스마트 디바이스 기반 ECG 감지 IoT 응용 서비스에 관한 연구

마리아판 비나야감*, 이승연**, 이정훈, 이주영***, 차재상*ⓒ, 정회원

Smart Device based ECG Sensing IoT Applications

Vinayagam Mariappan*, Seungyoun Lee**, Junghoon Lee**, Juyoung Lee***, and Jaesang Cha*ⓒ *Regular Members*

요 약

의료 센터에서 데이터 분석과 스마트폰 어플리케이션 권한을 부여함으로써 사물 인터넷 (IoT)은 환자 중심의 의료 관찰과 관리에서 대혁변을 일으킬 것이다. 네트워크 연결은 개인 의료 서비스에서 IoT 의학 장치로 부터 건강을 관찰하는 스마트폰으로부터 진료받는 사람들의 건강 정보를 모으기 위한 기본 요구사항이다. 스마트폰에 설치된 IoT 환경은 매우 효과적이고 이것은 사회 기반 시설을 필요로 하지 않는다. 본 논문은 ECG 캡처링에 영향을 주지 않기 위해 스마트폰이 개인 IoT 아키텍처를 효율적으로 사용하는 것을 보여준다. 적응 IoT 의료 장치 관문은 클라우드 구성에 관한 대용량을 가진 개인 의료 서비스에 사용된다. 이 접근법에서, 스마트폰 카메라는 개인 ECG 파형을 추출하기 위해 사용된 이미지 기술을 기반으로 하고, 그것을 IoT 아키텍처를 사용한 대용량 저장 연결에 근거한 클라우드로 보낸다. 정교해진 알고리즘은 스마트폰이나 테블릿 카메라로 부터 찍힌 얼굴이미지로 부터 효율적인 ECG 등록을 직접 가능할 수 있는 여지를 준다. 이 심도있는 기술은 아마 적절한 기능 강화들이 소개된 후에 개인 의료 서비스를 관찰하는데 있어서 특별한 가치를 가질 것이다.

Key Words : IoT, ECG, Health Monitoring, Non-Invasive, Medical Device, IoT Gateway, IoT Sensor, WBAN-IoT.

ABSTRACT

Internet of things (IoT) is revolutionizing in the patient-Centered medical monitoring and management by authorizing the Smartphone application and data analysis with medical centers. The network connectivity is basic requirement to collect the observed human beings' health information from Smartphone to monitor the health from IoT medical devices in personal healthcare. The IoT environment built in Smartphone is very effective and does not demand infrastructure. This paper presents the smart phone deployed personal IoT architecture for Non-Invasive ECG Capturing. The adaptable IoT medical device cum Gateway is used for personal healthcare with big data storage on cloud configuration. In this approach, the Smartphone camera based imaging technique used to extract the personal ECG waveform and forward it to the cloud based big data storage connectivity using IoT architecture. Elaborated algorithm allows for efficient ECG registration directly from face image captured from Smartphone or Tablet camera. The profound technique may have an exceptional value in monitoring personal healthcare after adequate enhancements are introduced.

I. Introduction

The rapid growth in healthcare technology is challenging the health care issues. The remote monitoring of vital signs includes not only the high accuracy diagnostic devices but also simple ones and user friendly for everyone. By observing most frequent examinations, cardiac pulse measurement plays a major role in health care monitoring. There are several approaches of contact measurement of a heart rate among which the golden standard is an electrocardiography (ECG).

There are many approaches adopted in medical devices to measure cardiac pulse which uses thermal imaging [1], Doppler phenomenon both optical [2] and ultrasonic [3] or piezoelectric measurements [4]. For detecting pulse rate [5], Photoplethysmography (PPG) is one more method

*서울과학기술대학교 미디어IT공학과, **동서울대학교 전기정보제어과
***서경대학교 전자공학과, ⓒ 교신저자: 차재상(chajs@seoultech.ac.kr)
※ 이 연구는 서울과학기술대학교 교내연구비의 지원으로 수행되었습니다.
접수일자 : 2016년 7월 25일, 수정완료일자 : 2016년 9월 7일, 최종게재확정일자 : 2016년 9월 23일

which utilizes the optical properties. PPG uses dedicated light sources, e. g. near-infrared light, which is a typical implementation. Pulse measurement from human face is also possible using light as the illumination source [6] is proved. Poh et al. has developed a robust method for computation of the heart rate from digital color video recordings of the human face.

