

Wearable devices, the next generation of mobile devices: Main features and uses

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Abstract: In a world in which students are exposed to all kinds of digital stimuli, the traditional educational, in which a teacher gives a lesson in front of a class full of students who listen attentively, may not be very motivating. That is why, in addition to offering new pedagogical possibilities, and helping teachers to nurture their students with new skills and competences, technology plays a key role in the classroom when it comes to generating motivation. In that sense, wearable devices can be a powerful ally. For this reason, in this article, we will show a classification of these devices and the analysis of the main parameters of each of them. Several bibliographical sources were used for this work, such as: research documents, technical articles and official websites of the wearable devices investigated. Seven parameters were obtained to analyze by rating scales to optimize the decision of its possible use.

Keywords: Accessories; devices; e-patches; e-textiles; wearables.

1. Introduction

The growth of wearable technology is increasing considerably as the years go by. The main reasons for the use of wearable technology in the current technological market tend to be the problems related to the health and well-being of people. These are wearable devices that are used in wireless body area network (WBAN), which work in applications not only related to health, but also in the areas of research, communication, entertainment, tourism and education. Wearable technology does not focus on the characteristics of smartphones, although it is true that both have similar functions for the user, the difference is that wearable devices have as their main objective to make the user and the device one, with their own characteristics such as their weight, their comfort and that they can work and provide information even when the user is not active with the device (Çiçek, 2015). Wearable technology works through WBANs, that are networks created by mini sensors connected to the human body and that work wirelessly to provide information.

The use of wearable devices used in m-learning can be seen in several works. For example, in the investigation by Santos et al. (2018) an integrated system is proposed in the form of an intelligent glove that takes advantage of the movement of the body to create the persistence of the effect of vision. This allows the visualization of letters and words in literacy activities. Nakasugi and Yamauchi (2002) created a system called “Viewer of the past”, which uses devices mounted on the head to increase reality and improve learning by using historical scenes. In the work presented by Yordanova (2008) the author proposes to develop adaptive learning contents based on metadata (obtained by wearable devices) that are composed of information related to the profile of the student. In this context, Jemni and Nasraoui (2009) used web mining techniques and information retrieval to provide customizable adaptive e-learning experiences.

The analysis of the main parameters of the wearables allows optimizing the choice of a device for its possible use or application. The sections of this document are detailed below: section 2, briefly explains what WBAN are and the types of use attributed to this type of body area networks; in section 3, we will present a brief collection of information about portable devices, characteristics, classification and applications; in section 4, we will indicate the method that was used to make tables that show a comparison between wearable devices in relation to the analysis parameters investigated; in section 5, the document shows the comparative analysis of the research; and finally in section 6, we will write the final conclusions of the topic analyzed and how they could improve in the future.

2. Wireless body area network

WBAN are characterized by networks formed by a set of sensors that are linked to the human body, that is, networks through which wearable devices can communicate with applications or external systems capable of controlling and providing information on health issues and well-being such as physical condition, entertainment and communication (Arefin, Ali, & Haque, 2017). Adding one more definition about WBAN, we can say that they are networks of a set of portable devices that control the user's direct environment (Hussain et al., 2017). In this modern world in which we currently live, it is necessary to implement functionalities in remote health operability techniques; however, the size, processing speed and response times in this type of networks composed of small or portable sensors are inaccurate and slow until now.

WBAN offer a short-range communication and are based on standards, technologies and requirements that conform to the specifications of a wireless local area network (WLAN). The most widely used technologies and standards are: Bluetooth, Wi-Fi, ZigBee and the IEEE 802.15.6 standard (Arefin et al., 2017). Bluetooth is used for its low power consumption, comes from the 802.15.1 standard and provides some security because it can create master-slave nodes, which allows simultaneous communication between devices, and it is suitable for short communication distances. On the other hand, Wi-Fi technology is very desirable in this type of networks, since it has the ability to create multiple nodes and users can connect at the same time using an access point (AP), however, one of the disadvantages of this type of technological standard (802.11 a, b, g, n) is its high-power consumption. With respect to the technology standard 802.15.6,

the requirements that define Kaschel, Alvarado and Torres (2014) must be taken into account. Examples of these are: the latency in medical applications must be less than 125 ms and in other applications less than 250 ms, they must have Quality of services (QoS), the WBAN must be able to support up to 256 nodes in a network, the bit rate must be in the range of 10 Kbps to 10 Mbps, etc. The main objective of the 802.15.6 standard is to provide a network that can use low power, short distances and wireless communication that is reliable enough to be used in the human body (Kaschel et al., 2014; Ravi, Wong, Lo, & Yang, 2017).

