Effective Developments in Biosignal Acquisition- A Review

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ABSTRACT: *The aim of this paper is to summarize developments in Bio-Signal Acquisition and their applications. In recent years analog system were replaced by newly developed digital system with additional usability and applications. Surveving the literature earlier system are moderate with specific features later systems are able to cater (fullfill) industrial and society needs. Proposed developments found in literature are the advanced system compared to of previous one with unique contribution enabling high technical needs. It is observed that the hardware and employed wireless technology selected by researcher is totally based on system requirement and its application. Experimental practices are performed by the authors to prove the system performance. In this literature study we did the comparative study of wireless biosignal acquisition systems based on recent developments in hardware and parameters.*

KEYWORDS: ECG,EMG, Bluetoot ,Wifi, Bio-Signal Acquisition, Host Interface, Applications.

I. INTRODUCTION

In recent years biosignal such as ECG and sEMG has proved a tremendous importance in industrial and biomedical applications. Because of their non-invasive behaviour they can be used in human-computer interface[2-5]. To utilize and facilitate convenience a complete systems in review consists of mainly two components a) Data Acquisition (Intelligent electrode) b) Acquisition Host. In this paper we reviewed the developments in acquisition system by researchers, in recent technical trends. Initial development in literature is found to be analog system with active electrode (Amplifier built in electrode) and FM transmitter[1]. Later all developments are digital systems with wireless technology[1-12,15-23] which facilitate measurement on moving subject [2-5]. As devices capable of 10Ksps(Kilosamples per second)[10], Similar of 10Sps to few hundred samples per second based on applications are availale in reviews[2,11-13]. Generally maximum devices in study consist of 1 to 2Ksps; which follows EMG band of 1 to 500Hz[14]. Some of special controller[21] selected by researchers focusing on particular application(HRV). Employing standard wireless technology by authors are generally zigbee and Bluetooth[6-9], keeping In mind respective application. However DR-ZHG(Dual Radio Zigbee Homecare Gateway) developed by author to fullfill remote patient monitoring[22]. Some of ultrawearable and advanced system also reviewed [15][19], respective comparision noticed with the ealier discussed system[16][17].

II. GENERAL ACQUISITION SYSTEM IN REVIEW

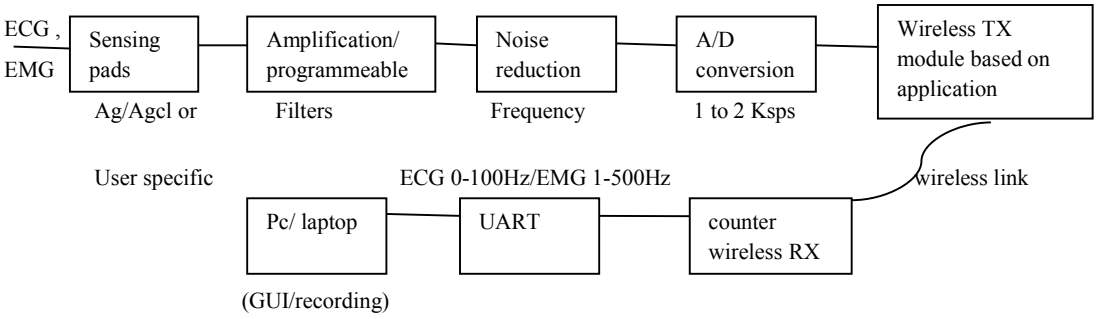

Fig 1: General block diagram of Biosignal Acquisition System

Fig 1 shows the general block diagram of data acquisition system which mainly consist of two main components; which is applicable to all developments in literature.

i) Electrode Based Intelligent Acquisition

As shown in fig 1. analog signal (ECG,sEMG) from body surface is sensed, amplified, digitally converted and transmitted to receiving host. In earlier analog system[1] each section need to be select and design while in recent digital system [1-12,15-23] Psoc (Programmeable system on chip) or embedded module by manufacturer enables compact size and software based parameter settings;Hence termed as 'Intelligent'.

ii) DAQ (Data Acquisition Host)

Generally in literature all systems having data acquisition as a combination of wireless receiving module (Bluetooth or Zigbee)[6-9] interface with PC/Laptop. Acquisition host provides recording and visualization of real time data.