The advancement in non-invasive medical devices with no contact with the mucous membrane or internal body cavity other than through a natural or artificial body orifice makes new technology growth in healthcare. Procedures used to evaluate health and/or detect presence of a disease such as taking a pulse, listening to the sounds of the heart and lungs, gauging blood pressure, and performing an oral exam, are all considered non-invasive devices. This paper presents imaging based non-invasive ECG signal extraction.

Currently healthcare field has entered to Internet of Things (IoT) which includes sending the human beings data in time to the specialist through network to aid the human beings autonomy and confidence.Providing healthcare in rural remote areas of developing countries has always been a tough task. Telemonitoring was the better option with limitations to access human beings health information by healthcare workers and specialists, but merging it with cloud services can be a best solution. Modern trend of using cloudlet is flexible and its efficacy of storage capacity is vast which is secured to retrieve and analyzing the data.

In the last couple of years, smart phones and Tablets are ruling globally. While the advent of smart devices functional characteristics and revolutionize the conventional health care methods, integrating the IoT on Smartphone can further increase intelligence, flexibility and interoperability. A Smartphone device utilizing the IoT scheme is uniquely addressed and identifiable at anytime and anywhere through the Internet. This paper, focus particularly on the clinical arena and examine the opportunities afforded by available and upcoming technologies.

As exemplified in, this paper describes the design of Smartphone based non-invasive ECG signal measurement device with IoT standard to provide personal healthcare services with cloud interface for a supervised human beings.

Ⅱ. Main Body

1. Non-Invasive Medical Device Technology

In present day, diagnosis is done by the observation of color of the skin, tongue, eyes, and the smell of a person's breath, skin temperature, pulse rate and painful areas of the body. The health of any person can be identified by such common indicators.Non-invasive medical technique is the technique diagnosed by external signs, no damage to the body. Today, diagnosis is done in the laboratories by a host of tests using various technologies by collecting the samples of blood, urine and other body fluids or tissue samples prescribed by doctors to have vital information about the health with little inconvenience to the human beings. The existing noninvasive techniques use specific imaging techniques in modern diagnosis. The Imaging based diagnosis approach started with the use of X-rays to identify problems with bones and today X-rays (CT scans), Ultrasound techniques, Thermal imaging andMagnetic Resonance Imaging (MRI)imaging based diagnosis used in the medical application on computing system for accurate images to know the internal system of the body. After the diagnosis, treatment may involve with medicine or surgery or a host of other methods. The techniques used for surgery are highly invasive. This paper, proposes the Smartphone based ECG measuring device using imaging techniques by seeing the calculative factors the Smartphone app took rise to reduice the risk and cost effect.

2. Imaging Based Non-Invasive ECG

The working model is shown in Figure 1 for Adult/Conditioned Human beings and Neonatal cases.

(a) Neonatal (b) Adult/Conditioned Human

Figure 1. Non-Invasive ECG Measurement Model

There are many blood vessels on the human face and the human facial skin color varies slightly with blood circulation. Photoplethysmography (PPG) is a simple and low-cost optical technique that can be used to detect blood

volume changes through variations in transmitted or reflected light. This paper applies Photoplethysmography theory to measure the Physiological Parameters like Heart rate, ECG of the human beings.

Figure 2 shows the diagram of non-contact physiological parameter detection for human beings. The camera can be fixed in front of the person who wants to measure the physiological parameter. In this approach the person's facial video signal is captured and the coordinates of the face location are identified. Then the facial image was separated into RGB channels. For each channel signal is normalized and then the noise is removed from the channel signals using blind source separation. Next the blind source separated signals are passed through band pass filter and then fast Fourier transform (FFT) is applied. At last the ECG Signals are extracted by applying the adaptive filter on the Fourier transformed data.

