Volume 7, Issue 4
August 2018

ITEE Journal
Information Technology & Electrical Engineering

ISSN: - 2306-708X

Applications of Wearable Technology - Opportunities and Challenge

Fazal-e-Amin
College of Computer and Information Sciences
Department of Software Engineering
King Saud University
Riyadh, KSA
famin@ksu.edu.sa

ABSTRACT

Recently, wearable technology or Smart Wearable Systems (SWS) become popular and gained attention from both industry and academia. SWS are being used in industries, healthcare, sports, education etc. Researchers and manufacturers are making continuous efforts to improve the quality of these systems. Wearable technologies have a potential to improve practices in many disciplines such as healthcare, education, security etc. In this paper, a review of SWS is conducted to discuss their applications, development platforms, technical requirements and their comparison, issues of wearable networks, challenges, and opportunities related to these aspects. It will help researchers, SWS designers, and developers to better understand this technology and to evaluate available solutions.

Keywords: *wearable technology, wearable applications, smart wearable system, wearable technology education/learning, wearable challenges, wearable review, WBAN*

1. INTRODUCTION

Research and development endeavors of Smart Wearable Systems (SWS) have been increasing rapidly in both industry and academia [1-3]. Wearable systems are electronic devices that can perform functions as a computer and can be appended to the body, carried or worn like clothes. Wearable systems can be of three forms [4]; computer/information machine that can be worn, wearable information appliances and computer as clothing. Three main wearable product types [5] include; smart watches, smart glasses, and body sensors. SWS have the capability of independent sensing, processing, communication and monitoring of people anywhere and at any time [3].

Wearable systems consist of a set of diverse modules that contains an input module, the main module, and an output module. The user uses the input module of the wearable system that translates the magnetic, thermal, mechanical and chemical signals into electrical signals by sensors or transducers. The main module usually consists of a processor, software, and memory. It provides the functionality of data processing. The output module provides the duty of monitoring the system and it is responsible for the transformation of the electrical signal into magnetic, thermal, mechanical or chemical signals [6].

According to recent research by International Data Corporation (IDC), wearable shipments volume exceeds 19 million units in 2014 that is three times more than last year's sales. The global market will climb to nearly 111.9 million units by 2018[7]. According to a survey about the use of wearable in enterprise conducted by Tech Pro Research [8] in April 2014, 54% healthcare sectors and 38% educational sectors show their interest in the use of wearable technology.

The adoption of this technology in educational sectors is significant due to rapid growth and availability of new wearable devices in the market. The education sector is in the beginning phase of implementation of this technology to enhance the quality of education by keeping in view the enormous potential applications of wearable technology [9]. In the higher education sector, productivity is one of the most undeniable prospective of wearable technology. In learning/education context wearable technology provide services [10] which include; extension of classroom beyond its physical position, location sensing facilities, and communication with teacher or learner beyond the boundaries of learning center.

Wearable technology also has features to provide flexibility to the learner in terms of where they like to study. One of the advantages of adopting this technology in the educational/learning environment is that it promotes collaborating and sharing with other peers [11]. Wearable gadgets like wrist computers make students capable to interact with a verity of data in more casual and differentiate manner. The functionality of GPRS and GPS in wearable devices can provide information about the location of the learner and it can also help in addressing massive learner groups together remotely [10]. In the education sector, this technology can enhance the child's ability to interact with the educational environment in a more natural and innovative way [12].

The educational and social advantages of mobile and wearable devices include enhanced flexibility for the learners by facilitating them to learn anywhere and anytime according to selected academic models. This technology also has benefits for part-time, distance and long life learners in terms of collaborative learning between locally based groups and disparately located groups. Further, in this paper, the applications of wearable technologies are discussed in the context of different areas such as education, health, sports, business and industries, security, and military.

This paper organized as following; in section 2 methodology of review is presented. In section 3, applications of wearable technology are discussed. In section 4, the challenges of wearable technology are presented. In section 5, wearable system network and challenges to WBAN are

highlighted. In section 6, operating systems and application development platforms of wearable systems are discussed.

2. METHODOLOGY

A literature search was performed for the articles by using databases include IEEE Xplore, google scholar, science direct and some related web pages that are written in English and published from 2001 to 2015. The keywords used for literature search include; wearable technology, wearable systems, wearable applications, smart wearable system, applications, wearable technology education/learning, wearable technology challenges, WBAN, wearable operating system, and wearable review. These keywords were used alone and in combination for the initial collection of research material. Only those articles that contain applications or challenges of wearable systems in different domains, especially in the field of learning/education, were included in this review. In addition, wearable operating system, application development platform and challenges to the wearable network were also reviewed.

