Exploring the User Requirements for Wearable Healthcare Systems

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Abstract—**Wearable healthcare systems are a promising and topical area, which opens up new potentials in health and fitness. Like any other information and communication technology in its infancy, one of the major problems concerning these systems is the user acceptance. The aim of the paper is to include the notion of user-centered systems design in the context of wearable healthcare systems. Among various factors affecting user acceptance, this paper discusses eleven critical user requirements that wearable healthcare systems should satisfy.**

Keywords-healthcare, smart clothes, user experience, user requirements, wearable systems

I. INTRODUCTION

In recent decades a dramatic increase in participation in various sorts of sport activities, as well as an increasing interest in health and fitness, has opened a new market for wearable healthcare systems. A growing attention has been attracted to this area in both research and business communities. Although extensive research is being drawn by the promising and potential future of wearable healthcare systems, this new technology has not yet established a stable market. It did not realize its goal of providing low-cost nor ubiquitous healthcare services, either

According to Donald A. Norman [1], the three dimensions of technology, marketing, and user experience are all crucial for a technological product to score a success. In particular, a cutting edge technology alone is not enough for user acceptance or mass acceptance. While a new technology, e.g. a disruptive technology [2] including wearable healthcare systems is at the initial phase welcomed only by early adopters who are creative and innovative minority, it should gradually gain average users' acceptance [1][3]. In this respect, user experience is eventually critical. At this point, however, researchers have primarily focused on technological aspects for wearable healthcare systems, while paying little attention to user experience pertaining to convenience, user-friendliness, and even pleasure. Recognizing the need for user experience studies, we would like to explore the user requirements of wearable healthcare systems as a very first step, which is also one of the critical issues in health related applications.

The following section of the paper explores this rarely studied area of wearable healthcare systems, discusses features of wearable health systems, and analyzes fundamental user requirements for a successful user experience and application in real-life situations.

II. USER REQUIREMENTS FOR WEARABLE HEALTHCARE SYSTEMS

The development and evaluation of a wearable healthcare system need to take into numerous considerations in order to satisfy the user needs. Some of the most important ones are discussed below.

A. *Wearability*

The demands of the body must be satisfied, because wearable systems use the human body as the support environment.

First of all, the system should have the features of low weight and small size to be easily carried or worn. Although advances in technology like integration and miniaturization promote the possibility of small, light and discreet devices, many existing systems cannot be considered truly wearable in the strict sense because the size of sensor, battery and on-body electronics are still bulky [4]. Clothing integration of these components is considered an efficient alternative solution [5].

Secondly, the system should also ensure a noninvasive, stable and comfortable placement on the human body. Under the premise of being able to collect desired biosignals, the system should not hinder the body's movement or balance and enable a comfortable experience. For example, the sensors should not cause any skin irritation or allergies to the user and also there should not be any unwanted radiation or infection concerns when the system is used continuously [6]; and an adjustable attachment system may be a good choice to accommodate various physical sizes.

In addition, secure and fitted attachment should also be provided in order to prevent the artifacts caused by relative motion between the system components (e.g. sensors) and the human body. For example, single point attachment such as clips may cause the obtained biosignals (and hence the results) to be unstable and unreliable.

Thirdly, the system should not severely affect the user's appearance [5]. Culture and in-use context will guide shapes, materials, textures, and colors that fit the user and their environment..

B. Interactivity

The traditional WIMP (Window Icon Menu Pointer) metaphor assumes that the interaction with the computer is the primary task. However, the operation of wearable systems should be understood differently from such a primary task, because the user is often distracted by the environment [7]. If possible, therefore, wearable systems should have the ability to provide a range of services with little involvement of user interaction.

This small quantity of user interaction needs to be consistent and compatible with the user's values, beliefs, and needs. It should also be performed with minimal cognitive effort of the user, i.e., simple and intuitive interface. For example, instead of having the user select a function from a complex hierarchy of menus, the system might derive the two most likely options and present the user with a simple binary choice [8].

Furthermore, a hand-free interface (an interface that the user controls without hands) such as speech recognition and speech synthesis, may make the system even more applicable and acceptable.

C. Security

The user's status information and personal medical data have to be protected and are forbidden to be disclosed to anyone except the system wearer and supervising physicians.

This necessitates the deployment of appropriate security and privacy solutions, which mainly focus on data transmission and storage. Since security support is additional requirement, it can reduce overall usability of the system. Considering that personal medical information is very privacy-sensitive, however, we have to take it seriously.

For example, mechanisms such as fingerprint scanner can be adopted to authenticate the identity of the wearer; secure links including sensors to the system's central node communication and wearable systems to base station transmission should be established and maintained; stored data and data in transit can be encrypted and the authorization to access these data should be controlled [9].