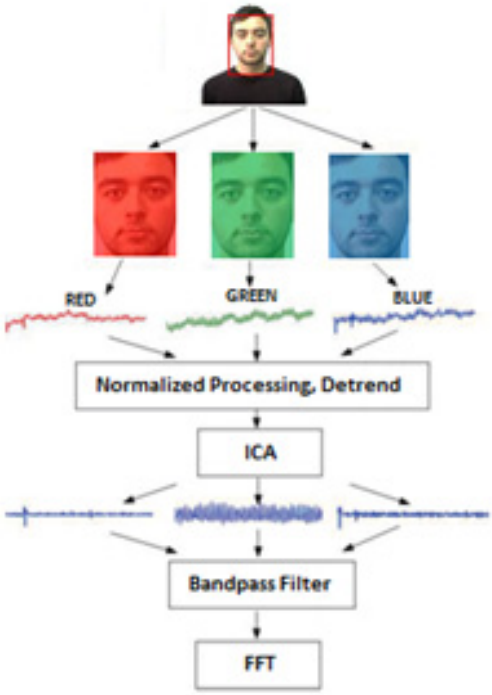

Figure 2. Functional Diagram for Physiological Parameter Detection

3. Cloud Based Modern Health Monitoring and Management

eHealth is an emerging application for health monitoring for chronic illnesses, lifesaving in emergency situations, and its ability to provide healthcare to disadvantaged areas. In particular, wirelesses Body Area Networks (WBANs) are the key enablers of remote and in-hospital health monitoring. However, WBANs technology alone is not sufficient to achieve the ultimate goal of eHealth care stakeholders, so the advanced technologies such as Internet of Things (IoT) and cloud computing are needed to further improve the Health monitoring system efficiency.

The cloud computing results of technological convergence, health care segment has profited from recent advances in sensors design and wireless communication technologies. Health monitor includes various types of medical sensors embedded in Smartphone's, wearable devices in, on or around the human beings bodies, working as important elements of WBAN. The health care tasks are therefore shifted from traditional clinical environment to pervasive user friendly environment. Also, the range of monitoring subjects could be significantly expanded, varying from the human beings at urgent care, e.g., in ambulance, to those with chronic diseases.

IoT sensors deployed in smart homes or at hospital rooms provide the environmental conditions with person's physiological parameters that allow the medical stuff to assist accurate diagnosis and to give efficient treatment. The eHealth monitoring framework is given in Figure 3, with following major components,

- Sensors: collecting data of interest from the human beings and transmitting them to the base station.
- Communication networks: Includes WBAN-IoT communications, IoT-IoT communications, as well as various relaying networks and access networks like 3G and wire line networks.
- Medical data processing servers: the data is stored and processed in remote cloud data centers, with secure and privacy-preserving computation and storage.
- Clinic terminals: the end users could be nurses, doctors or any other physicians, who will retrieve the medical information from cloud data centers via various access equipment's that could be deployed in hospitals, clinics, ambulances or any medical care Centre.

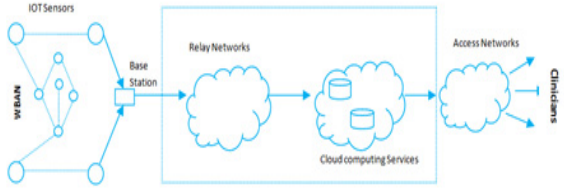

Figure 3. Cloud based Medical IoT Communication Network Model

4. Smartphone as an IoT Device

To enable healthcare support in personal space with IoT connected device, which costs more than 250$ on IoT Sensor and IoT Gateway. This paper is repurposing Smartphone as an IoT device with Sensor and Gateway functionality as a converged IoT solution on single device. The feasibility of enabling IoT functionality is analyzed with standard IoT open source HW platforms against the Smartphone features like Wi-Fi, Bluetooth, cellular radios, several gigabytes of storage, speakers and microphones, cameras, accelerometers, gyroscopes, compasses and touch screens. The integrity of too many HW components on Smartphone's gives wide openings to implement IoT features on Smartphone APPS. This motivated that, an operating system developed specifically to control the main board of a smart phone as though it's an embedded computing device on the Internet of Things. This hits the mind in an idea of repurposing Smartphone hardware could have big implications for manufacturing Internet of Things devices.The skilful act to reuse the outdated phone HW as an IoT HW platform since already being manufactured in bulk and get it on low cost. And all Smartphone's packs with Wi-Fi connectivity, good processing power, low power consumption and can be programmed with the low cost IoT Arduino development environment which reasonably down the cost of the IOT product development.

5. Smartphone Based Flexible ECG IOT Device

Recent years witnessed interest in wearable sensors for personal health care, fitness, and activity awareness. Data Acquisition is performed by multiple wearable sensors that measure physiological parameters, such as ECG, skin temperature, respiratory rate, EMG muscle activity, and gait.