A list of wearable system/devices with its domain and applications is presented in table 1.

3. APPLICATIONS

In this section various applications of smart wearable systems are presented.

A. Learning and Education

Wearable technology brings the revolution in the learning and education field. Wearable devices are considered to be an effective tool for research because of sensors that provide functionality to track data in real time. It can send information in form of email, text, audio, video and other indicators that can help educators and students to communicate with each other and keep the record of the latest activities [9]. In education sector this technology can also be used for orientation of new students, displaying learning material during lectures, record lectures or presentations, remote tutoring, taking attendance, record practice videos and close up viewing of lab demos [13].

In [14], a study was conducted on the utilization of smart wearable watches in the educational sector and found that this technology can improve learning outcomes and allow students to get the education in more flexible and comfortable environment. In [15], the role of iPod in education was highlighted and found that it is an effective learning tool that can enhance students thinking and creativity level about their subject matters. This technology can also offer collaborative learning and other key learning objectives for higher education institutes can be achieved.

Google Glass [16] is a wearable web-connected optical head-mounted display (OHMD) device. In the educational sector, medical students can use Google Glass to watch medical events in the real-time environment. It allows students and teachers to share information in various modes of interaction and students can wear this to record themselves in solving problems. It can also help students and educators to record videos, search, take pictures, answer questions and convert voice into foreign languages.

Muse [17] is a wearable wireless headband that can sense brain activity or fitness level. In the education sector, this device can display brain activity of learners directly on a tablet or smartphone via a wireless interface. This feature can provide help to detect what activities are required to keep students focused on study. Muse can also provide help to teachers by measuring the brain waves of students during working on some important projects.

Autographer [18] is a wireless wearable camera with sensors that help learners or students to capture direct photographs of instructor notes. This functionality allows students to get accurate information from their teachers. Keyglove [19] is a wearable open source wireless input device that is useful for data entry, design, art, music, device control, and 3D object. This device is the best option to facilitate single-handed tasks and this feature is also useful for disabled or handicapped students.

Virtual Reality (VR) [20] is a wearable head-mounted device that can provide the opportunity of hands-on experience to students to interact with desired objects in the virtual environment in order to increase their knowledge or discover more about them. VR can also present multifarious data to students in an accessible way which is easy to learn. GoPro [21] is a unique and interesting wearable camera device. In the learning/education sector this device can capture teachers or students point of view of events such as to record the lesson, student behavior, instructions recording and explore new possibilities. This device can also helpful for teachers to observe the behavior of students in order to make more informed educational and academic decisions.

B. Healthcare

The research interest in finding new healthcare solutions is growing with time to manage, support and provide care to patients anywhere at any time [22]. In healthcare sector wearable technology is commonly used for vital signs monitoring, vivo/implants, chronic disease management, brain/eye movement etc. SWS are used to monitor patient's condition 24 hours a day without concerning their physical location. The monitoring system is usually connected to an assistance center, where transmitted parameters from wearable device monitored or recorded continuously. Assistance centers can also provide help if required. In [23], a textile-based sensor (Biotex) was introduced to measure the chemical composition of body fluids with a particular focus on measuring sweat.

In [24], a wearable system was introduced for vital sign monitoring and to determine the cardiopulmonary commotion during emergencies. In [25], a multifunctional device was introduced for the monitoring of physical activity and heart rate. ‘Smart Vest’ based system [26] was introduced for PPG, ECG, heart rate, systolic and diastolic blood pressure monitoring. This system transmits the patient information using RF link to remote monitoring station along with the location of the patient or user. A self-monitoring wearable system ‘Glucowatch Biographer' [27] was designed to measures blood glucose through extraction of transdermal fluid and ‘microwave sensor' [28] based on microstrip ring-

resonator was introduced for accurate measurement of blood glucose level.

A shoe based system [29] consists of force-sensitive resistors (FSR), gyroscopes and accelerometer were developed for identification of human gait characteristics. In which data fusion algorithms processed the sensor data within a microprocessor. Some examples of wearable devices used for health care include; wireless EEG headset, hearing aid devices, biofeedback patch, and ingestible sensors.

C. *Sports*

In the field of sports SWS plays an important role. These wearable systems are widely used for sports performance evaluation, fitness monitoring, outdoor tracking/navigation, body cooling/heating measurement, virtual coaching etc. Body kinematics and physiological signs during exercise could be accessed by athletes and coaches with the help of wearable sensors. This can be helpful to track improvements of an individual athlete in sports performance and to understand and analyze how athlete body responds to specific exercise [23].