3. Wearable devices

Wearable devices are those devices that can be linked in the human body, that is, they can be used literally as garments in the human body. In 1966, when a professor from the Massachusetts Institute of Technology created a pair of smart shoes that cheated in a game (roulette), it was listed as the first wearable device in the world (Jiang et al., 2015). Although many meanings and definitions are attributed to wearable technology, it is important to understand that they are tangible devices that interact with or without smartphones through a WBAN to provide specific information to the user (Çiçek, 2015). The classification of wearable devices mentioned by Kalantari (2017) can be divided into two large groups: product forms and product function. However, there are researchers and scientists who classify portable devices in: accessories, electronic textiles and electronic patches (Seneviratne et al., 2017).

3.1. Accessories

The accessories correspond to the group of wearable devices that can be used as accessories in the human body, such as: those worn on the wrist called wrist-worn, those that are used on the face and head called head-mounted and others jewelry and belts (Seneviratne et al., 2017).

3.2. E-Textiles

Electronic textiles come from the classification of wearable devices that can be used as clothing. Most are used in therapeutic environments, such as physiology in sports and health, and are also used in psychological problems such as stress, because, the clothing is capable of offering therapeutic massage and also its scope extends to military applications (Gonçalves, Ferreira da Silva, Gomes, & Simoes, 2018).

3.3. E-Patches

This classification arises with the appearance of intelligent electronic patches able to adhere adequately to human skin. Its main use is the surveillance of human physiological problems and treatments of the skin for haptic purposes. They are not easy to find in the market, since having such small sensors, their development tends to be very difficult, very few of these patches are sold to the general public (Kilic, Brunner, Audoly, & Carrara, 2017).

4. Method

For the development of this article, it was necessary to focus on the published research articles on the subject and the scientific documents on the web that address the main parameters to be analyzed. According to the research by Seneviratne et al., (2017), the factors that should be taken more into account when choosing a device are: the type of connectivity, the battery life, memory, application of use and price, but also highlight parameters much deeper as the type of battery, processors, frequencies or cycles of clock, brand and CPU. On the other hand, an equally important factor is security, in the studies conducted in (Chuan, 2016; Saa & Lujan-mora, 2017) it can be shown that vulnerabilities at the time of communication made by wearable devices used in WBAN are very common. For example, when making payments using Near Field Communication (NFC) technology, credit card data and access passwords may be exposed. In the investigation (Khakurel, Porras, & Pöysä, 2018) the parameters that influence the acquisition or not of a wearable device are a matter of the size and duration of the battery. Users of these studies filed complaints, but investigations continue to improve these features quickly. This article will not develop parameters such as the ability to add sensors, software and firmware compatibility explained in (Haghi, Thurow, & Stoll, 2017) since it is designed to have a much more general vision from the point of view of the different requirements that users can have. Finally, the parameters to analyze are the following: Type of connectivity, battery life, application, price, security, size and type of device. Below, these parameters are detailed.

4.1. Type of connectivity

This parameter describes the behavior of each wearable device in relation to connectivity. We must take into account the way in which they connect to the network, it should be emphasized that each type of connectivity has different characteristics, advantages and disadvantages, some may be better in the transmission speed, others can be better in energy consumption. The important thing here is to classify them and that the reader feels what is convenient for them. For this reason, the following types of connectivity are contemplated: BLE (Bluetooth Low Energy), BT (4.0, 4.1), Wifi, NFC (Near Field Communication), CDMA (1.9 PCS GHz and 800 MHz).

