Electrocardiogram Sensor

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It is well-known that cardiovascular disease is one of the major causes of death worldwide nowadays. Electrocardiogram (ECG) sensor is one of the tools commonly used by cardiologists to diagnose and detect signs of heart disease with their patients. Since fast, prompt and accurate interpretation and decision is important in saving the life of patients from sudden heart attack or cardiac arrest, many innovations have been made to ECG sensors. However, the use of traditional ECG sensors is still prevalent in the clinical settings of many medical institutions.

Keywords: Electrocardiogram Sensor ; cardiovascular disease

1. Introduction

Heart disease refers to disorders that affect the functionality of our hearts [1]. It includes disorders of blood vessels associated with the heart, abnormal heart rate or rhythm, or defects in the structure of the heart. According to World Health Organization (WHO), about 17.5 million people are dying each year due to heart disease. Early diagnosis and detection of heart disease is important to avoid sudden death due to heart attack or cardiac arrest [2]. Electrocardiogram (ECG) sensor is a device commonly used by cardiologists to check for abnormal heart rhythm and signs of potential heart disease quickly and without intervention. Sometimes, the signs of heart disease for a patient do not show up in a short period of ECG signal recording and require longer recording and monitoring period of more than 24 h. This makes the interpretation of ECG graphs by cardiologists longer and more error prone. Thus, a lot of innovations have been made in the recent years on ECG sensors to reduce the mortality rate and assists cardiologists in making prompt, accurate, and quality decisions. The innovations encompass various perspectives such as the ECG hardware, signal preprocessing algorithms, automatic detection of heart disease algorithms from ECG graphs and data format interoperability with other applications of Electronic Health Record (EHR) system.

There exist significant survey works on various aspects of the ECG sensors. Survey work in [3] compiles progress in the field of wearable sensors and systems related to the rehabilitation field. Specifically, a brief explanation of various technologies needed for the implementation of the wearable systems is provided followed by a detailed explanation of their applications with a special focus on home rehabilitation, safety, health, and wellness. Another survey work in [4] reviewed wearable ECG monitoring systems for older adults based on the system's wireless, mobile, and remote technologies. Specifically, 120 ECG monitoring systems in this work were described and classified into wireless, smart wearable, and mobile ECG monitoring systems while also taking into account the related signal processing algorithms. A review of heart monitoring systems comprising details of their functions, progress, and limitations is provided in [5] based on several modules, namely body sensors, analog to digital conversion and compression, analysis and classification, wireless transmission, and signal conditioning. A survey on various denoising techniques for ECG signals was presented in [6]. Work in [7] carries out the study comparing several wearable sensors utilized for ECG measurements while also reviewing various technical hurdles encountered during their development. Specifically, the comparison is based on the working principle, materials and methods used to develop the sensors, implementation, and performance. Finally, work in [8] provided a detailed classification of ECG monitoring systems based on their monitoring contexts, targets, schemes, and technologies. In addition, the work provided other details including a generic architectural model, complete set of processes for analyzing, designing, and validating the reviewed ECG monitoring systems.

Although the survey work in the field of ECG sensors is significant, but to the best of our knowledge, a comprehensive survey of ECG sensors in terms of their hardware components, software algorithms and data format interoperability is still lacking. Besides the innovations, the use of traditional ECG sensors are still prevalent in real clinical settings of many medical institutions. A survey on ECG sensors from the perspectives of hardware, software and data format interoperability will help researchers to identify future works and facilitate the development of modern ECG systems that are suitable and approved for adoption in real clinical settings.

2. Advances of ECG Sensors from Hardware, Software and Format Interoperability Perspectives

ECG sensors have been studied thoroughly in the literature. However, several distinct aspects of these sensors pose significant challenges for the researchers, clinicians, and other users to select these devices based on their requirements. The hardware perspective is covered by introducing the general hardware architecture of an ECG sensor and categorizing it into three main units: sensing, communication and battery unit. In addition, several components and technologies belonging to these units are briefly discussed. In the software perspective, various techniques including denoising, machine learning and deep learning used in processing of ECG signals are discussed while also introducing the other computer paradigms such as cloud computing and smartphone-based applications that facilitates in the development of ECG monitoring systems. In addition, a survey of existing literature on ECG monitoring software architectures is carried out by highlighting the usage of these techniques and computer paradigms followed by a study on the existing privacy preservation techniques used in ECG monitoring systems. Finally, in the ECG data format interoperability perspective, a taxonomy of several ECG formats is provided comprising of a brief description on each of the individual format. Moreover, a survey on existing converters for different ECG formats is carried out, thereby highlighting the relationship among these formats. As part of the future directions, an investigation on robotics and healthcare automation and its impact on the current and next-generation monitoring systems will be carried out. Moreover, another possible research direction would be to explore ways to better integrate several IoT technologies and other connected devices (especially when the patient is in a mobile unit such as an ambulance) for the enhancement of the current ECG monitoring systems.

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