Hand Angular Measurement Using 3D Accelerometer

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Abstract— **The last decade has witnessed a surge of interest in new sensing and monitoring devices for health care. In several medical and non-medical applications it is necessary to measure the human activities. Detection and monitoring of human activities requires the use of external sensors around the body. This paper provides designing, constructing, and testing a three-dimensional accelerometer sensor system for measuring the angle formed due to hand movement. The system includes the flex sensor, Elbow caps, I/O display system and the signal processing and data acquisition circuit. New bi-directional Bi-Flex Bend Sensor™ is a unique component that changes resistance when bent. An un-flexed sensor has a nominal resistance of 10,000 ohms (10 K). As the flex sensor is bent in either direction the resistance gradually decreases. Sensor is also pressure sensitive, and may be used as a force or pressure sensor. The flex sensor operating temperature is -45F to 125F. The flex sensor is fitted in the elbow cap. The maximum and minimum values of resistance of flex sensor are noted. An angle (value) is entered which is then compared and accordingly a visual and listening indication is given when the required angle is attend. The experiment was successfully done and satisfactory results were obtained.**

Index Terms—**3D Accelerometer, Angular measurement, Microcontroller, Medical device**

I. INTRODUCTION

The last decade has witnessed a surge of interest in new sensing and monitoring devices for health care. With the growth of electronics and information systems it is possible to collect relevant physiological information and share them between local and global information systems for the purpose of health and as a monitoring system. In recent years, number of promising prototypes of both wearable and implantable monitoring devices has emerged. Sensors allow detection, analysis, and recording of physical phenomenon that are difficult to otherwise measure by converting the phenomenon into a more convenient signal. Sensors convert physical measurements such as displacement, velocity, acceleration, force, pressure, chemical concentration, or flow into electrical signals. The value of the original physical parameter can be back-calculated from the appropriate characteristics of the electrical signal (amplitude, frequency, pulse-width, etc.). Electrical outputs are very convenient because there are well known methods (and often commercially available off-the-shelf solutions) for filtering and acquiring electrical signals for real-time or subsequent analysis. Sensor size is often important, and small sensors are desirable for many reasons including easier use, a higher sensor density, and lower material cost. Over the last few years, micromachined inertial sensors (accelerometers) have become more widely available. Because they are small in size, they can be worn on the body. Like the vestibular system, the working principle of these sensors is based on the omnipresent inertia, enabling measurement anywhere without the need for a reference. A three-dimensional (3-D) accelerometer unit is a transducer that measures acceleration and gravity in three directions. It can be assembled by mounting three single-axis accelerometers in a box with their sensitive axes in different directions or using a sensor based on one mass. Calibrated accelerometers measure the gravity vector and the acceleration in three directions. If the acceleration is small compared to the gravity, the accelerometer can be used as an inclinometer. Accelerometers are frequently used because they are small, robust, and relatively cheap, have low power requirements, and can easily be attached to a human body segment. These properties enable the ambulatory monitoring of patients during daily life.

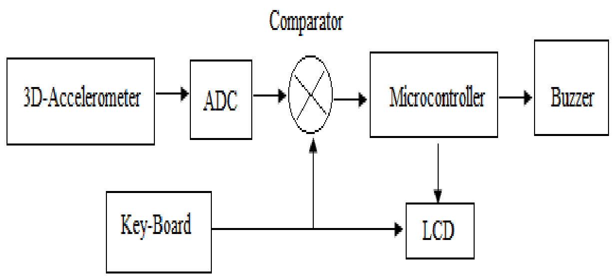
It is seen that a physiotherapist tests a patient and gives him exercises. The therapist can't visit the patient every day, and if the therapist visits then huge fees are to be bared by the patient. As a result the patient is not supervised every day. Thus errors in performing the exercises is observed, which results in negative results. Hence this device is being developed so that the accuracy is attained and the therapy becomes cost effective. The reported design provides a systematic approach for measurement of an angle formed due to hand movement. The design employs a 3D- accelerometer, a microcontroller and Buzzer for sensing the activities of a person. Human activity monitoring can be classified into external monitoring systems and wearable monitoring systems. These techniques can also be grouped as direct way of recording human activity. Since these techniques involve actual observation using human observers or using devices which are worn by subjects. Among indirect methods, physiological parameters are one of the common sources of activity information, but they are inadequate in providing information for discriminating between individual actions. The Activity Monitor System

