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Wireless Monitoring of Human Limb Motion

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Abstract— **Techniques that could precisely monitor human motion are useful in applications such as rehabilitation, virtual reality, sports science, and surveillance. Most of the existing systems require wiring that restrains the natural movement. To overcome this limitation, a wearable wireless sensor network using accelerometers has been developed in this paper to determine the arm motion in the sagittal plane. The system provides unrestrained movements and improves its usability. The lightweight and compact size of the developed sensor node makes its attachment to the limb easy. Experimental results have shown that the system has good accuracy and response rate when compared with a goniometer.**

*Keywords***— sagittal plane, goniometer, accelerometer.**

INTRODUCTION

Remote monitoring technique that could precisely monitor human limb motion is useful in applications such as medical science, sports science, rehabilitation and virtual reality. Most of the existing systems used for monitoring human limb motion require wiring that restrains the natural movement. To overcome this limitation, a wearable wireless sensor network using accelerometer has been developed for monitoring human limb motion. The wireless feature enables the unrestrained motion of the human body as opposed to a wired monitoring device and makes the system truly portable, fast and reliable. The lightweight and compact size of the developed sensor node makes it easy attachment to the body.

Tracking of human body parameters has attracted significant interest in recent years due to its wide-ranging applications such as rehabilitation, virtual reality, sports science and medical science .In recent times, wireless sensors and sensor networks have become a great interest to research, scientific and technological community. Though sensor networks have been in place for more than a few decades now, the wireless domain has opened up a whole new application space of sensors. Wireless sensors and sensor networks are different from traditional wireless networks as well computer networks and, therefore, pose more challenges to solve such as limited energy, restricted life time, etc.

Wearable systems for continuous health monitoring are a key technology in helping the transition to more practical and affordable healthcare. It not only allows the user to closely monitor changes in his or her physiological parameters but also provides feedback to help maintain an optimal health status.

Many new research is focused at improving quality of human life in terms of health by designing and fabricating sensors which are either in direct contact with the human body (invasive) or indirectly (non invasive).

One of the reasons for more development in this area is the global population and rise in ageing population, one statistic provided by the U.S. Department of Health that by 2050 over 20% of the world's population will be above 65 years of age. This results in a requirement for medical care, which is expensive for long-term monitoring and long waiting lists for consultations with health professionals. The cost of hospitalization is ever increasing, so is the cost of rehabilitation after a major illness or surgery. Hospitals are looking at sending people back as soon as possible to recoup at home. During this recovery physiological parameters need to be continuously measured. Hence, telemedicine and remote monitoring of patients at home are gaining added importance and urgency. Patients are being monitored using a network of wireless sensors. We seek to come up with solutions, which help to monitor patient from remote place. As a result, there is a need for an accurate, flexible, noninvasive, comfortable, reliable, and low-cost monitoring unit that unites all these demands.

The objective is to allow the patient to be monitored in a natural environment. For monitoring outside the clinical laboratory, a wearable system must not only record data, but also proficiently process data on-board. The proposed approach uses the wireless sensor network concept with all the sensor nodes communicated to the coordinator wirelessly.

The small form factor and lightweight feature of the sensor nodes also allow easy attachment to the body. This technology also used in sports technology, in this field we know about the player's behaviour. The wireless feature enables the unrestrained motion of the human body as opposed to a wired monitoring device and makes the system truly portable.

SYSTEM BLOCK DIAGRAM:

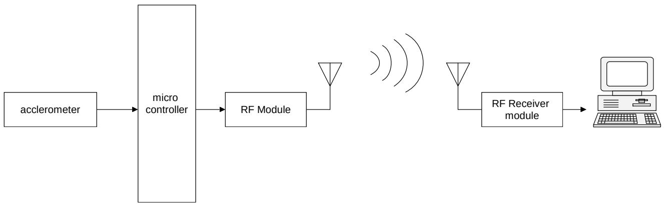

Figure 1: General Configuration of system

The system consists of accelerometer, .microcontroller and low power RF trans receiver. The accelerometer is placed on forearm of patient. The accelerometer measures hand movement. The accelerometer is connected to micro controller. The micro controller processes received data and transmit the data using low power RF transmitter module. The receiver should have RF receiver module to receive the transmitted data. The received data is stored on host computer, which can be used to analyse the overall rehabilitation of patient.

*1. **Accelerometer*** **:-**

The *ADXL335* is complete 3-axis acceleration measurement system. The ADXL 335 has a measurement range of ±3 g minimum. It contains a polysilicon surface micromachined sensor and signal conditioning circuitry to implement an open loop acceleration measurement architecture .The output signals are analog voltages that are proportional to acceleration . The accelerometer can measure the static acceleration of gravity in tilt sensing applications as well as dynamic acceleration resulting from motion, shock or vibration.

