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Review

Biosignal monitoring using wearables: Observations and opportunities

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ABSTRACT

Advances in data acquisition technologies, sensor design, data frameworks, smart device connectivities, Internet-of-things, rising health care costs and public awareness towards a better quality of life, have spurred a boom in development of wearable "health-tech" devices in the smart device market. Tele-monitoring of human body dynamics through activities of daily life has become a popular lifestyle choice for consumers, as it helps them keep track of parameters such as food intake, calories burnt, activity levels, or even calling the nearest health care facility during emergencies. Although these devices give the user an intuitive and interactive interface to track body parameters, their use is still limited when compared to vital body parameters in a clinical context. Through this study we are attempting to investigate the clinical applications of wearable devices for biosignal and disease monitoring. In this review study, we have covered a plethora of challenges and opportunities with respect to wearable device design and the inherent possibilities for biosignal analysis and interpretation. Additionally, we have also attempted a comparison of some vital biosignals obtained from wearables and clinical equivalents, which would be useful in determining specific criteria for designing a clinically relevant wearable device.

Contents

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1. Introduction

One of the earliest wearable devices that came in the consumer market was the calculator watch during the 1980s, which was also the beginning of advancements in ubiquitous computing. Recent developments in the smart device market comprising of smart phones, tablets and phablets, have extensively started implementing sensors such as tri-axial accelerometer, gyroscope, magnetometer and altimeter in order to give the consumer a very intuitive feel of virtual environment. Positioned and mushrooming within this arena, is the niche market of wearable devices and the associated start-ups which are leveraging the smart device sensor data for monitoring biosignal dynamics. Up until the last five years, clinically relevant wearables included devices such as blood pressure monitors, stethoscope, and Holter ECG recorder. But these devices never made it to retail consumer market, and were distributed only to authorised personnel by health regulatory authorities. Although this trend continues even today, wearable design firms have found novel methods and devices for recording and analysing body signals without the need of going through regulatory approvals. What we can learn from this fact, is that smart and non-invasive biosignal analysis embedded in smart devices, could enable the practical implementation of tele-monitoring of patients and people in general.

A quick glance over technology news forums such as Gizmodo™, Engadget™ and others, would yield us the most recent updates on how wearable devices such as the Apple Watch™, Samsung Gear™, Nymi™ band, are being used in generating certain health information such as pulse rate, step count, kilometers walked/ran, dietary requirements, calories burnt and more to the consumer. Delving into their specifications and software development kits (SDKs)also gave us a brief insight into how these devices capture certain biomedical signals from the human body for analysing activities of daily life [1,2]. Most of these signals also have a clinical significance from a disease or disorder management perspective. This being said, there exist a lot of open challenges and unmet potential in the wearable device market, from a clinical view.

To give the reader a few statistics, Vandrico™ Inc., a Vancouver based firm has a real-time update on the wearable device market, which indicates that there are about 335 wearable devices currently available in the market at an average price of USD 300 [3]. Interestingly, the most commonly used sensor in these devices is the accelerometer which captures motion-based data from the human body. Following charts indicate how the wearable market is distributed by niche verticals and human body areas. As per Business Insider™ [4], the wearable device market is predicted to reach out to about 385 million users in just North America, and could very well change how consumers collect and use their vital body signal information for health monitoring and better quality of life. In fact, it is expected that the healthcare system in North America can be profited by as much as over a billion dollars over the next 15-20 years, solely through "remote monitoring" aspect of healthcare that wearable technology brings with it [5].

Within the wearable niche market is the upcoming vertical in smart-patch market. A review by Wearable Technologies (WT) [6] indicates that wearable smart patch technology would compromise about 30% of the overall healthcare, sports and fitness wearable market. Smart patches have been trending in key categories which include transdermal, transmission, monitoring and electronic stimulation, although there are no currently available intelligent patches available in the market. The smart-patch market is one of the fastest way to get a wellness wearable into the market, as it would not require FDA approval [6].

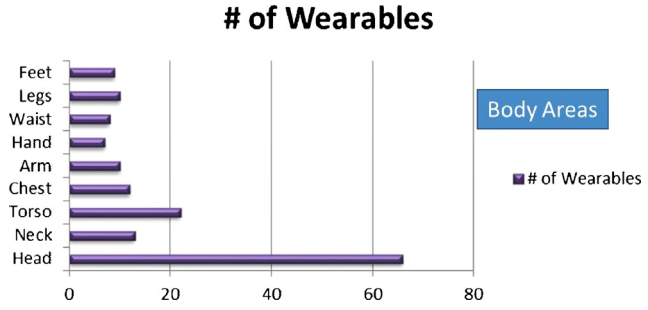

Fig. 1. Wearables by body areas.

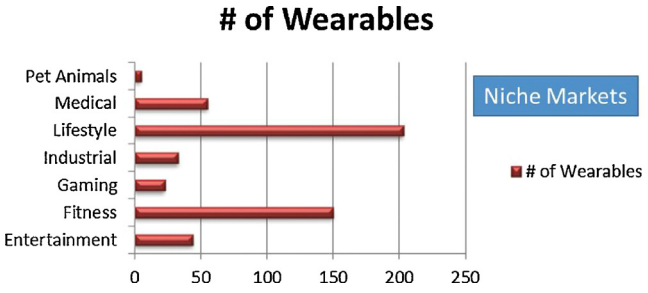

Fig. 2. Wearables by niche markets.

As indicated in Figs. 1 and 2, as of June 2016, only about 55 wearable devices exist in the medical application vertical, which is a big motivation for us to review the market dynamics, healthcare system needs, and postulate a practical design of wearable device for vital body signal analysis. Current healthcare systems around the world still rely on frequent patient–doctor visits, monitoring using cumbersome equipment, and doctor's experience based prognosis. Although this has been a de facto trend, rising healthcare costs coupled with rapid lifestyle and technology changes, has made tele-monitoring of health a hot topic in smart device market. Even though advanced body image acquisition equipment such as MRI, Tissue imaging, and body signal collection devices such as Holter recorders, Sleep Apnea monitors are being used in the hospitals and home-healthcare facilities, for giving informed decisions to doctors; modern sensors have opened up a potential gap for wearable design which could enable remote monitoring of patient health, especially for elderly citizens [1,2]. The boom in wearable technologies has also inspired other markets to position themselves accordingly such that at least one wearable device or subset gets included in their products. For example, the fashion industry is rapidly emerging with wearable sensor-based fabric design, which could integrate cloth and technology coupled with design aesthetics.

Our review study is focussed on investigating into the possibilities of using market-ready devices for biosignal monitoring and non-invasive medical applications. Specifically, we are investigating into how relevant wearable biosignal data is with respect