Chapter 40
Wearable ECG Monitoring and Alerting System Associated With Smartphone:
iHeart

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ABSTRACT

Heart disease has the second high mortality rate behind cancer in Japan, and requires quick treatment. To take a part in emerging mHealth, the authors developed a wearable electrocardiographic (ECG) monitoring and alerting system "iHeart". iHeart continuously monitors patient's ECG in his/her daily activities and issues an alert to the patient as well as surrounding people if it detects abnormal heart behaviour. iHeart consists of a wireless ECG sensor and a smartphone to achieve light-weighted, low-cost system that does not degrade the patient's Quality of Life. In parallel, the authors developed ECG analysis algorithm to detect R-wave as well as arrhythmia, and implemented these algorithms in wireless ECG sensor rather than in smartphone to save power consumption of ECG sensor caused by radio communication. The authors proof the practicality and usefulness of our system in clinical experiment. This paper describes the implementation of iHeart, evaluation experiment, and future requirements of the system.

1. INTRODUCTION

Mobile Health (mHealth) is a mechanism or a service that supports medical treatment and/or health-care by the use of mobile devices. The market of m-Health is expanding rapidly worldwide along with the penetration of mobile phones. Applications of m-Health include telemedicine, home healthcare and welfare services and they are expected to improve patient QoL (Quality of Life), resolve the uneven distribution of doctors and reduce ever-growing healthcare cost. Continuous monitoring and analysis of patient vital signs is a typical example of m-Health application. Recently, research and development of mHealth are becoming active for life-style diseases such as heart disease or diabetes (Varshney, 2007; Nkosi & Mekuria, 2010; Ren, Pazzi & Boukerche, 2010; Lee et al., 2012; Nemati et al., 2012; Agekura & Kageyama, 2010).

Heart disease is a general term to represent disease of a heart such as heart failure, myocardial infarct, angina, atrial fibrillation and ventricular fibrillation. According to the demographics reported by the Health, Labor and Welfare Ministry of Japan in 2011, heart disease has the second high mortality rate behind cancer in Japan. Furthermore, heart disease is characterized by its need of emergency treatment. For example, acute myocardial infarction requires treatment within several hours to three days after its occurrence. When it comes to the ventricular fibrillation, survival rate diminishes approximately 10% by every one minute after its occurrence. In this way, heart disease is familiar but fatal disease that requires immediate action and treatment.

Traditionally, the diagnosis of heart disease is performed in two ways; the one is cardiograph monitoring in a hospital for the duration of several minutes, and the other is wearing a Holter monitor for 24 hours to record cardiograph data and analyze it later in a hospital. Actually, however, heart disease such as arrhythmia or angina cannot always be detected. It may appear only several times per week. In such cases, it cannot be detected by conventional methods. Furthermore, if a fatal symptom comes up after hospital visit or outside the hospital, immediate action can be taken neither by the patient nor by hospital staff. This also makes the patient uneasy. Although there are implantable devices for fibrillation removal, not a small number of patients feel repulsion in implanting foreign substances into the body.

For above reasons, there is a evident need for Electrocardiogram (ECG) monitoring and alerting system that meets following requirements: (1) endure long time wearing up to about a week, (2) need not be implanted into the body, (3) not expensive compared with other medical devices, and (4) does not debase QoL of patient.

In these circumstances, we developed iHeart as a Wearable Heart Disease Monitoring and Alerting System associated with Smart-phone. iHeart continuously monitors and analyses the patient's ECG, raises an alert automatically if it detects abnormal heart waveform, and further shows the coping strategy and/or emergency action request on the smartphone screen to the patient and surrounding people.

This paper describes the architecture and behavior of iHeart, ECG analysis algorithm and its evaluation through experiment regarding the detection of arrhythmia.

1.1. Related Works

As for continuous health status monitoring, Brones et al. (2002) propose a framework of context-aware m-health applications by illustrating a wearable m-health system to issue a warning to a wearing person and caregivers about the acute symptom taking the epilepsy patient for instance. However, neither implementation nor validation of the proposed framework is performed in this work. Halteren et al. (2004)

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