TABLE I
BIOMEDICAL SENSORS AND BIOSIGNALS

Biosignal	Sensor	Description
Electrocardiogram (ECG)	Skin/Chest Electrodes	Electrical activity of the heart
Heart rate	Pulse Oximeter/Skin Electrodes	The rate at which the heart beats
Phonocardiogram (PCG)	Stethoscope	Sounds and murmurs made by the heart
Blood oxygen saturation (SpO2)	Pulse Oximeter	The amount of oxygen that is dissolved or carried in a person's blood
Blood pressure	Cuff-based monitor	The pressure exerted by circulating blood upon the walls of blood vessels
Respiration	Piezoelectric/ piezoresistive sensor	The bodily process of inhalation and exhalation
Electromyogram (EMG)	Skin Electrodes	Electrical activity produced by skeletal muscles
Skin conductance	Galvanic skin response	The amount of skin's resistance to electricity due to sweat gland activity
Body/skin temperature	Temperature probe or skin patch	Heat change of the body
Electroencephalog ram (EEG)	Scalp-placed electrodes	Electrical activity generated by the brain
Physical activity	Accelerometer	Acceleration generated by motion

D. Sensing capabilities

Noninvasive biomedical sensors play an important role in the design, development, performance and acceptance of wearable healthcare systems. The measured biosignals from these sensors and the extracted physiological parameters can provide a comprehensive estimation and evaluation of the wearer's health condition. The common available biomedical sensors and corresponding biosignals measured [10] are summarized in Table. I.

E. Effectiveness

Systems may encounter numerous unexpected difficulties when using in the real-life situation. For example, high biosignals noise, measurement artifacts due to user movement and displacement/bad contact of sensors with the skin, low connectivity, low battery etc. Therefore the system is required to perform well and robustly under all circumstances.

The measured biosignals should achieve high accuracy and low distortion, and the results produced by the system should have a high degree of reliability and hence be trustable by the professionals. It means the performance of the in-use system should reach clinical effectiveness and the result should be the same to those obtained by traditional methods or at least acceptable to the user. For example, the ECG obtained using a wearable healthcare system should provide reliable and acceptable quality and accuracy as that obtained by a regular ECG system [6].

F. Real-time processing

The ability to transmit and process the obtained data in real-time has many advantages which can raise the user acceptance of the system. The wearer can see the result display without delay. He or she can be aware of the health or body state real-time. And the convenience of transmitting the monitored data from anywhere to the physician or a hospital also provides higher degree of security to the user which may not be possible with a traditional system.

Emergencies can be detected and handled in time which could be lifesaving. In particular, the vital sign data obtained real-time such as ECGs, respiration, and the like can play a crucial role in this context. However, this enhancement of the computational power will also increase the complexity and development cost of the system.

G. Decision support

Even if physiological measurements and other general health-related data can be provided to the physicians, they still need to tediously read a large amount of data to investigate the health status of the wearer which could be time and money consuming. Then, a decision support system including essential analysis of the data can aid the physician in identifying and addressing health problems at the moment of occurrence. Such intelligence can be very helpful for the acceptance and implementation of wearable healthcare systems.

The system should provide algorithms to extract higher level of information or knowledge from raw biosignals measurements. The extracted physiological parameters, the wearer's context and activity level coming from different sensors can be integrated to provide a more comprehensive picture of the wearer's health state and suggest the timely and appropriate medical diagnosis and treatment. The system can also detect alarm based on sensor measurements that may indicate a health hazard, e.g. reporting values that exceed predefined safety thresholds [12].

H. Communication

A wearable healthcare system is part of one or several networks. Short and long range communications are both involved, which can be classified into two categories: 1) communication for the measured biosignals from the sensors to the system's central node; and 2) communication for the measurement collection from the wearable healthcare system to a remote medical station or to a physician's hand-held device [10].

The first type of transmission belongs to short range communication which can be addressed either by wire or by wireless technology. Considering the wearability requirements of the system, the combined usage of conductive yarns or digital yarns in textile clothes and wireless technologies (e.g. Bluetooth and Zigbee) in nontextile wearable systems are efficient solutions.

For long range communication, i.e., the second type of transmission, wireless technologies like GSM and GPRS are common solutions. They can support a wide coverage and sufficient network anywhere to connect the wearable healthcare system to a remote base station.

In addition, technical standardization and protocols are also required. They can enable structured and open communication and hence satisfy the interoperability demand. This will eventually benefit the cooperation among possible stakeholders [10] [13].

I. Power Supply

Power management is another crucial consideration when we design a wearable healthcare system. Here, low power consumption does not only contribute to extended peration time, but also to system miniaturization. This is primarily because for most ambulatory devices developed, the power supply takes up about half of the size and weight of the system [14].

There should be a trade-off rather than pursuing ideal design because the power consumption of a system depends on many factors including system capacity, the operating system employed, board and modules used, and the physical environment that the unit is exposed to [10].

Rechargeable lithium ion batteries have been the standard power source for wearable systems [10]. However, many innovative technologies like energy harvesting (e.g., from body movement or body heat), low-power transceivers and improvements in battery technology are promising solutions for energy supply of wearable healthcare systems.

J. Scalability

The Plug-and-Play (PnP) is an ease-of-use paradigm in personal computer market, which allows the installation of new hardware without user intervention. Introducing this concept into the field of wearable systems can improve the scalability and reconfigurability of the system and hence improve the system applicability and user acceptance. Though it is not so easy to realize it technically, the PnP paradigm is urgently requested for the sake of convenience.