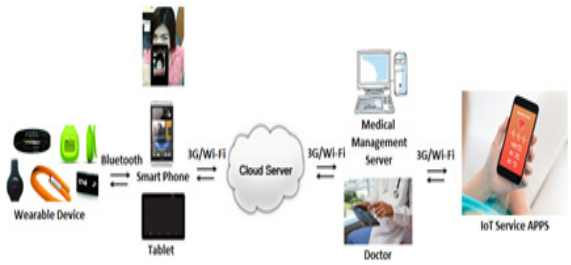

Figure 4. Smartphone Based IoT Architecture

The sensors connect to the network through an intermediate data aggregator or concentrator, which is typically a smart phone located in the vicinity of the human beings is called as an IoT Gateway. IoT gateway is responsible for conveying physiological parameters from the human beings at any remote location to the data centre of the Healthcare Organization (HCO) with assured security and privacy, ideally in near real-time.

The sensory acquisition platform is equipped with a short range radio such as ZigBee or low-power Bluetooth, which it uses to transfer sensor data to the concentrator. Aggregated data is relayed to a HCO for long term storage using Internet connectivity on the concentrator via a Smartphone's Wi-Fi or cellular data connection. Sensors in the data acquisition part form an Internet of Things (IoT)-based architecture as each individual sensor's data can be accessed through the Internet via the concentrator.

Often a storage/processing device in vicinity of a mobile client, sometimes referred to as a cloudlet, is used to augment its storage/processing capability whenever the local mobile resources do not fulfill the application's requirements. The cloudlet can be a local processing unit which is directly accessible by the concentrator through Wi-Fi network.

Cloud Processing has storage, analytics, and visualization components. This is designed for long term storage of human beings biomedical information as well assisting health professionals with diagnostic information. Analytics that use the sensor data along with e-Health records that are becoming prevalent can help with diagnoses and prognoses for a number of health conditions and diseases. In addition, Visualization is a key requirement for any such system because it is impractical to ask to pore over the voluminous data or analyses from wearable sensors.

In addition to the IoT gateway device, the smart phones function as an IoT Sensor device to extract ECG of the person who interested on measuring physiological parameters. In part of Smartphone based IoT device implementation, the imaging techniques based ECG extraction techniques are described below:

5.1 Face Detection

The accurate ECG signal extracted is decided by the precision of facial contour tracking, identification and extraction. This paper intricate the person's face tracking, identification and extraction were based on Object Detection using Haar feature-based cascade classifiers

method called Adaboost is used to effective object detection by Paul Viola and Michael Jones.

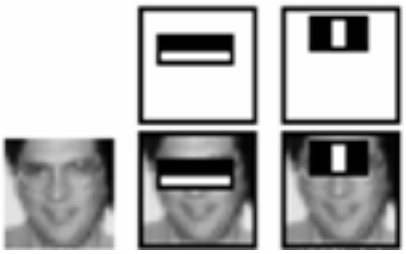

Figure 5. Adaboost Face Detection[11]

5.2 Facial Image Processing

The obtained facial video frames were separated into the three RGB channels red, blue and green. Each channel averaged all pixels for each frame. The formula is as follow, Other Recommendations Where n, m denotes the row and column of the pixels. For each i = R, G, B, Ii is the pixels of each frame, Ii=IR, IG, IB. The VR, VG, VB composed the raw signals. When environmental parameters change, the collected image will be noising and drifting. The raw signals were detected using smoothing filter with the smoothing parameter λ = 10 and cut-off frequency = 0.059 Hz.

5.3 Blind Source Separation

The extracted R, G, B components are combined with multivariate signal due to human movement and blood circulation and other environmental factors. Independent Component Analysis (ICA) is a method for separating a multivariate signal into additive subcomponents. This implementation analysis uses the joint approximate diagonalization of Eigen matrices (jadeR) algorithm and uses ICA algorithm to further remove noise from the physiological signals.

5.4 ECG Extraction

Before ECG is extracted, the signals are passed through band pass filter (128-point Hamming window, 0.3-4Hz) and the signals are normalized using expression: Xi (t) = (Vi (t)-Ui)/∂i, for each i = R, G, B where Ui and ∂i are the mean and standard deviation of Vi (t), respectively. The ECG waveform predicted adaptively by applying Fast Fourier Transform (FFT) followed by adaptive filtering.