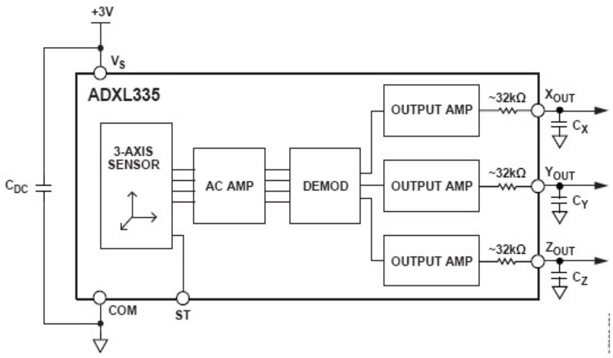

Figure 2: Block diagram of ADXL335

In this project we are going to measure the movement of human arm along the sagittal plane, i: e, the plane that bisects the human body into left and right .This corresponds to the exion and extension movements of the fore arm and the upper arm .exion is the bending movement in which the relative angle of the joint between the adjacent segments decreases. Extension is a straightening movement in which the relative angle of the joint between two adjacent increases as the joint returns to the reference anatomical positions. For the physical therapist, the range of the elbow motion and shoulder joint of the patient is of particular interest for monitoring and rehabilitation progress. To capture the arms rotational motion, an accelerometer is integrated to the sensor node as an inclinometer. An accelerometer in general can be used to measure the arm motion that is in static and dynamic conditions. The details are described in following section.

A. Tilt/Static Measurement

Fig.3. shows an accelerometer mounted on the forearm. In the static conditions, i.e., the arm is not moving, the tilt angle of the accelerometer can be determined by measuring the acceleration due to gravity g, as shown in Fig.3.From figure 3,the acceleration Ay in y axis and Az in the Z axis that are due to gravity can be determined as

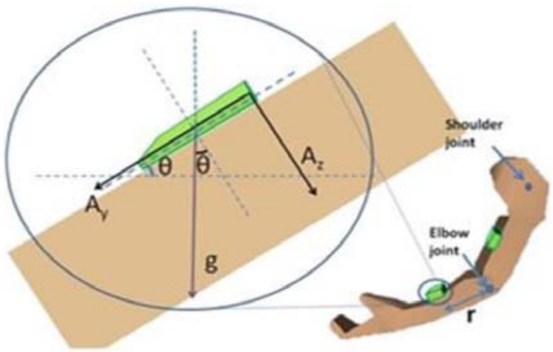

Figure 3: Tilt angle measurement in y-z plane

$A_y = g \sin \Theta$ …… (1)

$A_z = g \cos \Theta$ …… (2)

From (1) and (2)the tilt angle Θ can be determined as

$\Theta = \tan^{-1} (A_y / A_z)$ …… (3)

The quadrant of Θ can be determined by the sign of A_y

The output voltage V_{out} of the accelerometer is related to the acceleration A_i of a particular axis(i = Y or Z) by the following relationship

$V_{out} = V_{offset} + S + A_i$ ……. (4)

Where S is the sensitivity of the accelerometer (in volts per meter per second square), and V_{offset} is the offset os the acceleration at 0g.

B. Latency Measurement

Latency is the time between a motion is made and captured. In an ideal tracking system the mean time delay after a motion is initiated until corresponding data are transmitted should be less than 1 ms [1]. Moreover, the latency between the initiation of motion and motion rendering should be less than 100ms to avoid degradation of performance.

Figure 4: accelerometer placed on wrist of patient.

2. *Micro controller* :-

The LPC2141/2/4/6/8 microcontrollers are based on a 32/16 bit ARM7TDMI-S CPU with real-time emulation and embedded trace support, that combines the microcontroller with embedded high speed flash memory ranging from 32 kB to 512 kB. A 128-bit wide memory interface and unique accelerator architecture enable 32-bit code execution at the maximum clock rate. For critical code size applications, the alternative 16-bit Thumb mode reduces code by more than 30 % with minimal performance penalty.

Due to their tiny size and low power consumption, LPC2141/2/4/6/8 are ideal for applications where miniaturization is a key requirement, such as access control and point-of-sale. A blend of serial communications interfaces ranging from a USB 2.0 Full Speed device, multiple UARTS, SPI, SSP to I2Cs and on-chip SRAM of 8 kB up to 40 kB, make these devices very well suited for communication gateways and protocol converters, soft modems, voice recognition and low end imaging, providing both large buffer size and high processing power.

3. **RF trans-receiver module**:

CC2500 is been used as trans-receiver module. It's a small size and low power consumption module. CC2500 is a low-cost 2.4 GHz transceiver designed for designed for very low power wireless applications. The circuit is intended for the 2400-2483.5 MHz ISM (Industrial, Scientific and Medical) and SRD (Short Range Device) frequency band. The MAX RF output power can be set as high as +1dBm, with data rate as high as 500Kbps. The module integrated many RF functions thus you can use it conveniently and reducing your development time.

