Future Market Trends and Opportunities for Wearable Sensor Technology

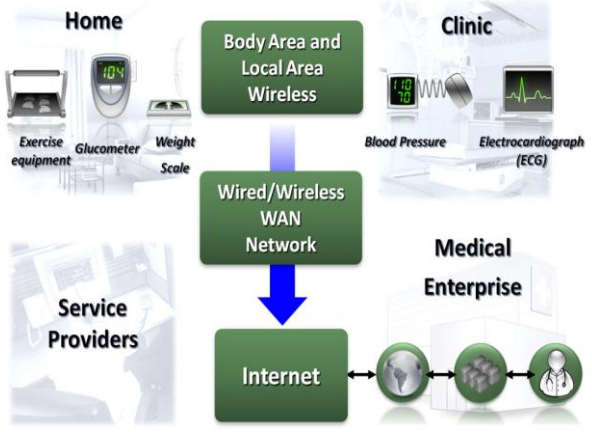
Usman Ahmad Usmani and Mohammed Umar Usmani

***Abstract*—Wearable sensors enable long term continuous psychological monitoring, which is important for the treatment and management of many chronic illnesses, such as neurological disorders and mental health issues. Examples include diabetes, problems with socials skills to some extent, empathy, communication, depression, drug addiction, and anxiety disorders. In the current paper we present a few mobile health technologies developed by our group and shall also discuss future market trends and opportunities for wearable sensor technology. Technologies presented include wearable sensors for electro-dermal activity (EDA), mobile plethysmography and the supporting wireless network architecture. The companies that are recently in the market and are putting great emphasis on wearable sensors are gradually changing the level of technology to a significant high level.**

***Index Terms*—Wearable sensors, electro foxy, cute circuit, Tn games, electro dermal activity, mobile plethysymography.**

I. Introduction

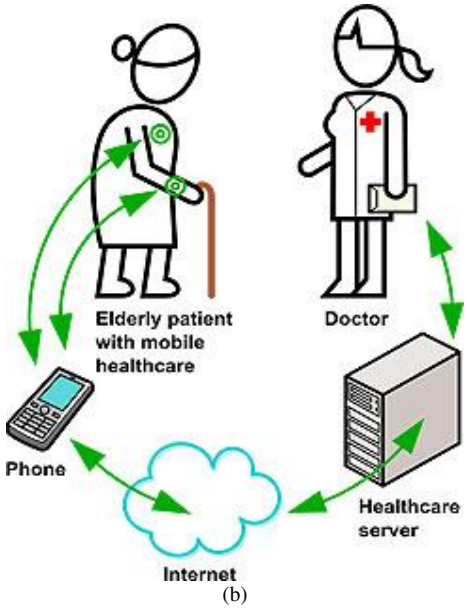
In this paper we have discussed the future market trends and opportunities in the area of wearable sensors and various health issues and treatment. Various companies are listed that are now emerging in the wearable sensor technology sector. The primary focus is on building up wearable sensors that would take the present generation to a high level of advancement in field of science and technology. The authors have also displayed the sample network architecture for mobile health monitoring system. (see Fig. 1 & Fig 2).



(a)

Fig. 1. Sample network architecture for mobile health monitoring system.

Text: Wearable sensors [1], [2] have been successfully integrated into clothing garments as well as fashion accessories such as hats, wrist bands, socks, shoes, eyeglasses and headphones and almost in everyday life. These systems often include temperature sensors and accelerometers, which are often used to monitor and classify a person's physical activity. In addition to these, our group has explored sensors that are fundamental to psychophysiology and understanding of human emotions. Two general categories are:



(b)

Fig. 2. Sample network architecture for mobile health monitoring system.