A real-time wearable system [30] for car racing teams was designed to determine how the driver reacts during simulated circumstances or to monitor the racing driver's emotional state. A wearable golf swing training system [31] was designed to capture the movement of the golf swing and to provide golf swing training. The system was also able to provide feedback on wrist rotation and quality of movement for purpose of golf training.

Wearable chemical sensors have been introduced to monitor the body fluids such as blood, tears, urine, and sweat of players for the different type of tests [32]. A real-time snowboard system [33] consists of on-body wireless sensors was introduced to detect common mistakes during snowboarding and provide immediate guidance to students that how to correct their mistakes. The system was consisting of different sensors that were used to analyze rider posture and motion on a snowboard.

Some popular wearable sports products include; activity tracker band, smart training shoes, heated clothing, bio-harness, and smart sunglasses.

D. Industry/Business

Wearable systems are helpful to improve business and industrial applications due to significant growth of wearable devices as well as an enhanced interface between the device and user [34]. In industrial/business operations these systems are commonly used in logistics for stock management, knowledge sharing, information access, customer services, and access control.

A context-aware wearable system [35] was introduced for the automotive industry to track out workers activities and give out in-time information about activities. Remote tech support, stock scanner, event ticket band, and hotel key band are some examples of wearable devices used in industry or business.

E. Security/Safety

The applications related to security or safety issues include emergency services, rescue/tracking, identity recognition, environmental observation etc. Commercially available devices like life alert classic [36] and Alertone medical system [37] are well-known examples of wearable systems used for safety monitoring purposes. These devices contain push button on them that generates an alarm message in emergency situations.

Hovding [38] is collar is worn around the neck that is controlled by accelerometers, sensors, and gyros in order to protect the head. It contains airbag shaped like a hood, airbag pump up and surrounds the head in abnormal movements and if an accident occurs. Some popular wearable devices used for security/safety purpose include; trackable wallets, personal locator beacon, fall detection system and identity bracelet.

F. Communication

The wearable technology has a significant role in communication. This technology can provide the functionality of email, multimedia, voice mail and text messages for personal communication. Interactive groups can communicate through social media by using this technology.

G. Military

Military or armed forces use wearable technology to help soldiers on the battlefield. A wearable system [39] was designed to help the soldiers by providing the facility of navigation, reading maps, capture and transmit images, receive/send field reports and access battlefield activities.

A wearable motherboard [40] that contains integrated sensors and communication capability was designed to rescue soldiers by monitoring the status of their health in real-time.

H. Fashion

The role of wearable technology in the fashion industry has gained high interest from fashion industry manufacturers in recent years. A fashion company Cutecircuit [41] introduced dresses by the use of wearable technology that contains LED lights and reflective material for unique and special performances.

A fashion company Moon Berlin [42] designed outfits by integrating LED components into the fabric to create dynamic light and shadow effects in fashion shows.

I. Entertainment

A music player Jacket [43] was introduced that was compatible to attach a number of musical files and maintainability of music player. A Mi. Mu glove [44] has a feature that can turn the hands and arms of performers into musical instruments and facilitates the composition of music with gesture control. This glove is able to capture the hand posture, the direction of hand and flex of fingers.

4. CHALLENGES

Challenges to wearable technology and devices are presented in this section.

A. Power consumption

The high power consumption of wearable devices is a major challenge for wearable devices manufacturers. These devices use GPS, Bluetooth, wireless networks and other technologies that consume high power. Battery timing of these devices is not very long. For example, battery timing of "Google glasses" is just 4 to 8 hours during rigorous usage.

B. Privacy and Security

Privacy and security of wearable devices is another major challenge in acceptance of wearable technology and it requires serious attention of manufacturers. These devices provide the functionality of monitoring the activities of user all the time

ITEE Journal
Information Technology & Electrical Engineering

ISSN: - 2306-708X

that apparently challenges user privacy [45]. There is always a risk of catching user confidential data by some unauthorized third parties.

C. User's acceptance

Acceptance of new technology by users is only possible by providing a proper introduction of technology to the users. Any negative discernment of technology can cause a hurdle to its acceptance [46]. So the elimination of user concerns about wearable technology is a threatening challenge.

D. Cost

Cost of wearable technology devices is an important challenge for manufacturers. It's one of the key factors to gain this remarkable popularity. The cost of wearable devices needs to be decreased while functionality and reliability require improvement [47].