4.2. Battery Life

The battery life is one of the most important parameters to analyze, since it depends on the use of a device. Users want extensive battery life due to the ubiquity that the portable devices guarantee. For this reason, there are efforts that could solve this problem; they are known as energy replenishment techniques. One of them is the solar energy harvesting (SEH): Collection of solar energy, consists of the capture of solar energy from ultraviolet rays, transforming it into electrical voltage to power the batteries, an example of a device that performs this action is the SEIKO watch. Another example is kinetic energy harvesting (KEH): Collection of kinetic energy. It works by the principle of human movement, the sensors located in specific places in the wearable device and the movements of the body react to this kinetic energy, some smart shoes for athletes use this principle. In the research (Seneviratne et al., 2017) it is shown that 500 mV of root mean square (RMS) voltage can be generated with a frequency of 5 Hz. Finally, the thermoelectric energy harvesting

(TEH): Collection of thermoelectric energy is another technique that bases its principle on the transformation or conversion of the internal temperature of the human body with the external temperature of the environment. Most studies of this nature were done with smart watches (Khakurel et al., 2018; Seneviratne et al., 2017).

The representation of the parameter to measure the battery life is as follows:

Battery life	Short	Medium	Long
Wrist type	1 - 3 days	4 - 9 days	10 - n days
Head-mounted type	2 - 4 hours	5 - 10 hours	11 - n hours
Other types of accessories	4 hours - 1 days	2 - 5 days	6 days - n month
E-Textiles	8 hours - 2 days	3 - 10 days	11 - n days
E-Patches	9 hours - 3 days	4 - 7 days	8 days - n weeks

Table 1 - Representation of the parameter to measure the battery life

4.3.Applications

This parameter that indicates the place or places where a wearable device acts, in this way, it is possible to choose with greater precision the device that best suits the needs. The analysis parameter will be divided into: Health and medicine, industrial, military, tourism and informationt. This is because they are the most common applications in which wearable devices work (Smita Jhajharia, S. K. Pal, & Seema Verma, 2014).

4.4.Price

The price factor is the most common when it comes to analyzing the aspects related to the acquisition of goods or material services, and technology is no exception. The prices in this field are too high, but it is very important to analyze them in order to get closer to the correct device. Obviously, prices will depend on the region in which the buyer is located; this document takes as reference the prices of the US market.

	Cheap	Moderately expensive	Expensive	Very expensive
Smart watches	150 - 230	231 - 300	301 - 350	351 - n
Wristbands	23 - 50	51 - 100	101 - 300	301 - n
Smart eyewear	100 - 250	251 - 450	451 - 700	701 - n
Smart headsets	88 - 100	101 - 200	201 - 300	301 - n
Smart Jewelry	20 - 80	81 - 130	131 - 190	191 - n
Smart belts	75 - 150	151 - 250	251 - 530	531 - n
Smart Garments	70 - 200	201 - 350	351 - 500	501 - n
Shoes / Socks / Smart Gloves	75 - 150	151 - 300	301 - 350	351 - n

Table 2 – Representation of the parameter to measure the price (USD)

Price of e-patches, due to the limited price information about electronic patches, it has been decided to place only the reference of known prices for the devices Valedo Back Therapy and Thync.

4.5. Security

Security is the most important parameter to analyze, because wearable devices connect and transmit information wirelessly. The efforts must be reflected in order to guarantee confidentiality, integrity and availability of the information generated by these devices. Although we only start with the research and development of these devices, there are ways to mitigate current vulnerabilities (Ching & Singh, 2016). According to the level of security found for each of the devices analyzed, one of the following values can be taken: low, medium and high. Low, if it has low security features such as authentication. Medium, if the values are more advanced; and high, if the security of the wearable device in terms of communication flows through the servers within independent companies that guarantee the security service.

4.6. Size

To analyze a wearable device, an important parameter to include and detail is the size of it. Information was collected on the different wearable devices of watches and glasses in their official web pages to take into account the dimensions they provide, in height, width and depth, basically the three axes that govern the 3 dimensions. The size also implies the weight that the devices have, however, in this article we will provide general information about the size in relation to the dimensions. If a wearable device is very small, as is the case with smart jewelry, the user cannot expect very complex functionalities.