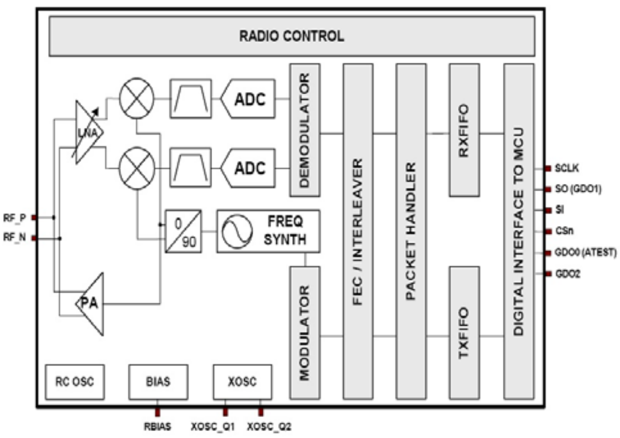

Figure 5: functional block of CC2500

Note:

1 . The module transmission data rate will affect transmission distance, the higher the data rate, the closer the distance, and the lower the receiving sensitivity.

2. The supply voltage to the module will affect TX power, in the operating supply voltage range, the lower the voltage, the lower the TX power.

3 . The module central frequency will change as the operating temperature change, use it under suggest temperature, the module can work well.

4 . The antenna will strongly affect the communication distance, please select matched antenna and connect it correctly.

5 . The module mount will affect the communication distance.

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Receiver Section:

The receiver section consists of RF receiver module CC2500 and computer. The RF receiver module is connected to computer by RS 232.The received data can be seen on Mikro C. The Baud rate selected should be maximum i: e 9600. The port should be selected at which the RS232 is attached. The signal will be visible on window in mikro c as shown in figure 6.

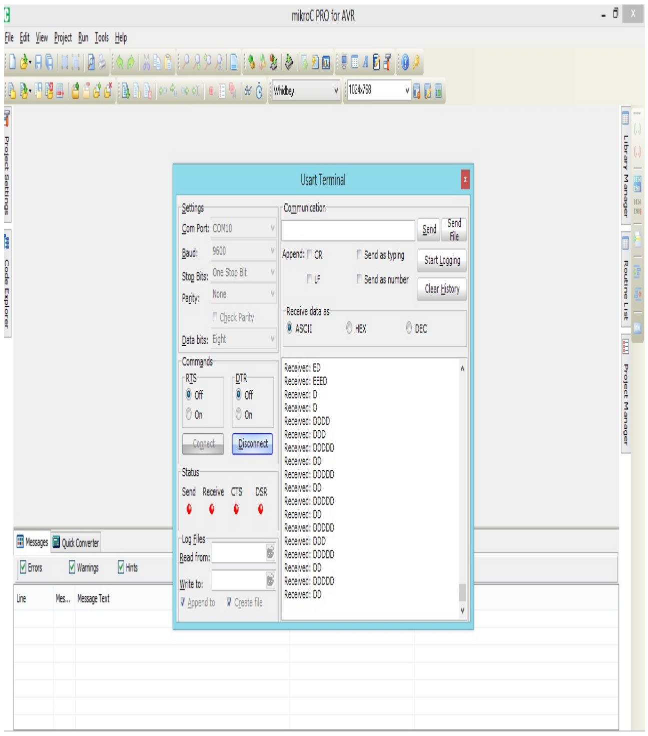

Figure 6: Received signal in Mikro C.

IV. Result And Analysis

The received data is processed by using matlab. The data can be simplified for the use of end user. End user may and may not understand electronic measuring quantities. In order to make user friendly the data received in the form of voltage is converted into angle in the step of 0^{o} ,45^{0} ,90^{0},135^{0}, and 180^{0}. And respective images are shown

Figure: Image for 180^0

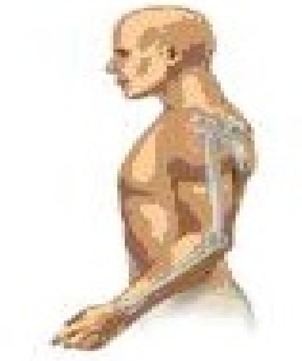

Figure: Image for 135^0

Figure: Image for 90^0

Figure: image for 45^0

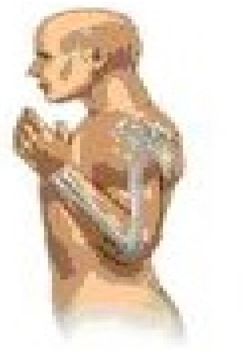

Figure: Image for 0^0

CONCLUSION

An ambulatory and unstrained measurement system based on wearable wireless sensor for tracking the human arm motion in the sagittal plane has been proposed. The wireless features enable the unstrained motion of the human body as opposed to a wired monitoring device and make the system truly portable. This allows the system to be deployed in a cluttered home environment. The small form factor and lightweight feature of the sensor node also allows easy attachment to the limbs.

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