A. Electro-Dermal Activity

Electro-dermal activity [1], [2] (also known as skin conductance or galvanic skin response) directly correlates to the *sympathetic* nervous system activity and thus provides a powerful tool for monitoring arousal and certain aspects of autonomic regulation. EDA sensors are promising for providing people with Autism Spectrum Disorder (ASD) a means of measuring stress or anxiety in situations where these feelings cannot be communicated verbally or socially. EDA sensors can thus provide feedback to caregivers and to the patients themselves to help understand specific stimulators of stress or anxiety.

B. Mobile Photo Plethysmography [1] (PPG)

In order to measure parasympathetic as well as sympathetic aspect of the autonomic nervous system, we have also devoted some light research on mobile measurement of heart rate and its variability.

Several different measurement methods have been investigated, including electromagnetic methods. This work is ongoing. However, much of our work has been devoted to developing new form factors for photo plethysmography

Manuscript received October 28, 2013; revised December 21, 2013.
Usman Ahmad Usmani is with the Aligarh Muslim University, Aligarh. (e-mail: ahmadusmani12@gmail.com)

(PPG), which could detect the pulse volume by measuring the relative absorption of near infrared light over skin. Since oxygenated and de-oxygenated blood exhibit different light absorption, the measurement at two wavelengths can be used for calculation.

C. Wireless Connectivity

For many applications, real-time wireless connectivity to the wearable sensors is not required. In this case, the data can be logged on locally on the sensor module itself for many hours continuously or days.

However for many emerging applications, there is an interest to provide *real-time interventions* to the patient. In this case, it is often necessary for multiple wearable sensors to communicate with an external computer (such as a mobile phone) that can receive the sensor data and automatically classify certain events based on a pattern-recognition or machine-learning algorithm in order to provide some type of real-time intervention in the form of an alert, message to the user, or a text message to a remote caregiver. In this case real-time wireless connectivity is essential.

D. Bluetooth

Certainly for mobile phone applications, bluetooth connectivity is preferred, and Bluetooth radio modules (e.g. Roving Networks) are readily available. Unfortunately, Bluetooth (Fig.3) has several important limitations including relatively high power consumption (50-100mW). Also the master-slave protocol only supports up to 7 slaves with one master node. An additional inconvenience of bluetooth is the handshaking required to establish the connection. If the radio signal is temporarily dropped (due to occlusion or multipath), the host (master) must explicitly re-establish the connection.

Fig. 3. Bluetooth.

Fig. 4. ZigBee

E. Zigbee (Fig. 4)

In cases where more than 7 sensor nodes are needed or when extreme low power is required, a different radio is used based on the IEEE 802.15.4 physical layer protocol. Since this protocol is ad-hoc and varies from peer-to-peer, a larger number of nodes can be supported [2]. The MAC layer protocol implemented in these radios enable them to move gracefully in and out of the local sensor network without breaking the flow of communications. Furthermore, these radios require less than 1 mW to communicate over a 30 meter range, which is perfectly adequate for mobile health applications.

If a PC is used as the base station, a USB receiver is employed to collect the data (Fig. 5). However, for mobile phone integration, we have designed a bluetooth hub (called PAN-HUB) which contains both an 802.15.4 radio and a bluetooth radio. The PAN-HUB essentially creates an 802.15.4 Personal Area Network (PAN) and then aggregates and relays the information to a bluetooth stream going to the mobile phone.

F. RFID (Fig. 5)

For certain applications, inexpensive passive RFID [2] tags can be used to identify people, places, and things.