[1] provides a way of monitoring and summarizing an individual's physical activity. Like a pedometer, the AWare Activity Monitor System can count steps, but it can also accurately summarize the type and level of physical activity of the monitored person on a minute-by-minute basis. This information is sent wirelessly to a receiving console where it can be recorded, displayed on a local computer display.

Electromyography (EMG) [2] is a technique for evaluating and recording physiologic properties of muscles at rest and while contracting. EMG is performed using an instrument called an electromyography, to produce a record called an electromyogram. An electromyography detects the electrical potential generated by muscle cells when these cells contract, and also when the cells are at rest. To perform intramuscular EMG, a needle electrode is inserted through the skin into the muscle tissue. A trained medical professional (most often a physiatrist, neurologist, or physical therapist) observes the electrical activity while inserting the electrode. For long-term recording of human motion outside clinical facilities, portable sensors that do not rely on external references are an interesting alternative [3]. Among those devices, some of the most popular are inertial sensors, such as accelerometers and gyrometers [4], particularly if assembled as wireless units. Those systems may provide high bandwidth information, but the provided estimates may be corrupted by different types of errors [5]. In order to minimize the effect of those errors, some approaches rely on precise placement of those sensors on the body segments [6], which may be a limiting factor for some applications. Another approach then is to rely on the complimentary features of both system and compute the best estimate using sensor fusion. Indeed, other portable sensors, such as magnetometers, may be included in the integration in order to improve the overall quality [7]. Inertial measurement unit (IMU) developed by Luinge et al. [8] is used for accurate measurement of the orientation of human body segments. IMU containing three single-axis accelerometers and three single-axis micromachined gyroscopes was assembled in a rectangular box, sized 20×20×30 mm. The presented orientation estimation algorithm continuously corrected orientation estimates obtained by mathematical integration of the 3D angular velocity measured using the gyroscopes. The correction was performed using an inclination estimate continuously obtained using the signal of the 3D accelerometer. For all movements with normal to high velocities an inclinometer (INC) (Logger Technology, Sweden) measured the degree of arm elevation with very high precision. At very high velocities and, especially when the direction of the velocity was perpendicular to the vertical line. In field studies INC has proved to be very safe and useful in assessment of arm movements. INC was easy to handle and easy to wear for the researcher and the subject, respectively [9]. Luinge et al. [10] describes the design and performance of a Kalman filter to estimate inclination from the signals of a triaxial accelerometer. This design is based on assumptions concerning the frequency content of the acceleration of the movement that is measured, the knowledge that the magnitude of the gravity is 1 g and taking into account a fluctuating sensor offset. It is shown that for measuring trunk and pelvis inclination during the functional three-dimensional activity of stacking crates, the inclination error that is made is approximately 2° root-mean square. This is nearly twice as accurate as compared to current methods based on low-pass filtering of accelerometer signals.

II DESIGN APPROACH

A. *Block Diagram and Description*



Accelerometer -As shown in above block diagram, the sensing of inclination (i.e. angle) is done by Accelerometer. The total operation or sensitivity is mostly dependent on the Accelerometer. Thus selection of Accelerometer is important criteria for successful angle detection and necessary required control action to control amount of angle the hand is being rotated in. The angle detection shall be implemented using digital sensors which offer low cost, long life, and good sensitivity to the Hand movement. The angle thus achieved is implemented from the unique capacitors available in accelerometer. Therefore the sensor must required to have following necessary requirements -

- Good sensitivity to small rotation.
- Long life and low cost
- Simple working.