E. Design and weight

Design constraint and weight of wearable devices is a major concern and cause of discomfort for the users of wearable technology [48]. These devices should require minimum bulk and weight.

F. Educate Users

Wearable technology is a rising technology in both industry and academia, so it requires various new skills like analytical, creative, technical and interpretive to attract users. To develop these skills different organizations should need to introduce training programs. Moreover, educational institutes need to introduce courses on wearable technology.

G. Efficiency and reliability

Widespread use of wearable technology requires an efficient and reliable system. These systems must require efficient and reliable software and hardware [49].

H. Accessibility

Accessibility of wearable devices is another considerable challenge in the growth of this technology. If learning/education through wearable technology is to be implemented, then all educators or teachers must have access to wearable systems as a part of their training [50].

I. Technical limitations

Some important technical limitations to wearable technology include; small screen size, limited software, low bandwidth on wireless networks, and insufficient memory capacity [51]. Wearable manufacturers should pay serious attention to overcome these technical limitations.

J. Technical and material support

Technical and material support regarding learning/education context is also a serious challenge for the growth of this technology in educational institutes. Educational staff received negligible educational and technological assistance from higher education institutes with regards to effective implementation of this technology in educational settings [52].

Table1: wearable system/devices with its domains and applications

Domain	System Description/Devices	Applications	Ref
Education/Learning	Smartwatch	Learning outcome improvements	[14]
	iPod	enhance students thinking and creativity, collaborative learning	[15]
	Google Glass		[16]
	Muse	Medical experiment in real time, solving mathematical problems, voice conversion in a foreign language.	[17]
	Autographer	Learner's brain activity monitoring, brain waves during a study	[18]
	Keyglove		[19]
	Virtual Reality	Capture photographs of instructor notes	
	GoPro	Facilitate disabled or handicapped students, data entry and device control	[20]
			[21]
		provide an opportunity of hands-on experience to students to interact with desired objects in a virtual environment	
		record lesson, student behavior, instructions recording and explore new possibilities	
Healthcare	textile based sensor (Biotex)	measure the chemical composition of body fluids	[23]
	wearable system	Vital sign monitoring, determine the cardiopulmonary commotion during emergencies.	[24]
	Multifunctional device		[25]
	Smart vest		[26]
	Glucowatch Biographer	monitoring of physical activity and heart rate	[27]
	Shoe	PPG, ECG, heart rate, systolic and diastolic blood pressure monitoring	[29]
		Blood glucose measurement	
		Human gait characteristics	
Sports	Textile based wearable sensor	Track improvements of an individual athlete	[23]
	Real-time wearable system		[30]
	Wearable system	The reaction of the racing driver during simulated circumstances	[32]
	Golf swing system	Monitor player body fluid	[31]
	Snowboard system	Wrist rotation, golf swing movement, and	[33]

		training analyze rider posture and motion on a snowboard	
Industry/Business	context-aware wearable system	Track workers activity in the automotive industry	[35]
Security/Safety	Life alert Alertone Hovding	Safety monitoring Safety monitoring in emergency Provide security to head in case of an accident	[36] [37] [38]
Military	Wearable system Wearable motherboard	Provide assistance in the battlefield by navigation, reading maps, capture and transmit images Rescue soldiers by monitoring health status	[39] [40]
Fashion	Fashion clothing Outfit	Unique and special performances Light and shadow effect in fashion shows	[41] [42]
Entertainment	Jacket Glove	Music player The composition of music with gesture control	[43] [44]

5. WEARABLE SYSTEMS NETWORK AND CHALLENGES

Body sensor network (BSN) or wireless body area network (WBAN) is a wireless network that is used by wearable devices for communication [53, 54]. The WBAN standards of communication protocols that are defined by IEEE standards committee for Wireless Sensor Network (WSN) communications include; IEEE 802.15.1 (Bluetooth) [55], IEEE 802.15.3 (ultra wideband) [56], IEEE 802.15.4 (zigbee) [57] and IEEE 802.11 (Near Field Communication). Some other suitable wireless communication protocols for WBAN include Rubee, Z-wave, ANT, Zarlink, Sensium and RFID [58]. The characteristics of communication protocols used in WBAN are presented in Table2. Some of the important challenges that WBAN faces are discussed below:

A. Sensor validation

Most of the wearable devices use sensors for communications in WBAN. Validation of these sensors especially in healthcare sectors is extremely important that all sensors readings are validated. Sensor validation can be helpful to minimize false alarm generation and identify possible weaknesses within software and hardware design [59].