A. Electrode Based Intelligent Acquisition

Now in this section we will summarize above mentioned two components of developed system in literature.

1)Senesors & Amplifier

The system proposed by park et al.[15] used a QUASAR sensor to avoid skin preparation for subject before measurement. It is an advanced sensor that does not require direct contact to skin surface as it consist of not only sensing device but also analog signal circuicity. Mainly amplification components are low-noise amplifier and voltage reference chips providing an output voltage ranges from (-4.5V to +4.5V) also (0V-4.5V). QUASAR sensor consumes maximum of 1mW which is a prime feature to satisfy wearable application.

Youn et al.@2009 focused on the design of preamplifier design for sEMG system. Ag/Agcl electrode were used to sense sEMG signal and a series of LPF with 500Hz and High pass filter with cutoff frequency of 10Hz to cover the sEMG signal range[14]. Band reject filter is designed by author additionally to remove 60Hz power line interference.

Surveying literature King Mang chang et al.[17] developed a system for sEMG, to amplify the signal(AD8236, ADI company) with a gain of 10 were utilized. Cascaded series of high pass filter of 30Hz, Non inverting amplifier of Gain 100, low pass filter of 1KHz designed by using AD8609 operational amplifier. A peak rectifier (R // C) of 10KU and 1uF respectively by AD8609 is structured to extract sEMG envelope.

Study carried out by J.Son et al@2015 uses a capacitive sensing based electrode (capacitor plate) irrespective of skin contact. Analog received signal noise were reduced by

LPF then a series of amplifier and high pass filter utilized to achieve required ECG band 1 to 100Hz[14].

J.Stefan et al.[19] proposed a novel application smart T-shirt in which they integrated textile sensors as sensing element. Three layer textile architecture facilitates ECG, EMG amplification and respective recording at host.

The work presented by Lars Hoff et al.[20] uses a transducer made for a cardiac monitoring by imansonic SAS(Besancon, France). Amplifier at receiving side is mainly AD8332-EVALZ ultra low noise amplifier.

Two prime application in literature[22][23] represent a complete society based real life system, mainly the sesing device for the systems are smart watch, mobile, belt etc.

2)Hardware Selection Review

Above sub-section indicates the review of sensor and amplifier in literature. In this sub-section we will review the hardware component developed and selected by authors.

Surveying literature park et.al@2006 selected a Eco PCB for digital conversion and transmission. Dimension of 'Eco' as 13mm(L) X 11mm(W) X 7mm(H) and weight of 2gms makes it a ultrawearable sensor node. Current consumption of 'Eco' as 10mA in receiving mode while 22mA in transmitting mode which is a prime feature in wireless transmission facilitates improved battery life[].Eco has 2.4GHz RF transceiver compatible with MCU(DW8051); MCU enables 512-byte ROM for bootstrap loader, 4KB RAM user programmeable, RS-232 and 9-Channel ADC. Programmable feature of ADC as it is software configurable for 6-12 bit of resolution. Power subsystem of 'Eco' has a regulator(LTC 3410) with o/p voltage as 2.7V, 40mAh reghargeable Li-Ploymer battery. Selected hardware by author as 'Eco' PCB having all wireless node features including 125 frequency channel upto 1MHz apart of nRF24EI's(2.4GHz TRS) to communicate base station.

Youn et al.[15] selected a DSP processor as tms3202812, Texas Instrument responsible for A/D conversion, digital processing and transmission via Bluetooth module. DSP processor process the analog signal to digital IIR filter to reduce power line interference as prime focus on preamplifier design of system.