For example, the ability of supporting the addition (or removal) of sensors during runtime can be very useful in adapting the changeability of user demands; an upgradable system may have longer lifetime; and software that can adapt to the environment in which it is deployed can optimize the use of available resources and hence reduce the power consumption.

K. Validation

One possible question that the user may raise is whether the system can provide meaningful and accurate observation and medical diagnosis or not. Therefore, the system validation becomes an important concern and its outcome can give strong support in convincing such stakeholders as wearers, care-givers, physicians, and so on.

Experiments using standard medical equipments must be carried out together with the use of the developed system to demonstrate its validity and practicability. However, full clinical validation of wearable healthcare systems is complex in nature, and sometimes time and resource consuming. Therefore, one efficient approach is to test the possible clinical scenarios with respect to normal and abnormal medical values, i.e., diagnostic tests (where a disease is suspected) and screening tests (where there is little or no evidence that the person has the disease) [15].

III. CONCLUSION

This paper has explored the major user requirements in order for wearable healthcare systems to become efficient and applicable health-related solutions in real-life situation. In summary, a wearable health system should be lightweight, ease-to-use, secure, effective, reliable, low power consuming, scalable, cost-efficient, of embedded intelligence, and able to keep connection with a remote medical station. These numerous and sometimes conflicting features of wearable health systems do not only inform the design and development process, but also indicate the difficulties to resolve in a near future.

Despite various considerations and challenges still need to be addressed to become more practical to suit real-life scenarios and gain user acceptance, it is expected to enable a new generation of health management and disease treatment. While admitting that technological improvement should be equally stressed, and process oriented information and design related approaches are requested to some extent, we hope that the paper will help the design and development process from user perspectives.

REFERENCES

[1] D. A. Norman, *The Invisible Computer: Why products Fail, the Personal Computer Is So Complex, and Information Appliances Are the Solution*. Cambridge, MA: MIT Press, 1999.

[2] C. Christensen, *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*. Cambridge, MA: Harvard Business School Press, 1997.

[3] G. J. Dickelman, "Information appliances and performance support," *Performance Improvement*, Vol. 38, No. 7, 1999, pp. 33-37.

[4] Chulsung Park, P. H. Chou, Ying Bai, R. Matthews, and A. Hibbs, "An ultra-wearable, wireless, low power ECG monitoring system," in *Conf. Biomedical Circuit and Systems*, London, 2006, pp. 241-244.

[5] A. Pantelopoulos, and N. G. Bourbakis, "A survey on wearable biosensor systems for health monitoring," in *Proc. 30th Annu. Int. Conf. Engineering in Medicine and Biology Society*, Vancouver, 2008, pp. 4887-4890.

[6] Sungmee Park and S. Jayaraman, "Smart textile-based wearable biomedical systems: a transition plan for research to reality," *IEEE trans. Information Technology in Biomedicine*, vol. 14, pp. 86–92, Jan. 2010.

[7] K.C. Andrea, A. Nuernberger, T. Pingel, and Du Qingyun, "User interface design for a wearable field computer," in *Proc. '02 Annu. Nat. Conf. Digital Government Research, Los Ang*eles, 2002.

[8] P. Lukowicz, T. Kirstein, and G. Troster, "Wearable systems for health care applications," *Methods of Information in Medicine*, vol. 43, pp. 232-238, 2004.

[9] S. Warren, J. Lebak, J. Yao, J. Creekmore, A. Milenkovic, and E. Jovanov, "Interoperability and security in wireless body area network infrastructures," in *Proc. 27th Annu. Int. Conf. Engineering in Medicine and Biology Society*, Shanghai, 2005, pp. 3837-3840.

[10] A. Pantelopoulos and N. G. Bourbakis, "A survey on wearable sensor-based systems for health monitoring and prognosis," *IEEE Trans. Systems, Man, and Cybernetics, Part C: Applications and Reviews*, vol. 40, pp. 1-12, Jan. 2010.

[11] J. Luprano, J. Sola, A. Ridolfi, S. Pasche, and O. Chetelat, "New generation of smart sensors for biochemical and bioelectrical applications," *Proc. pHealth Conference*, Porto Carras, 2007.

[12] A. Pantelopoulos and N. G. Bourbakis, "Prognosis - a wearable health-monitoring system for people at risk: methodology and modeling," *IEEE Trans. Information Technology in Biomedicine*, vol. 14, pp. 613-621, May 2010.

[13] A. Lymberis, "Research and development of smart wearable health applications: the challenge ahead," *Studies in Health Technology and Informatics*, vol. 108, pp. 155-161, 2004.

[14] F. Axisa et al., "Flexible technologies and smart clothing for citizen medicine, home healthcare, and disease prevention," *IEEE Trans. Information Technology in Biomedicine*, vol. 9, pp. 325-336, Sept. 2005.

[15] A. Lymberis and A. Dittmar, "Advanced wearable health systems and applications - research and development efforts in the European Union," *IEEE Engineering in Medicine and Biology Magazine*, vol. 26, pp. 29-33, May-June 2007