B. Interference

Large-scale implementation of WBAN systems requires minimum interference and high coexistence with other network devices that are available in the same environment [60].

C. Data Management

WBAN generates a huge volume of datasets, data management and maintenance of these huge datasets is an important task for this network [61].

D. Data Consistency

Data consistency in WBAN is another important challenge that needs to be addressed properly. There are lots of wearable devices that are connected to single WBAN at the same time. There is a need to collect and analyze data in a seamless fashion. There are chances that user data may be fragmented over a number of nodes and across a number of networked devices like PC's or mobiles that may cause degradation in network service.

E. Data Authentication

All the applications of wearable technology devices require data authentication. WBAN nodes require verification that data is sent from a trusted device [62]. In WBAN data authentication can be achieved by key exchange techniques.

F. Data Integrity

When data is transmitted to ensure WBAN then there will be chances that information can be altered. Therefore it needs to be assured that received data is not altered, data integrity can be achieved by using data authentication protocols [62].

G. Data freshness

Data freshness ensures that data frames are in sequence and not reused or replayed. In WBAN data freshness assurance is an important factor for collecting data from wearable devices. There are two common types of data freshness includes; (i) strong freshness; which guarantee that data is in sequence with some estimated delay (ii) weak freshness, which provides partial data frames ordering but carries no delay information. For both strong and weak freshness protecting the network from replay attack is a big issue [63].

Table 2. Characteristics of communication protocols used in WBAN

Comm. Protocol	Data Rate	Frequency	Coverage	Network Topology
Bluetooth 802.15.1 [55]	780 kbps	2.4 GHz	10-150 m	star
Ultra Wideband 802.15.3 [56]	110-480 Mbps	3.1-10.6 GHz	5-10 m	star
Zigbee 802.15.4 [57]	20, 40, 250 Kbps	868, 915 Mbps, 2.4GHz	10-100 m	Star, mesh, cluster tree
Near Field Communication	102, 212,424 Kbps	13.56MHz	Up to 20 cm	Peer-to-peer
z-wave	9.6 Kbps	900MHz	30m	mesh

Rubee [64]	9.6 Kbps	131 KHz	30m	Peer-to-peer
ANT	1Mbps	2.4GHz	30m	Star, tree, peer-to-peer, mesh
Zarlink	200-800 Kbps	402-405MHz, 433-432MHz	2m (in the body) only)	Peer-to-peer
Sensium	50 Kbps	868,915 MHz	1-5m	star

6. OPERATING SYSTEMS AND APPLICATION DEVELOPMENT PLATFORMS

The operating system is a set of software that manages the interface between hardware and software [65]. Operating systems for wearable devices has gone through years of development. Google launched an operating system for smartwatches called Android Wear. IBM launched smartwatch named WatchPad with Linux operating system. An American company Fossil designed a wearable device called wrist PDA by using Palm Open Source [66] operating system. Microsoft designed SPOT operating system for smart wearable devices. Samsung release wearable device called Galaxy Gear by using Android as an operating system then it introduces the second generation of smartwatches by using independently designed operating system Tizen [67]. Wearable operating systems should design with respect to features of wearable devices, so that following important objectives can be achieved [68].

A. Multitasking

The wearable operating system should be able to execute multiple programs or applications in parallel.

B. Convenience

The design of the operating system should be more convenient for wearable devices users.

C. Scalability

A wearable operating system should be able to develop and test new system functions.

D. Effectiveness

A wearable operating system should manage in such a way that it can take advantages to form resources like software and hardware.

E. Openness

To achieve portability and interoperability of different applications, wearable operating systems should support collaborative integrated network.

At present, there are many hardware design platforms for wearable devices. A development platform WICED (Wireless Internet Connectivity for Embedded Devices) [69] was launched by Broadcom to create secure embedded wireless networking applications. The WICED development kit can also provide functionality to integrate WiFi and Bluetooth into wearable devices. An open-source, scalable Wearable Reference Platform (WaRP) [70] developed by company Freescale with the collaboration of over fifteen manufacturers. The WaRP platform supports open operating systems such as Linux and Android with features like flexibility and scalability.

A number of software reference platforms contributes their efforts in order to accelerate software application development of the wearable market. A software developer kit (SDK) including an emulator and some tools for Android Wear [71] released by Google. Android Wear can allow developers to integrate this platform with their own applications and devices. Developers can also utilize all the tools that they need in the development of a new wearable application. Tizen is a Linux based open source operating system for wearable devices and mobile phones. It provides a full-fledged development platform for wearables including IDE, simulator etc.