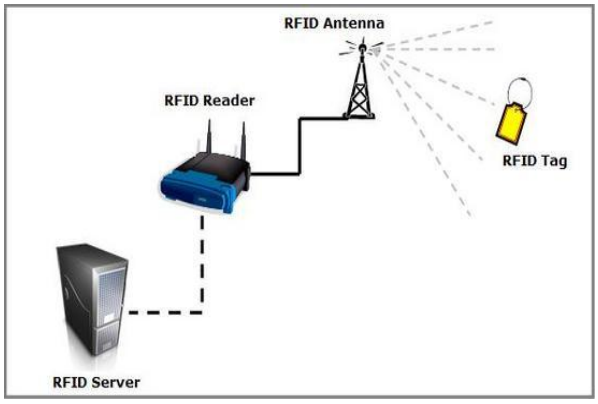


Fig. 5. RFID

More recently, we have explored the use of RFID tags as a wearable sensor for patient identification. In a study conducted in Karachi, Pakistan, RFID ankle bracelets have been used as a means of automatically identifying infants in large pneumonia infant immunization program. To date, the technology has successfully been used to track more than 2000 infants over the course of two years in 26 clinics in the study area. For the purpose of the study, special mobile phones were used which contained an embedded RFID NFC reader (Nokia E61) [3].

II. Methodology

New technologies facing ongoing challenges have emerged to support health monitoring and telemedicine. Many challenges still remain before this technology can find widespread use. A few of these are discussed below.

A. Differences in Objectives

The discussion of mobile health technologies and telemedicine is often clouded by the existence of many

competing technologies and different design objectives. Even among a single common platform, there are different opinions regarding how the system should be used. An engineering team, for example, may prefer to compress the data and use low-duty-cycle transmission in order to save power; the clinical team, on the other hand, would prefer to see large amount of data collected at a high sampling rate in real-time exercise. Since the clinical use of these sensors will vary greatly, there is a need for wearable sensors that can be easily programmed or reconfigured by the end user.

B. Power Consumption

Long continuous monitoring would require creative system design as well as commercially available solutions.

1) Fashion and alternative paradigms for computing

Any spectator of a Lady Gaga performance has witnessed the phenomenon of wearable technologies in fashion via her "living dress." Here the LED [3], [4] often reigns supreme.

Female technologists looking for avenues to increase girls' participation in the tech sector are building on this concept through the development of fashionable wearables. *Bitch* magazine [4] recently ran an article highlighting a number of these initiatives and websites, including blogs such as Fashioning Technology, switch, Electric foxy and talk2myshirt.com as well as the Arduino microcontroller board designed specifically for fashion-oriented wearables, Lily Pad Arduino. The fashion space has tremendous potential and our list is far from exhaustive. Here are a few of the more interesting initiatives:

Cute Circuit (Fig. 6), the London-based Fashion design firm, bills itself as a pioneer in the field of interactive fashion and the use of wearables with smart textiles and micro electronics. It is the developer of the Hug Shirt, which can give and receive hugs via mobile phone and which *Time* rated as one of the best inventions of 2006 [4]. The shirt is a Bluetooth accessory for a Java– enabled phone that sends a signal from the shirt's sensors to the phone, which triggers a text message.

Fig. 6. Cute circuit

Fig.7. Electric foxy

Fig.8. Pulse health monitor.

Electric foxy [4] (Fig. 7) has a number of interesting wearable-computing technologies that rarely make the list of mobile and sensor technologies in mainstream blogs. The 'Move' garment uses gentle signals to lead the user to adopt the right movements in anything from yoga and gyrates to dance performances or physical therapy.

Pulse (Fig. 8) is a heart-rate monitor in the form of a ring that connects to the smart phone via an app to help you stay in the right target zone for the workouts. Ping is a fashionable garment that contains a sensor in the shoulder that "pings" the user when a message is received from a connection on Facebook.

Lily Pad Arduino has recently become the focal point of an MIT research group called High-Low Tech that has created a computational-textiles curriculum to teach students how to build gesture-recognition gloves and other technologies that can bring the wearable-computing idea to mainstream audiences[5], [6].

Other programs include soft circuits and adhesives.

One MIT Lily Pad user created a jacket that displays a turn signal useful for cyclists. The other data point of importance about fashion and wearables is the success of the Pebble and Kickstarter.

Pebble is a concept for rethinking the watch to work with the iPhone to receive text messages, among other things [5], [6]. In a short time the Pebble has broken records for Kickstarter in the amount of money raised i.e., over 7 million in a matter of weeks. The growing consumer demand and the potential application spaces for wearable computers and platforms could make these devices a significant growth market in the coming years.