Ⅲ. Conclusion

Non-contact heart rate and ECG extraction using video image processing technology and blind source component technologies implementation on Smartphone is described in this paper with real-time evaluation data. It is ideally suitable for IoT healthcare applications in the automotive to monitor the physiological parameters of drivers, because it is non-contact, easily implemented in hardware and has low cost. The real-time heart rate and ECG extraction IoT healthcare systems were designed. Compared with the existing commercial detection equipment, non-contact detection method can measure the heart rate and ECG extraction, but the participant's large motion can affect the accuracy

References

[1] M. Garbey, N. Sun, A. Merla, and I. Pavlidis, "Contact-free measurement of cardiac pulse based on the analysis of thermal imagery," IEEE Trans. Biomed. Eng., vol. 54, no. 8, pp. 1418 - 1426, Aug. 2007

[2] S. Ulyanov and V. Tuchin, "Pulse-wave monitoring by means of focused laser beams scattered by skin surface and membranes," Proc.SPIE, vol. 1884, pp. 160 - 167, July 1993

[3] D. W. Holdsworth, C. J. Norley, R. Frayne, D. A. Steinman and B. K. Rutt, "Characterization of common carotid artery blood-flow waveforms in normal human subjects," Physiology Meas., vol. 20(3), pp. 219-40, Aug. 1999

[4] K. Aminian, X. Thouvenin, Ph. Robert, J. Seydoux and L. Girardier, "A piezoelectric belt for cardiac pulse and respiration measurements on small mammals," Engineering in Medicine and Biology Society, 1992 14th Annual International Conference of the IEEE, vol.6, pp. 2663-2664, Oct.29 1992-Nov. 1 1992

[5] J. Allen, "Photoplethysmography and its application in clinical physiological measurement," Physiol. Meas., vol. 28(3), pp. R1-39, Mar. 2007

[6] M. Garbey, N. Sun, A. Merla, and I. Pavlidis, "Contact-free measurement of cardiac pulse based on the analysis of thermal imagery," IEEE Trans. Biomed. Eng., vol. 54, no. 8, pp. 1418 - 1426, Aug. 2007.

[8] P. Comon, "Independent component analysis, a new concept?" Signal Process, vol. 36, pp. 287 - 314, 1994.

[9] A. Pantelopoulos and N. Bourbakis, "A survey on wearable sensor-based systems for health monitoring and prognosis," IEEE Trans. Sys., Man, and Cybernetics, Part C: Applic. and Reviews, vol. 40, no. 1, Jan 2010.

[10] N. Bui and M. Zorzi, "Health care applications: A solution based on the internet of things," in Proc. of the 4th Int. Symposium on Applied Sciences in Biomed. and Com. Tech.,

ser. ISABEL'11. New York, NY, USA: ACM, 2011
[11] Paul Viola and Michael Jones, "Rapid Object Detection using a Boosted Cascade of Simple Features," Conference on computer vision and pattern recognition 2001.

저자

비나야감 마리아판(Vinayagam Mariappan) **정회원**

- 2008년 6월 : Director in VENMSOL TECHNOLOGY & ESILICON LABS
- 2014년 3월 : MS in Media IT Eng., Seoul National Univ., of Science & Tech., Seoul, Korea

<관심분야> : IP Video Surveillance, IoT, LED-IT, Network Multimedia, Video Analystic, VLC

이 승 연(Seungyoun Lee) **정회원**

- 2001년 : 성균관대학교 전기전자 및 컴퓨터공학과 석사졸업
- 2006년 : 성균관대학교 전기전자 및 컴퓨터공학과 박사졸업
- 2006년 ~ 현재 : 동서울대학교 전기정보제어과 교수

<관심분야> : 유무선 통신기술, 전력제어기술, 방송통신기술

이 정 훈(Junghoon Lee) **정회원**

- 2001년 : 성균관대학교 전기전자 및 컴퓨터공학과 석사졸업
- 2012년 : 서울과학기술대학교 IT정책전문대학원 박사졸업
- 2015년 ~ 현재 : 동서울대학교 전기정보제어과 교수

<관심분야> : 디지털통신, 무선통신, 홈네트워크 응용기술

이 주 영 (Juyoung Lee) **정회원**

- 1992년 2월 : 한양대학교 전자공학과 석사졸업
- 2002년 2월 : 한양대학교 전자공학과 박사졸업
- 2002년 3월 ~ 현재 : 서경대학교 전자공학과 교수

<관심분야> : IoT응용기술, IT융합기술, 방송통신기술, 고속 스위칭 모델링

차 재 상(Jaesang Cha) **정회원**

- 2000년 : 일본 東北(Tohoku)대학교 전자공학과 공학박사
- 2002년 : 한국전자통신연구원(ETRI) 무선방송 기술연구소 선임연구원
- 2008년 : 미국 플로리다 대학교 방문교수
- 2005년 ~ 현재 : 서울과학기술대학교 전자IT미디어공학과 교수

<관심분야> : LED-ID, 조명IT융합신기술, LBS, ITS, UWB, 무선 홈 네트워크, IoT응용기술 등