7. CONCLUSIONS

Wearable technology is an emerging technology but it is not very popular in the education sectors as compared to other technologies like tablets. It is hard to determine whether students and teachers are ready to use this technology in classrooms. Educational sector authorities need to make it sure to provide professional training to teachers and relevant staff that how to manage learners and use effectively wearable technology in educational settings. In this study, the importance of wearable technology in learning/education with applications is highlighted. It can be assumed that wearable technology has the potential to drastically change the situation in the educational sector. This technology requires recommendations for revision of curriculum from educational boards in order to introduce this technology properly in educational sectors in near future.

Lack of application development platforms is one of the barriers to the growth of wearable technology. The available network communication protocols for wearable devices are mainly focused on wireless functions. Wearable devices need more and more functionalities like mobile phones, such as GPRS, WAP, large data transmission etc. However, this technology requires the formal attention of the research community and wearable manufacturers to make improvements in this technology. The future research direction identified in this research is to conduct studies in educational institute involving students and teachers to identify the factors resisting the use of wearable technology in learning and to suggest their possible solutions.

REFERENCES

[1] P. Lukowicz, *et al.*, "Wearable systems for health care applications," *Methods of Information in Medicine-Methodik der Information in der Medizin,* vol. 43, pp. 232-238, 2004.

[2] D. Konstantas, "An overview of wearable and implantable medical sensors," *IMIA Yearbook,* vol. 2, pp. 66-69, 2007.

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

[4] C. Baber, "Wearable Computers: A Human Factors Review," *International Journal of Human-Computer Interaction,* vol. 13, pp. 123-145, 2001/06/01 2001.

[5] A. Sheehy. (2014, *8 Mind-blowing Uses of Wearable Technology*. Available: http://www.futurestructure.com/8-Mind-blowing-Uses-of-Wearable-Technology-Seriously.html

[6] M. Chedid, "Wearable systems in harsh environments: realizing new architectural concepts," 2010.

[7] R. T. Llamas. (2014, *Worldwide Wearable Computing Device 2014-2018 Forecast and Analysis* Available: http://www.idc.com/getdoc.jsp?containerId=prUS24794914

[8] T. Hammond. (2014. Available: http://www.techproresearch.com/article/research-interest-high-in-wearables-despite-low-adoption-rates/

[9] L. Johnson, *et al.*, "The NMC horizon report: 2013 higher education edition," 2013.

[10] S. De Freitas and M. Levene, "Evaluating the development of wearable devices, personal data assistants and the use of other mobile devices in further and higher education institutions," *JISC Technology and Standards Watch Report*, pp. 1-21, 2003.

[11] NetGen. (2013, *Wearable Technology*. Available: http://netgened2013.flatclassroomproject.org/Wearable+Technology

[12] K. Lam. (2014, *Wearable Technology in Education*. Available: http://edtechtimes.com/2014/07/16/wearable-technology-education/

[13] TeachThoughtStaff. (2014, *36 Ways To Use Wearable Technology In The Classroom*. Available: http://www.teachthought.com/technology/36-ways-to-use-wearable-technology-in-the-classroom/

[14] C. Chiu and M. Liu, "An innovative teaching model research affect the elder smart watch usage efficacy," *Gerontechnology*, vol. 13, pp. 102-103, 2014.

[15] C. Dale and J. M. Pymm, "Podagogy The iPod as a learning technology," *Active Learning in Higher Education*, vol. 10, pp. 84-96, 2009.

[16] GoogleGlass. (2014. Available: https://www.google.com/glass/start/

[17] Muse. (2014. Available: http://www.choosemuse.com/

[18] Autographer. (2014. Available: http://www.autographer.com/#home

[19] Keyglove. (2014. Available: http://www.keyglove.net/

[20] VirtualReality. (2014. Available: http://www.vrealities.com/

[21] GoPro. (2014. Available: http://gopro.com/

[22] M. Chan, *et al.*, "Smart wearable systems: Current status and future challenges," *Artificial intelligence in medicine*, vol. 56, pp. 137-156, 2012.

[23] S. Coyle, *et al.*, "Textile-based wearable sensors for assisting sports performance," in *Wearable and Implantable Body Sensor Networks, 2009. BSN 2009. Sixth International Workshop on*, 2009, pp. 307-311.

[24] A. Lanata, *et al.*, "A multimodal transducer for cardiopulmonary activity monitoring in emergency," *Information Technology in Biomedicine, IEEE Transactions on*, vol. 14, pp. 817-825, 2010.