King Mang Chang et al@2012 selected a MSP430-F5438 based hardware having12-bit ADC with bluetooth transmission chip. As Bluetooth selected [17] for wireless transmission which results in less interference at receiving host.

J.Son et al[18] uses a control box mentioned in literature having a MCU unit, Bluetooth and USB interface section; with the mentioned control box the analog signal is converted to 10-bit digital data indicating 10 bit ADC within microcontroller. Both Bluetooth and USB connectivity is available with PC or interface host enabling wired and wireless transmission.

The study carried out by J Stefan et al.[19] uses a 8-channel Bluetooth acquisition prototype consist of CPU, A/D conversion and memory card. Prototype[19] consist of an multichannel data acquisition unit with 0.1Hz HPF to supress baseline drift and digital high pass filter at 20Hz to avoid artifacts in low frequency region. However, surveying literature Lars Hoff et al@2008 system based on evaluation boards by telecom manufacturer. Evaluation board of Lars et al[20] system is wired connected with transmission board as MD1210DBI(Supertex Inc.Sunnyvale CA, USA), Oscillator of 40MHz and (IQXO,350c,IQD Ltd. Somerset,England) transmit/receive switch with Diode Network and AD8232-EVALZ analog amplifier. Evaluation board mentioned by Lars Hoff et al[20] uses a electronics circuicity of (NIPC-522, National Instrument Inc, Austin TX,USA) as 14-bit digitizer to sample the received pulses.

Advanced ECG processor[21] designed in review by chia-ching chou et.al @2011; processor consist of 10-bit ADC controller to receive 3-Channel ECG data with HRV engine to enable time-frequency analysis of variation in heart rate. However, the proposed processor consist of an additional compression engine and control unit with UART interface at output; which facilitate analysis computation and various communication protocol for o/p data. Designed specification of advanced processor satisfies the improved performance enabling 3-channel, 256Hz of sampling rate with 50Hz LPF having output voltage range (0.3-1.5).

Two important application for telehealth in review [22][23] selected the smart devices such as smart watch, mobile, belt as sensing device having compact in built hardware. Former application[22] in review proposed DR-ZHG to improve zigbee data rate and reduce delay in telehealth; later application [23] in review uses BSN(Body sensor network) technology in IOT based system development.

B.DAQ Host Review

In this section we summarized the data acquisition host based on employed wireless technology[6-9] and GUI tool used for visualization. Commonly we found in review that no additional hardware required for host interface except standard wireless module such as Zigbee or Bluetooth[6-9].

Selective host by park et al.@2006 consist of base station with specific transceiver having all possible interfaces as USB, Fast Ethernet and 802.11 b/g. The USB interface uses a nRF24E1 as wireless transceiver while Ethernet and 802.11b/g uses nRF2401 as transceiver supporting 12Mbps,100 Mbps and 11Mbps bit rate respectively.

As noted in previous section prime focus by Youn et al@2009 is to improve SNR therefore Bluetooth wireless technology used by author to receive the data at host. Visualizing tool selected by Youn et al.[16] as (Labview 8.0, National Instrument,USA) which simultaneously store and process the data. On contrary the study carried out by King-Mang et al@2012 used Bluetooth technology to receive sEMG data at host; but MATLAB selected for analysis and user interface.

In case of J.Stefan et al@2008 acquisition host is simply a interfacing of 8-Channel prototype[19] employed with Bluetooth acquisition and computer.

Lars Hoff et al@2008 consist of wired acquisition host which comprises PC interface through PCI-bus with 14-bit digitizer NI-PCI 5122, Natinal Instrument Inc, Austin,TX,USA).Graphical user interface used by author as software written in LabView which facilitate operation and analysis easy for non-technical one.

Acqusition Host for J.Son et al.[18] system supports bluetooth and USB communication to receive ECG data. However, android application developed for ECG visualization and result prediction(Driver's Health).

Remote patient monitoring[22] and modern health care system[23] are two major applications came across review; acquisition host for applications [22] [23] consist of servers and telecommunication infrastructure to surve large population worldwide.