2) The intersection of wearables, gaming and entertainment

On the border of emotional sensing and fashion, a new domain is using sensors in clothing to detect and display emotions or states of being [5], [6].

Philips has developed the Emotions Jacket, which explores the connection between emotions and touch. The jacket is used in conjunction with a DVD of a movie to create linkages between the user of the jacket and the emotional content of the movie, in order for the viewer to experience part of what the character on-screen is feeling [6]. The jacket is being developed explicitly for use in the entertainment sector to create more aligned and immersive experiences.

The Design Research Lab's Skintimacy project features, a skin-based wearable used for musical collaboration. The technology has been developed to make a more inter - personal musical experience as well as to facilitate the development of alternative digital musical instruments. On the interactive side, the goal is to enhance intimacy through sound and explore how the boundaries of intimacy can change with computer-generated music and interpersonal touch.

TN Games has created a heavy-duty vest called the 3rd Space that enables the user to have more-realistic gaming experiences and actually feel gaming characters' sensory experience such as kicks, stabs and g-forces [5], [6].

Fast Company writes of wearables as the new "fifth screen" in the advertising space, owing to which advertisers will be able to utilize both high-involvement and low-involvement

types of advertising [5]. In the article, Kit Eaton argues that with the rise of wearables everyone will be competing for consumers' attention on the fifth screen (the other four screens being the TV, PC, smart phone and tablet). The difference is that wearables are potentially with the user all the time. Furthermore, the range of advertising modalities is a new paradigm for the advertising industry that will require more advanced understandings of behavior. A new platform, more data and perhaps raising more controversy? The question will be whether consumers find new forms of advertising or useful and entertaining or just another nuisance that contributes to an information overloading.

3) Augmented reality in wearable technologies

The growing field of augmented reality opens up many possibilities for the use of wearable technologies. The Mobile Individual Measurements of Air Quality project, or MIMAQ, is an interesting example that illustrates the possibilities well. The project uses mobiles and mobile sensors focused on the individual's surroundings rather than the usual government air-quality measurements to provide real-time pollution indicators. These are sent to the user via augmented-reality wearables and also compute averages over time. The information is displayed on the phone for the prototype but could readily take advantage of the eyeglass platforms in the emerging wearables market.

Oakley has been developing glasses, or heads-up-display technology, that can project data onto lenses, along the same lines as the Google Glass project. *DARPA* is also collaborating with Lockheed Martin on next-generation holographic glasses that can overlay battlefield data in the wearer's line of vision.

There are many existing applications that can provide insights into where AR apps and wearable technologies may go, including Augmented Car Finder, which helps users find their car in parking lots, and Twitter 360, which shows where people around you are tweeting from.

Fig. 9. AR Apps

Omron has developed AR apps (Fig. 9) that instantaneously translate signs or menus from foreign languages [6]. Aurasma is "the world's first visual browser" designed for the iPhone and iPad. It allows the user to find location-specific data on points of interest as well as create AR apps that function within the Aurasma environment. One of the key drivers of wearables is the release of *Bluetooth 4.0*, which uses less power and can instantaneously pair with devices. Bluetooth 4.0 is also a boost in the health market, due to connectivity with medical devices and greater use with bracelets and watches, which are rapidly becoming important device platforms in the fitness and body-monitoring spaces.

NFC (Fig. 10) or near field Communication will likely play a growing role in wearables too, as it becomes a more common place technology used in mobile-money applications and services [5]. There is already talk of embedding NFC technology in wearable devices so users can pay for movie tickets, subway tokens, sporting events and a latte at Starbucks without even pulling out a card or phone. This has provided consumers' trust in the technology to handle their financial transactions.