[25] K. Kario, *et al.*, "Ambulatory blood pressure monitoring for cardiovascular medicine," *Engineering in Medicine and Biology Magazine, IEEE*, vol. 22, pp. 81-88, 2003.

[26] P. Pandian, *et al.*, "Smart Vest: Wearable multi-parameter remote physiological monitoring system," *Medical engineering & physics*, vol. 30, pp. 466-477, 2008.

[27] A. Sieg, *et al.*, "Simultaneous extraction of urea and glucose by reverse iontophoresis in vivo," *Pharmaceutical research*, vol. 21, pp. 1805-1810, 2004.

[28] B. R. Jean, *et al.*, "A microwave frequency sensor for non-invasive blood-glucose measurement," in *Sensors Applications Symposium, 2008. SAS 2008. IEEE*, 2008, pp. 4-7.

[29] H. Jagos and J. Oberzaucher, *Development of a wearable measurement system to identify characteristics in human gait-eSHOE*: Springer, 2008.

[30] C. Katsis, *et al.*, "A wearable system for the affective monitoring of car racing drivers during simulated conditions," *Transportation research part C: emerging technologies*, vol. 19, pp. 541-551, 2011.

[31] H. Ghasemzadeh, *et al.*, "Wearable coach for sport training: A quantitative model to evaluate wrist-rotation in golf," *Journal of Ambient Intelligence and Smart Environments*, vol. 1, pp. 173-184, 2009.

[32] S. Coyle, *et al.*, "BIOTEX—Biosensing textiles for personalised healthcare management," *Information Technology in Biomedicine, IEEE Transactions on*, vol. 14, pp. 364-370, 2010.

[33] D. Spelmezan and J. Borchers, "Real-time snowboard training system," in *CHI'08 Extended Abstracts on Human Factors in Computing Systems*, 2008, pp. 3327-3332.

[34] M. Aleksy, *et al.*, "Wearable Computing in Industrial Service Applications," *Procedia Computer Science*, vol. 5, pp. 394-400, 2011.

[35] T. Stiefmeier, *et al.*, "Wearable activity tracking in car manufacturing," *IEEE Pervasive Computing*, vol. 7, pp. 42-50, 2008.

[36] LifeAlert. (2012, *Life Alert Classic*. Available: http://www.lifealert.com/classic.aspx

[37] Alert1. (2014, *AlertOne Medical Alert System*. Available: http://www.alert-1.com/

[38] Hovding. (2014, *Air bag for cyclist*. Available: http://www.hovding.com/

[39] M. J. Zieniewicz, *et al.*, "The Evolution of Army Wearable Computers," *IEEE Pervasive Computing*, vol. 1, pp. 30-40, 2002.

[40] S. Park, *et al.*, "The wearable motherboard: a framework for personalized mobile information processing (PMIP)," in *Proceedings of the 39th annual Design Automation Conference*, 2002, pp. 170-174.

[41] cutecircuit. (2014. Available: http://cutecircuit.com/

[42] MoonBerlin. (2011, *Handmade Tech-Couture*. Available: http://www.stretchable-circuits.com/products/moon

[43] G. Cho, *Smart clothing: technology and applications*: CRC Press, 2010.

[44] K. Broder. (2014, *Glove from Imogen Heap Will Change the Way You Make Music*. Available: http://www.wearabledevices.com/2014/06/24/glove-from-imogen-heap/

[45] D. Upton. (2014, *Five key ways to counter the threat to security and privacy posed by wearables*. Available: http://fieldservicenews.com/five-key-ways-counter-threat-security-privacy-posed-wearables/

[46] J. Bergmann and A. McGregor, "Body-worn sensor design: What do patients and clinicians want?," *Annals of biomedical engineering*, vol. 39, pp. 2299-2312, 2011.

[47] Flextronics. (2013, *Wearable Technology, Fashioning the Future*. Available: http://www.flextronics.com/Documents/White%20papers/WT%20Fashioning%20the%20Future%20-%20FINAL_AE.PDF

[48] K. Hung, *et al.*, "Wearable medical devices for tele-home healthcare," in *Engineering in Medicine and Biology Society, 2004. IEMBS'04. 26th Annual International Conference of the IEEE*, 2004, pp. 5384-5387.

[49] K. M. Daniel, *et al.*, "Emerging technologies to enhance the safety of older people in their homes," *Geriatric Nursing*, vol. 30, pp. 384-389, 2009.

