be used effectively in human-computer- interaction. Human-computer-interaction is related to exchange of information between human beings and the computers. In this research work by recognizing the particular gesture given by the user, the microcontroller activates a corresponding relay circuit which in turn, operates the appropriate device. The microcontroller was programmed to transmit the status of a particular device, whether ON or OFF, to a laptop using the ZigBee wireless protocol. Gesture recognition provides a user-friendly modus operandi and a personalized touch to the operation of household devices. We used MEMS Accelerometer to capture motion trajectory information based on accelerations of objects to recognize gestures. The Accelerometer sensor measures acceleration values related to the gesture movements and passes this information to a PIC microcontroller, which will operate the corresponding device. Other authentication methods such as voice activated command system require very high accuracy. Especially when used by stressed or distracted people, the accuracy of authentication by voice command system is lower, whereas higher accuracy of device authentication can be obtained by the proposed gesture recognition. The proposed method is also highly cost effective compared to the voice command authentication systems.*

Keywords: *MEMS Accelerometer, Gesture Recognition, Device Control*

1. Introduction

MEMS stands for Micro-Electro-Mechanical systems. The term 'MEMS' or Micro-Electro-Mechanical-Systems was first used by R. Howe as well as several other researchers [1] to differentiate the mechanical elements developed at microelectronic circuit scale than the mechanical elements developed using lathe machining. The MEMS devices have features below 10 micro-meters that are developed using micro fabrication technology. The MEMS devices can be manufactured in silicon, polymer, quartz and metals.

MEMS have been used in diverse applications, from display technologies to sensor systems to optical networks. MEMS are attractive for many applications because of their small size and weight, which allow systems to be miniaturized. The MEMS technology allows the development of devices to operate or function in the micro-world, where it is not feasible to use ordinary machines. Another advantage of MEMS technology is that it provides the possibility of miniaturization of machines for cost effective operation and better precision [2].

To perform new development of MEMS devices, it is better to start from stable MEMS

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*Corresponding Author
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technology platforms. IMEC platforms provide means to perform MEMS integration, RF-MEMS, MEMS interconnection and packaging. In the paper by Pieters [3], the use of IMEC's CMORE for technology development, prototyping and small volume production is described. In the recent years MEMS technology is used for manufacturing accelerometers. These MEMS accelerometers are small-sized devices with simple operating procedure. A basic MEMS accelerometer can be a cantilever beam with a proof mass. Due to the external accelerations the proof mass is displaced from its neutral position and this displacement can be measured by the calculation of capacitance difference [4].

Gesture recognition has been investigated by several researchers. In the research study by Cao and Balakrishnan [5], a plastic stick was tracked in 3-dimensional space, for use as an input device for large scale displays. The endpoints of the stick were tracked by a pair of cameras. By using computer vision techniques, the endpoints of the stick were tracked in three dimensions. A rich vocabulary of actions was encoded by the endpoints of the stick.
In the research study by Kela et al. [6] gesture control using accelerometer was investigated as an alternative interaction method. They developed gesture commands that can be trained by the user to perform the operations on external devices. They conducted an investigation to compare the utility of gesture based control with other methods such as speech, laser pen and RFID objects. The results of their investigation also showed that gesture control was a preferred choice for operations related to spatial association in design environment control. Liu et al. [7] developed an algorithm for performing interactions based on gestures using accelerometers. They developed 'u-Wave' algorithm for identifying various gestures using accelerometer readings. They reported to achieve an accuracy of 98.6%.

The research work by Meenaakumari. M and M. Muthulakshmi [8] investigated the development of hardware module consisting of a MEMS accelerometer, microcontroller, and Zigbee wireless transmission module for sensing and collecting accelerations of handwriting and hand gesture trajectories. Another research paper by S.Karthick and R.Radhika Shridevi [9], investigated the development of an automatic gesture recognition algorithm to identify individual gestures in a sequence. The particular gesture was recognized by comparing the acceleration values with the stored templates that has been stored in EEPROM.

2. System Model for Device Control

In this research paper, we used MEMS based accelerometer to perform gesture recognition to perform the controlling function of various household devices in an orderly manner. The accelerometer is connected to the PIC microcontroller which performs gesture recognition.