Microcontroller Unit - As the name indicates, this section will deal with all the data acquisition and controlling task to be performed. The data from sensor circuitry is fed to this unit. The controller will convert the data into required form. Then as the set points are provided, the proper controlling action will be taken according to control logic with the help of microcontroller

Comparator-It is not a circuitry as far as hardware is concerned. But there is a need to compare the values of entered angle and the instantaneous value of the angle. Thus using software we compare these values in the code of the controller and thus give the result

Buzzer, *LED & LCD display* -When the angle will go beyond the set value, to alert the user, we will require Buzzer and LED. At the same time, to show the instantaneous angle LCD display will be required. LCD display will also be required to see the entered value. Thus to enter this value, keyboard is used.

III HARDWARE DESIGN

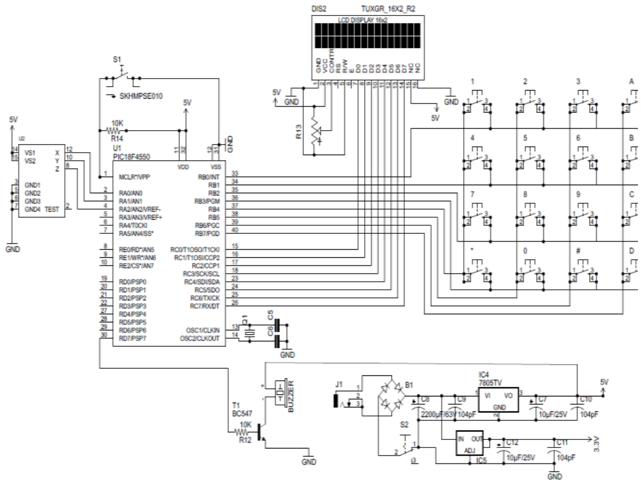


Figure1. Circuit diagram

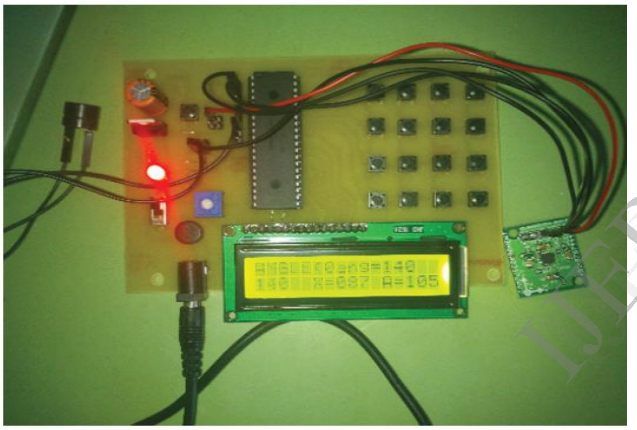


Figure 2: Hardware layout

Figure 1 and Figure 2 shows the circuit diagram and hardware layout of the proposed system respectively. The working of the system is described below.

- Connect the DC jack to the main supply with the help of the Adaptor. And switch on the main supply switch.
- Turn on the supply of the PCB. The LED glows to show the PCB is powered.
- The LCD turns on and it displays “Angle(0~180)” and it shows the value for current position of accelerometer as “X= ”(some value).
- Enter the desired angle as directed by the therapist with the help of keys provided on PCB. The LCD displays the angle entered by user immediately. It also displays the instantaneous angle for the current position of the user’s hand.
- The user should set his hand to the initial position so that the value for instantaneous angle is zero.
- The user should now start exercising as directed by the therapist.
- Once the desired angle is achieved (i.e. instantaneous angle = entered angle) the buzzer turns ON and gives indication to user to stop his exercise.
- The user can repeat this exercise as many times as directed by the therapist.
- When the exercise is to be changed or the angle is to be changed the reset button provided on the PCB needs to be pressed.
- And repeat the procedure from 4^{th} step.