[50] A. Cushing, "A case study of mobile learning in teacher training-MENTOR ME (mobile enhanced mentoring)," *Mobile Learning in Widening Contexts: Concepts and Cases*, vol. 19, pp. 1-14, 2011.

[51] T. Franklin, *et al.*, "PDAs in teacher education: A case study examining mobile technology integration," *Journal of Technology and Teacher Education*, vol. 15, pp. 39-57, 2007.

[52] T. S. Foulger, *et al.*, "Innovators in Teacher Education: Diffusing Mobile Technologies in Teacher Preparation Curriculum," *Journal of Digital Learning in Teacher Education*, vol. 30, pp. 21-29, 2013.

[53] M. Chen, *et al.*, "Body Area Networks: A Survey," *Mob. Netw. Appl.*, vol. 16, pp. 171-193, 2011.

[54] S. Movassaghi, *et al.*, "Wireless Body Area Networks: A Survey," *Communications Surveys & Tutorials, IEEE*, vol. 16, pp. 1658-1686, 2014.

[55] IEEE Standard for Information technology-- Local and metropolitan area networks-- Specific requirements-- Part 15.1a: Wireless Medium Access Control (MAC) and Physical Layer (PHY) specifications for Wireless Personal Area Networks (WPAN)," IEEE Std 802.15.1TM, 2005.

[56] IEEE standard for information technology—telecommunications and information exchange between systems—local and metropolitan area networks—specific requirements part 15.3: wireless medium access control (MAC) and physical layer (PHY) specifications for high rate wireless personal area networks (WPANs) amendment 1: MAC sublayer, IEEE Std 802.15.3b, 2006.

[57] IEEE Standard for Information technology-- Local and metropolitan area networks-- Specific requirements-- Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low Rate Wireless Personal Area Networks (WPANs), *IEEE Std 802.15.4-2006 (Revision of IEEE Std 802.15.4-2003)*, pp. 1-320, 2006.

[58] C. Huasong, *et al.*, "Enabling technologies for wireless body area networks: A survey and outlook," *Communications Magazine, IEEE*, vol. 47, pp. 84-93, 2009.

[59] J. O'Donoghue, *et al.*, "Sensor Validation within a Pervasive Medical Environment," in *Sensors, 2006. 5th IEEE Conference on*, 2006, pp. 972-975.

[60] M. R. Yuce, "Implementation of wireless body area networks for healthcare systems," *Sensors and Actuators A: Physical*, vol. 162, pp. 116-129, 2010.

[61] J. O, *et al.*, "Data Management within mHealth Environments: Patient Sensors, Mobile Devices, and Databases," *J. Data and Information Quality*, vol. 4, pp. 1-20, 2012.

[62] S. Saleem, *et al.*, "On the Security Issues in Wireless Body Area Networks," *JDCTA*, vol. 3, pp. 178-184, 2009.

[63] H. Nemati, *Security and Privacy Assurance in Advancing Technologies: New Developments: New Developments*: IGI Global, 2010.

[64] Rubee. (2011. Available: http://www.rubee.com/

[65] *Operating systems: design and implementation* vol. 2: Prentice-Hall Englewood Cliffs

[66] PalmOpenSource. Available: http://www.palmopensource.com/index.php?category=6

[67] TIZEN. Available: https://www.tizen.org/

[68] H. Jiang, *et al.*, "Software for Wearable Devices: Challenges and Opportunities," *arXiv preprint arXiv:1504.00747*, 2015.

[69] BROADCOM. (2015, *Wireless Internet Connectivity for Embedded Devices*. Available: https://www.broadcom.com/products/wiced/

[70] Freescale. *Wearables Reference Platform*. Available: http://www.freescale.com/webapp/sps/site/overview.jsp?code=APLWEAR

[71] B. Woods. (2014, *Android Wear SDK available to download for developers from today*. Available: http://thenextweb.com/google/2014/06/25/android-wear-sdk-available-download-developers-today/

AUTHOR PROFILE

Fazal-e-Amin received the BS degree in computer science from Hamdard University in 2003. He received a master's degree in information technology from Quid-i-Azam University in 2005 and a master's degree in software engineering from International Islamic University in 2008. He received a Ph.D. degree from Department of Computer and Information Sciences, Universiti Teknologi PETRONAS in 2012. Currently, he is serving as assistant professor at Department of Software Engineering at College of Computer and Information Sciences, King Saud University. He has authored and co-authored more than fifty research publications. His research interests include smart devices, IoT, software usability, software quality, and complex systems.