The output of the PIC microcontroller is in turn connected to three relay devices as shown in Figure 1. Based on the particular gesture, one of the three relays is activated. Each of the three relays is connected to a household device such as a lamp, an LED light and a fan. The activation of a particular relay as determined by the particular gesture, eventually turns on a particular device and facilitates device monitoring.

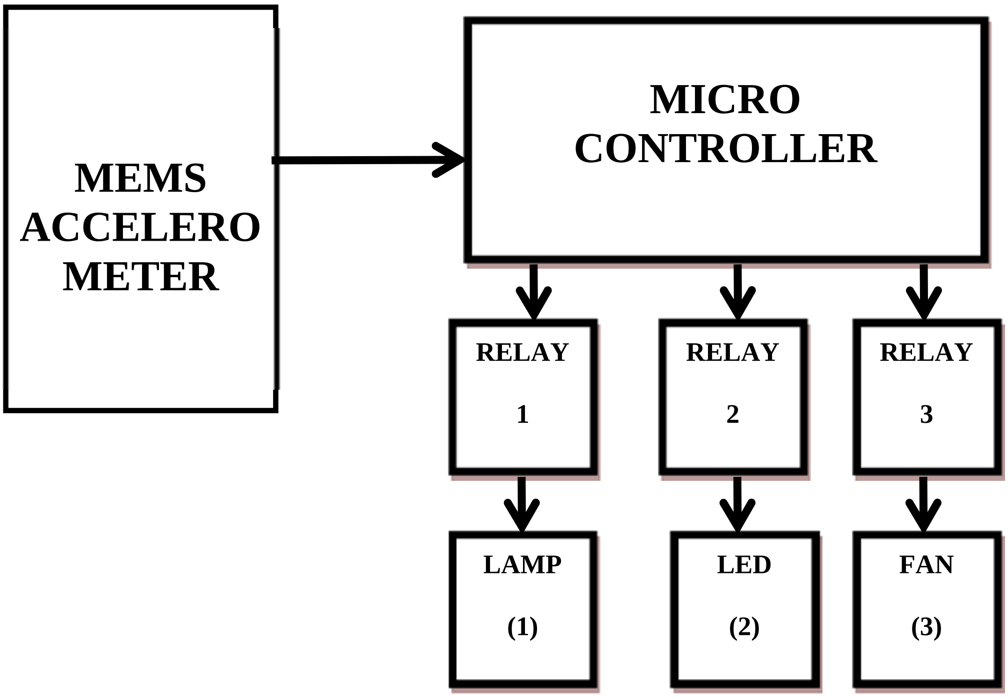

Figure 1: System model of the household device control system.

3. Components Of Device Control System

In this research work we have selected the MEMS accelerometer developed by Analog Devices. The accelerometer ADXL325 used in this research work is a low-power, triple-axis accelerometer. It can measure acceleration with a full-scale range of ±5g. It can be used to measure both dynamic acceleration and static acceleration. Since this accelerometer operates using low power and uses a voltage range of 2.4 Volts to 5.25 Volts, it is suited for battery powered applications. This accelerometer is connected to the PIC microcontroller using an analog-to-digital converter.

The acronym 'PIC' stands for programmable intelligent computer. PIC microcontrollers are easily programmable and easy to interface with other devices. The PIC microcontrollers consist of a microprocessor, memories, I/O ports, timers, and other hardware components. In this research paper we used the PIC microcontroller PIC16f877. This microcontroller is a high performance RISC processor. It uses reduced instruction set for achieving higher processing speed, it supports 35 instructions. All the instructions are single-cycle instructions except for the branch instructions which are two-cycle instructions.

The microcontroller has an operating speed of 200 MHz. This microcontroller was connected to a 10-bit analog-to-digital converter (ADC). The data memory of the microcontroller is in 8-bit byte format. Hence the 10-bit analog-to-digital converter (ADC) output was scaled using left shifting into the 8-bit format.

The microcontroller supports 8 KB flash memory which was used to store the program for gesture recognition. The gesture recognition program used in this research work can identify 3 different gestures. We used 3 simple gestures based on the letter C. The 3 gestures are used in this research work are normal C, reverse C and inverted C. Based on the particular gesture identified by the microcontroller, a particular relay circuit of the 3 available relay circuits was activated.