IV ANALYSIS

- We know that the ADC in 18f4550 microcontroller is 8 bit, hence the input analog voltage will be divided into 2^8=256 steps (i.e. 0 to 255).
- The ADC input voltage range is 0-5V.
- Hence the 5 volts will be divided into 255 steps.
- Therefore the step size is 5/255=19.60mV.
- But the output of ADC for accelerometer is 66 to 100 steps.
- Therefore output voltage range of 3D accelerometer is 66x19.60mV=1.29V To 100x19.60mV=1.96V.
- For LCD display 66th step should correspond to 0 degree and 100th step should correspond to 180 degree.
- As a result 34 steps are divided into 180 degrees i.è. 34/180 = 0.189 .Hence the following formula is used to find the angle
- Angle=(Step - 66) x 0.189

V CONCLUSION

The system includes the flex sensor, Elbow caps, I/O display system and the signal processing and data acquisition circuit. New bi-directional Bi-Flex Bend Sensor™ is a unique component that changes resistance when bent. An un-flexed sensor has a nominal resistance of 10,000 ohms (10 K). As the flex sensor is bent in either direction the resistance gradually decreases. Sensor is also pressure sensitive, and may be used as a force or pressure sensor. The flex sensor operating temperature is -45F to 125F. The flex sensor is fitted in the elbow cap. The maximum and minimum values of resistance of flex sensor are noted. An angle (value) is entered which is then compared and accordingly a visual and listening indication is given when the required angle is attend. The experiment was successfully done and satisfactory results were obtained.

REFERENCES

[1] Aware, "http://www.awaretechs.com/wirelessaccelerometer.html."

[2] Electromyography, "http://en.wikipedia.org/wiki/electromyography."

[3] C. V. Bouten, K. T. Koekkoek, M. Verduin, R. Kodde, and J. D. Janssen, \A triaxial accelerometer and portable data processing unit for the assessment of daily physical activity." IEEE Transactions on Biomedical Engineering, vol. 44, no. 3, pp. 136-147, mar. 1997.

[4] D. H. Titterton and J. L.Weston, Strapdown inertial navigation technology. Peter Peregrinus LTD., 1997.

[5] P. Cheng and B. Oelmann, \Joint-angle measurement using accelerometers and gyroscopes - a survey," IEEE Transactions on Instrumentation and Measurement, vol. 59, no. 2, pp. 404 -414, feb. 2010.

[6] H. Dejnabadi, B. Jolles, and K. Aminian, \A new approach to accurate measurement of uniaxial joint angles based on a combination of accelerometers and gyroscopes," IEEE Transactions on Biomedical Engineering, vol. 52, no. 8, pp. 1478 -1484, aug. 2005.

[7] A. P. L. B_o and G. A. Borges, \Low cost 3d localization system for application on aerial robots," in Symposium Series in Mechatronics, P. E.Miyagi, O. Horikawa, and J.M. Motta, Eds. Associa_c~ao Brasileira de Engenharia e Ci^encias Mec^anicas, 2008, vol. 3, pp. 355-362.

[8] H. J. Luinge, P. H. Veltink ," Measuring orientation of human body segments using miniature gyroscopes and accelerometers", Medical and Biological Engineering and Computing ,2005, Volume 43, Issue 2, pp 273-282

[9] Bernmark, E., andWiktorin, C. (2002): 'A triaxial accelerometer for measuring arm movements',*Appl. Ergon.*,33, pp. 541–547.

[10] LUINGE, H. J., ANDVELTINK, P. H. (2004): 'INCLINATION MEASUREMENT OF HUMAN MOVEMENT USING A 3D ACCELEROMETER WITH AUTOCALIBRATION',*IEEE TRANS. NEURAL SYST. REHABIL. ENG.*,12, PP. 112–121