III.ALL PURPOSE PARAMETER REVIEW

In this section we will discuss comparative study of all possible parameter for wireless acquisition system in review. As discussed earlier in section1 initial system are analog developed using FM transmitter[1],Later all system are digital with improved performance[2-13, 15-23].Also in review the high data transmission speed[10] and employed wireless technology[6-9] discussed in previous sections; additionally in this

section we summarized on more reviews[15][16][17][18][19] which depicts that each newer development is an improved system compared to previous one in literature; which is shown in table.

TABLE1: PARAMETES REVIEW

Parameters	**[15]**	**[16]**	**[17]**	**[18]**	**[19]**	**[20]**	**[22]**	**[23]**
Online adjutibility	No	No	No	No	No	No	Yes	Yes
Size(Eletrode H/W)	13lx11w x7h (mm)	37x17 mm2	MSP430 kit	-	Smart T Shirt	-	Complet e sytem	Complete sytem
Data Rate/fs	1 Mbps	-	2KHz	-	1khz	-	250kbps	GPRS
A/D conversion	6-12 bit	10-bit	12-bit	10-bit	14-bit	-	-	-
Wireless Technology	USB, Ethernet , wifi	Bluetooth	Bluetoot h	USB, Bluetoot h	Bluetooth	Wired PCI bus connct ed	Wifi	wifi
Power	1 mW	Tms320f2 812	MSP430 kit	-	-	-	-	-
Battery	Li-polymer	Li-Polymer	4.5V Li	Taken from Car	-	-	Li battery	-
Sensor	QUASA R	Ag/Agcl lead	Ag/Agcl	Capaciti ve sensor	Textile sensor	Trans ducer	Smart wearabl e device	Smart watch etc
HPF	Program mable	10Hz,DCo ffset	30Hz,B utterwor th	5Hz	-	-	-	-
LPF	Program mable	500Hz,DC	1kHz, Butt	20Hz	0.1hz, 20hz digital	-	-	-
wearability	Yes	No	No	No	No	No	yes	yes
Signal	ECG	EMG	EMG	ECG	ECG	ECG	ECG	ECG

IV.Application Discussion

However, the initial focus in review on hardware developments and parameters improvement, later in review study its noticed that mostly developed system by author contribute important applications which is described in this section. Park et al.[15] developed a truly wearable system with novel QUASAR sensor enabling wearable application for subject having compact size sensor. Kang-Ming Chang et al.[17] developed a system to record muscle fatigue which is useful in homecare and rehabilition environments. Experimental study performed by Ming et,al@2012, also concluded based on results that female has more muscle fatigue than Male. One of important application to monitor driver's state is performed by J.Son et.al.[18] on three different surfaces as urban road, curvy hill and highway. Driver's state is monitored through R peak recorded with Lumbar cushion[18] based ECG system. J.Stefan et.al.[19] developed a prototype T-shirt integrated with textile electrodes enabling long term recording of muscle and cardiac activity which can be used for treatment of musckuloskeletal disorder of neck and shoulder. To monitor the caridiac activity of patient continuously during and after a surgery; a system is developed by Lars Hoff et al.[20].DR-ZHG designed by Hoi Yan et al.[22] facilitate performance improvements in remote patient monitoring; also it improves the transmission data rate which is essential for Home telehealth system.

V.Conclusion

We have reviewed the developments of all purpose ECG/EMG acquisition system using wireless technologies in this paper. Electrode based intelligent acquisition transmits the biosignal and data acquisition host receives them, which is applicable to all system in review. We have summarized the hardware selected for acquisition unit as well as for interface host in literature. Employed wireless technology selected by authors is totally depends on respective application and design goals. Comparative study of all purpose parameter is also listed in review. Detailed discussion is done for systems in literature focusing on their applications. Most of smart systems in review has novel applications and available for future advancement to research community e.g. smart T-Shirt.

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