PIC microcontrollers are highly popular microcontrollers developed by Microchip Technology. So far more than 12 billion of these devices have been used in various designs of embedded system applications.

There are 3 relay circuits that are used in this research work. Each of the 3 relays is connected to a particular I/O port of the microcontroller. When the microcontroller identifies a particular gesture, it activates the corresponding I/O pin and the particular relay is turned on.

A relay is a switch which can be operated by an electrical means. A relay is used when several components must be controlled by using some type of electrical signal. A simple electromagnetic relay consists of an iron core, armature and moving contacts. The armature is hinged to the iron core and mechanically connected to the moving contacts. A coil is wound around the armature. When an electrical current passes through the coil, it generates a magnetic field that activates the armature and the consequent movement of the movable contacts makes a connection with a fixed contact.

A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal.

The first relays were used in long distance telegraph circuits as amplifiers: they repeated the signal coming in from one circuit and re-transmitted it on another circuit. Relays were used extensively in telephone exchanges and early computers to perform logical operations. A type of relay that can handle the high power required to directly control an electric motor or other loads is called a contactor. Solid-state relays control power circuits with no moving parts, instead using a semiconductor device to perform switching. Relays with calibrated operating characteristics and sometimes multiple operating coils are used to protect electrical circuits from overload or faults; in modern electric power systems these functions are performed by digital instruments still called "protective relays".

The status of the various devices (whether ON or OFF) is transmitted from the microcontroller to a laptop or personal computer using ZigBee wireless protocol.

ZigBee is a specification for low-power wireless transmission up to a distance of 10 meters. It is based on IEEE 802.15.4 specification and used for personal area networking (PAN).

Since ZigBee can span the area of a house and is less expensive, it is used for device monitoring in this research work. The microcontroller is connected to the ZigBee transmit section via serial port interface.

If for example device 1 is on, then a message 'ON 1' will be transmitted from the microcontroller to the ZigBee transmit section. Using wireless transmission via ZigBee protocol, this message is in turn transmitted from the ZigBee transmit section to the ZigBee receiver section which is connected to the laptop or personal computer and the message will be displayed on the laptop or computer.

4. Demonstration Kit

Figure 2 illustrates the demonstration kit showing the important hardware parts of the device control system. The relay part consisting of three relays such as Realy1, Relay2 and Relay3 is depicted on the left of the Figure 2. The relays are located between the PIC microcontroller and the three devices such as Device1, Device2 and Device3. The relays provide the actuating signals to turn on the devices.

The PIC microcontroller is located in the center of the Figure 2. The microcontroller performs the computing tasks using the accelerometer input and generates the actuating signals. Most of the programming was performed using MPLAB.

