Chapter 6

Acquisition of ambulatory ECG along with physical movement detection

The important contribution of this research work is to provide researcher the simultaneous acquisition of the AECG signal along with the physical movement detection signals. The developed wearable system acquired AECG signal from the subject's body and transmit it wirelessly to the base station through wireless channel. The wearable wireless watch from Texas Instruments (TI) having facility to transmit wirelessly 3-axis accelerometer signals in real time to the base station. The AECG signal is received on base station via Zig-Bee at 2.4 GHz operating frequency, while the wireless watch transmit the accelerometer data at 912 MHz frequency. So, both the signal received at different wireless modules, and the receiver modules are connected to the base station at different USB ports. The GUI program is used to record both the signals by reading from both serial port and display it on real time graph. In this chapter we will discuss the experimental setup for acquisition of AECG signal and TI eZ-Chronos wireless watch accelerometer signal. Before we discuss about experimental results of this acquisitions we discuss the TI eZ-Chronos module in detail in next subsection.

6.1 MSP430 eZ-Chronos module for accelerometer signal acquisition

As we discussed in the previous chapter about acquisition of 3 channel accelerometer signals with TI eZ-Chronos module is well suited for such wearable systems [44]. There is a MSP430 series of microcontroller reside into this module can be programmed to have acquisition of accelerometer sensor output and transmitted wirelessly through wireless channel available on chip MSP430. eZ-Chronos module can be programmed through IAR workbench which is describe into previous sections of this chapter. The snap shot of the Ti eZ-Chronos wireless watch is shown in Figure 6.1. The module is interfaced with simultaneous acquisition of AECG signal with accelerometer output signal by integrating it with LabVIEW GUI program. In this application LabView program running on PC is used to record signals from eZ-chronos module and ECG hardware module. The developed wearable system is operated through battery for portability requirement. The usage of system on chip controller reduces the chip count of the system and it consumes low power to improve the battery life of the wearable devices.
6.2 LabVIEW GUI program for data acquisition

The LabVIEW window program is combined to have acquisition of physical movement data and the ambulatory ECG signal acquisition together. As shown in Figure 6.2, the front panel of the LabVIEW GUI is to acquire ambulatory ECG signal with various parameter setting options like baud rate, no. of data bits, input buffer size, parity bit and stop bits etc. There is provision for data logging into memory of base station by providing one soft button. You can stop the operation by stop button provision will stop the operation of the system.

![LabVIEW GUI front panel for simultaneous data acquisition](image_url)
Another option of Graph tab button is to select the real time graphical window on which the acquired data are display in real time with respect to time. The GUI for real time display of accelerometer and ambulatory ECG signal is such that both graph can be visible on parallel window, so that one can compare the ECG with movement of the subject. The graphical window is as shown in Figure 6.3.

![LabVIEW GUI diagram for simultaneous graphical data display](image1.png)

**Figure 6.3 LabVIEW GUI diagram for simultaneous graphical data display**

The actual block diagram for front panel developed for simultaneous data acquisition is shown in Figure 6.4.

![LabVIEW GUI block diagram for simultaneous data acquisition](image2.png)

**Figure 6.4 LabVIEW GUI block diagram for simultaneous data acquisition**
The experimental setup was carried out for acquisition of the accelerometer and ambulatory ECG signal while subject is in some daily activity is described in the next sections.

6.3 Experimental setup

The experiment for acquisition of ambulatory ECG along with the physical movement detection system is shown in Figure 6.5.

![Figure 6.5 Snap shot of experimental setup](image)

The experiments are carried out with the developed hardware by keeping the sensor at the different position of the body. The body movement detection results are taken and ambulatory ECG is acquired with the developed hardware. The simultaneous detection of the body movement along with the ambulatory ECG signal carried out with the TI eZ-Chronos wireless
watch and the developed wearable AECG hardware. The body movement detection and the AECG signal acquisition is discussed in the next section.

6.4 Body movement data acquisition along with ECG signal

The main objective of the system is to acquire the body movement data along with ECG signal in real time. Here we show the plots of the data acquired by the TI-eZ-Chronos through the acceleration sensors during various different types of body movement activities. The AECG signal is also acquired by developed hardware and which is wirelessly transmitted to the base station by Zig-Bee wireless channel. Here the physical movement detection and AECG signal simultaneously monitored and recorded into the base station. For example in Figure 6.6, there are 3-axis acceleration signals plotted during standing still position of a person wearing the sensor at back of the waist, at the same time the AECG signal is also acquired. The signal values in the plots are nearly a constant as expected for a standstill condition. The differences among the levels of the 3-axis signals are attributed to the static gravitational acceleration. The AECG signal are quiet steady waveform like normal ECG waveform. We can clearly observe the various ECG points like P, Q, R, S and T.

![Figure 6.6 3-axis acceleration signals and ECG signal acquired during standing still position](image)
Next, we have acquired data to represent movement of any arm. In Figure 6.7, 3-axis acceleration signals are shown for repetitive movement of a hand in a veridical plane and along with ECG signal. These acceleration signals are acquired from the sensor tightly attached on the wrist. We can observe that there is a cycle in acceleration signals corresponding to each repetition of the movement and nearly four repetition of same type of hand movement are performed here. The AECG signal is also acquired during stand still position of the subject. Since the sensor of ECG signal observed a physical artifacts noise the acquired AECG signal is corrupted with low frequency noise. The frequency of ECG signal is overlapping with such noise frequency the ECG signals is affected.

![Figure 6.7 3-axis acceleration signals for up and down movements of right arm](image)

Similarly, in Figure 6.8, the acceleration signals from a sensor attached to the wrist are plotted which are acquired during repetitive up-down movements of the body. Here also the cyclic nature of the acceleration signal is visible because of repetitive actions of hand. The acquired AECG signal is also corrupted with such low frequency noise due to physical artifacts.
Similarly, in Figure 6.9, the acceleration signals from a sensor attached to the wrist are plotted which are acquired during slow walking of the subject. Here the slow walking of the subject won’t affect the accelerometer sensor but the AECG signal is quit noisy.
Finally, we performed the experiments for several other physical activities like running, climbing stairs while both the signals are acquired. The recorded data of ambulatory ECG and accelerometer signals in a file is shown in Appendix C.

6.5 Summary

In this chapter simultaneous recording of ambulatory ECG signal along with the physical movement detection is discussed. By analysis of those signals offline, one can derive the useful information regarding the various activities from AECG signal itself. The algorithm developed by this analysis can be used to make autonomous wearable system that gives the information about the activities of wearer. This is our main contribution to the researcher who is interested in this area of signal processing. The analysis of such offline signal processing is another area of research where one can find the recognition of activity detection from AECG signal itself. This type of arrangement of acquisition is very much useful for researcher.