Fig. 10. NFC

4) Companies to watch

Microsoft is a major player in this ecosystem, and with devices such as the Kinect there are tremendous opportunities for wearables to alter the gaming industry [6]. Microsoft has recently patented a wearable technology called the electromyography-based controller that would allow users to control smart phones, Xboxes and many other devices. Given the evolution of the Kinect and the growing number of user-led innovations, this could make for a promising platform for wearables in the future.

Fig. 11. Run keeper

Others think Apple risks falling behind in the wearables race. This is supported by a view that Apple took the lead originally with the iPod, but despite integration with Nike+ it will need to make far more than watches and lightweight wearables to remain competitive. Forrester[/] sees the major platforms building partnerships with the apparels industry over the next few years, and the major platform players building partnerships with a parallel industry over the next few years. Follow the script from the mobile space.

According to Forrester, the scenario will likely unfold as follows: Apple will first create an early ecosystem, followed by Google developing a more open ecosystem via Android (provided Android's fragmentation doesn't become a hindrance) [6]. Microsoft will follow with an anti platform based on open-web standards that tries to offer more flexibility than Apple's and Google's platforms. In the health

space, a major segment of this platform that dominates across the fitness app, personal-health-record and self tracking spaces.

Run Keeper (Fig. 11) is becoming the Health player in the fitness space, and it remains to be seen if any major player can assume a substantial integrative or aggregator role for health data market. We may see a cast of characters that combine big data analytics with wearables.

III. Discussion

In this paper there has been a vast discussion of wearable sensors and the technology that could be used on a large scale in the upcoming centuries or decades. Every company is competing in the area of wearable sensor technology. The invention of various wearable sensors has been in large effect and would shape the future of the upcoming era in a well defined and precise way. The wearable sensors have a large way relation with the health issues and its treatment in various areas of medicine and health. Thus it has shaped and linked the area of medicine and technology on a regular basis.

IV. Conclusion

Wearable sensor technology has been recently shaping the area of medicine in a variety of ways. There is need for developing those sensors that would shape the way of technology in a different way. Companies are vying with each other in the area of wearable sensor technology invention and manufacture thereby affecting the lives of people in every aspect. Thus to conclude, sensors need to be developed that could cure those diseases which still cannot be cured.

In addition there is a need for effective shaping of the present technology.

References

[1] P. Bonato, "Wearable sensors/systems and their impact on biomedical engineering," *IEEE Eng Med Biol. Mag.*, vol. 22, pp. 18-20, 2003.
[2] R. Picard, "Future affective technology for autism and emotion communication," *Philosophical Transactions of the Royal Society B: Biological Sciences*, vol. 364, no. 1535, pp. 3575-3584, 2009.
[3] T. Gao, T. Massey, L. Selavo *et al*., "The advanced health and disaster aid network: A light-weight wireless medical system for triage," *IEEE Trans Biomed Circuits Syst*, vol. 1, pp. 203-216, 2007.
[4] C. Scanaill, S. Carew, P. Barralon, N. Noury, and D. Lyons, "Lyons G: A review of approaches to mobility tele-monitoring of the elderly in their living environment and opportunities and challenges for low cost-health care," *Annals of Biomed Engg,* vol.34, pp. 547-563, 2006.
[5] F. Wilhelm and W. Roth, "The somatic symptom paradox in DSM-IV anxiety disorders: suggestions for a clinical focus in psychophysiology," *Biological Psychology*, vol. 57, pp. 105-140, 2001.
[6] J. Ranck, *The Wearable Computing Market*, A Global analysis, 2004.

Usman Ahmad Usmani was born in Aligarh, India, April 1993. He is currently a btech computer engineering 3rd year student at the Aligarh Muslim University, Aligarh. He did his 12th class from A.M.U with a percentage of 77% and did his 10th class with a percentage of 89.4% from CBSE His is area of research interests are programming, computer security, wearable sensors, internet security, web programming, cloud computing. He attended the 4G Technology Workshop at the International Conference IMPACT in the Department of Electronics, A.M.U.