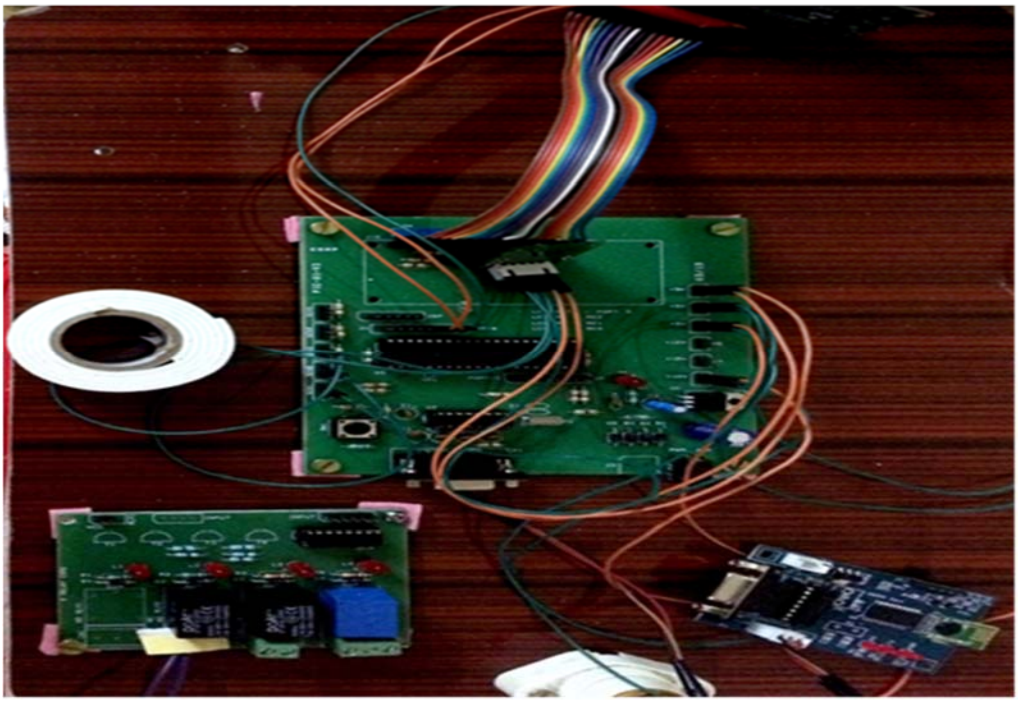

Figure 2: Demonstration kit of the device control system.

MPLAB is a software integrated development environment for the development of embedded applications on PIC microcontrollers. Microchip Technology has developed MPLAB software.

MPLAB is designed to work with MPLAB-certified devices such as the MPLAB ICD 3 and MPLAB REAL ICE, for programming and debugging PIC microcontrollers using a personal computer. PIC Kit programmers are also supported by MPLAB.

In Figure 2, the first electronic system to the right, is the interface containing the accelerometer ADXL325.

5. Experimental Results

When a particular device is turned on by the accelerometer gesture activation, the corresponding device number is displayed on the laptop connected to the demonstration kit. The device number 1 is used for Lamp. The device number 21 is used for LED. The device number 3 is used for Fan. A sequence of the device monitoring status is presented in Figure 3.

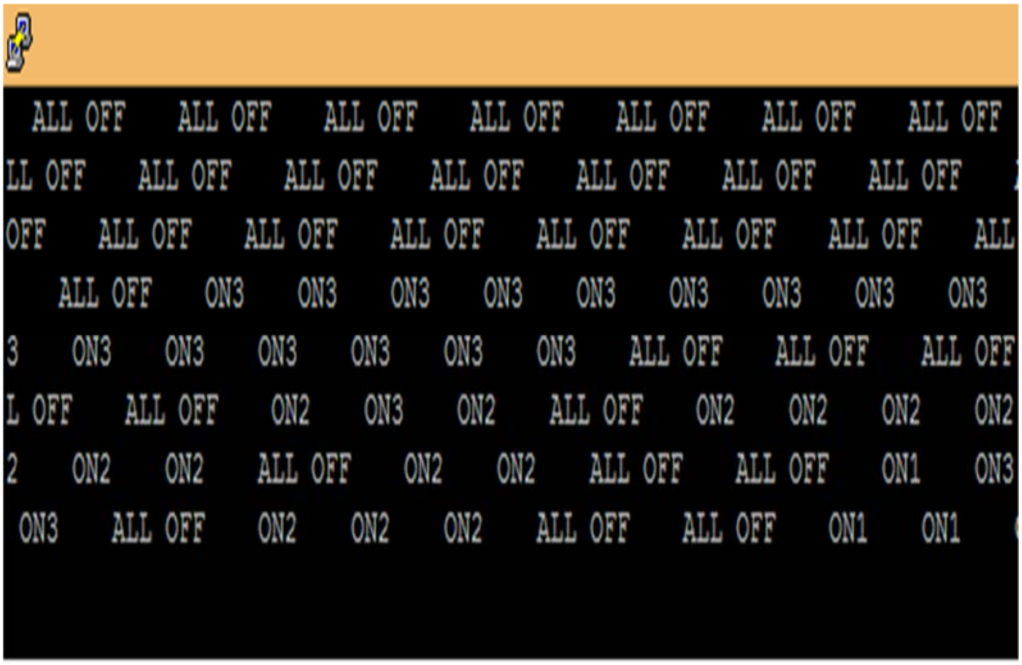

Figure 3: The ON/OFF status of various devices connected to the device control system.

The operation of the demonstration kit for household device monitoring was verified using the Putty software which is a free and open-source terminal emulator, serial console and network file transfer application. It supports several network protocols, including SCP, SSH, Telnet, rlogin, and raw socket connection. It can also connect to a serial port.

When Lamp which is device 1 is activated then the display is "ON1". If the LED which is device 2 is activated then the display is "ON2". Finally if the Fan which is device 3 is activated then the display is "ON3". When all the devices are not activated then the display is "ALL OFF".

It can be observed that in the beginning all the devices were inactive as depicted by the "ALL OFF" tag. Next the device 3 was turned on as depicted by the "ON3" tag. After this, all the devices were off are depicted by "ALL OFF" tag and then the device 2 was turned on as depicted by the "ON2" tag. Finally the device 1 was turned on as depicted by the "ON1" tag. The intermittent 'ALL OFF' tag indicates the temporary OFF status of all the devices.

6. Comparative Study And Discussion

In the research paper by V. Sundara Siva Kumar [10], a MEMS accelerometer based system was simulated to enable the movements of the wheel chair of physically handicapped individuals. They used Keil software for compilation part and Proteus 7 software for simulation part. When a change in the hand gesture happened, then the MEMS accelerometer generates a particular analog signal from mechanical signal. This is given as input to the analog-to-digital converter (ADC) which converts the analog signal to digital signal. According to the change in direction in the MEMS sensor, the micro controller controls the motor direction by motor driver, either as right or left or forward or backward. For future improvements, by combining the research work presented in this paper with the research work given in [10], and using a larger set of gestures, an improved version of the wheel chair movements can be implemented. By using a larger set of 32 gestures, the motor connected to the wheel chair can be driven in 32 different ways and better control of the wheel chair by the physically handicapped person can be achieved. Over the last decade, IOT based systems for networking hand-held devices are becoming very popular [11]. By integrating the IOT concepts with this research work, an IOT network for helping physically handicapped individuals can be developed.

7. Conclusion

This paper investigated the use of MEMS accelerometer for household device control via gesture recognition by a microcontroller. To capture the gestures a triple-axis accelerometer ADXL325 was used.

The microcontroller PIC16F877 was used to identify three different gestures via the software development environment MPLAB. Experiments with the demonstration kit verified that a particular household device was activated based on the particular gesture. Gesture based monitoring of household devices using MEMS accelerometer is one of the technological steps towards building user-friendly and personalized technology for consumers using gesture recognition.

The status of a particular device, whether ON or OFF, was transmitted to a laptop using ZigBee wireless protocol, for monitoring purposes. The sequence order of the various devices being turned ON was verified.

Further improvements can be made by increasing the number of gestures recognized to 32 in order to control more number of devices. Another future scope of this research work is to increase the number of recognizable gestures to 32 and develop an advanced wheel chair with high resolution movements for the physically handicapped people.

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Authors' Profile:

Kalyan Kasturi obtained B. TECH. degree in Electronics and Communication Engineering, from V.R. Siddhartha Engineering College, Vijayawada, India in the year 1999. He received M. S. and Ph.D. degrees from University of Texas at Dallas, USA in the years 2002 and 2006 respectively. Presently, he is attached with Bharat Institute of Engineering and Technology, Hyderabad, India, as an Associate Professor in the Department of Electronics and Communication Engineering. His research interests include DSP and Embedded Systems. He has published numerous papers in International Journals and conferences. He is a recipient of Fast Track Young Scientist Research Grant from Department of Science and Technology (DST).

Vikas Maheshwari passed B.Tech. degree in Electronics and Communication from U.P. Technical University, Lucknow, U.P., India in the year 2006. He received the M.Tech. degree in Microelectronics and VLSI from National Institute of Technology, Durgapur, West- Bengal , India in the year 2010. He received PhD degree in Microelectronics & VLSI from National Institute of Technology, Durgapur, West-Bengal, India in the year 2014. His research interest includes Analog VLSI Design, VLSI interconnect modeling and optimization and Antenna Design & optimization. He has published 35 International Journals and 45 International Conference papers.