Due to this, the size is divided into: small, medium and large. If any user is willing to choose a wearable device whose characteristics and functions are multiple, deep and complex, then it would have to be made of a wearable device with large dimensions. We will consider the size of an electronic band-aid patch as small, the medium size would take into account the physical dimensions of smart watches and wristbands, and the large size would take the physical dimensions of intelligent clothing, helmets and straps.

4.7. Type of wearable device

It is difficult to compare a smart watch with smart glasses, although both use the same functionalities, they are totally different products, the characteristics could be different between both. This parameter will help us simplify the search in decision making during the execution of an election. We will divide the parameter using the classification developed by Seneviratne et al. (2017) what corresponds to wearable devices type accessories of the subgroups that are: Accessories (watches, bracelets, headphones, glasses, belts and jewelry), e-textiles (clothes and shoes/ socks/gloves) and e-patches (sensor patches and tattoos/skin patches).

5. Comparative analysis

The main objective of the comparative analysis of this section is the creation and construction of comparative tables of all wearables, for which the parameters developed

in section 4 of this article will be used. To facilitate the reading of the tables, we have indicates with a letter (X) if the device has the characteristic according to the analysis parameter, otherwise the information about that characteristic could not be found in the research carried out. The most representative devices (the best known and most sold) of each category were chosen for this analysis. These data were taken from the websites of Amazon, Ebay and Wish. The search of the different devices was ordered using the following options:

- Average customer opinion, and
- Featured articles.

Type/subtype		Accessories / used on wrist (watches)				
Device		Apple Watch	Motorola Moto 360	Samsung Gear S2	Huawei Watch	Fitbit Surge
Connectivity	BLE					
	BT	X	X	X	X	X
	Wi-Fi	X	X	X	X	X
	NFC	X	X	X	X	X
Battery duration	Short	X	X	X	X	
	Medium					X
	Long					
Application	Health and medicine	X	X	X	X	X
	Industrial	X				
	Military					
	Tourism		X			
	Information	X	X	X	X	
Price	Cheap					
	Moderately expensive					X
	Expensive	X	X	X	X	
	Very expensive					
Security	Low	X	X	X		X
	Medium				X	
	High					
Size	Small					X
	Medium	X	X	X	X	
	Big					

Table 3 – Smart watches

Type/subtype		Accessories / Smart wristbands				
Device		Sony Smartband 2	Mi Band 2	LG Gizmopal 2	FitBit Flex 2	Empatica E4 Wristband
Connectivity	BLE		X		X	
	BT	X	X			X
	Wifi					
	NFC					
	CDMA			X		
Battery duration	Short					X
	Medium	X		X	X	
	Long		X			
Application	Health and medicine	X	X	X	X	X
	Industrial	X				X
	Military					
	Tourism					
	Information	X	X		X	X
Price	Cheap		X			
	Moderately expensive	X		X		
	Expensive				X	
	Very expensive					X
Security	Low					
	Medium				X	
	High					X
Size	Small		X	X	X	
	Medium	X				X
	Big					

Table 4 – Smart wristbands

Type/subtype		Accessories / smart glasses			
Device		Microsoft HoloLens	FUNKI Ambient Glasses	Recon Jet	Google Glass
Connectivity	BLE		X		
	BT		X	X	X
	Wifi	X		X	X
	NFC				

Battery duration	Short	X			
	Medium			X	
	Long				
Application	Health and medicine		X		
	Industrial				
	Military				
	Tourism	X			X
	Information	X	X	X	X
Price	Cheap		X		
	Moderately expensive				
	Expensive			X	
	Very expensive	X			X
Security	Low				
	Medium	X	X	X	
	High				X
Size	Small				
	Medium		X	X	X
	Big	X			

Table 5 – Smart glasses

Type/subtype		Accessories / smart jewelry					
Device		NFC Ring	Smarty Ring	Nod	Motiv Ring	Bellabeat Leaf	CliMate Clip-on
Connectivity	BLE						
	BT		X	X	X	X	
	Wifi						
	NFC	X					
Battery duration	Short		X	X			
	Medium				X		
	Long					X	X
Application	Health and medicine				X	X	X
	Industrial			X			
	Military						
	Tourism						
	Information	X	X	X			X

Type/subtype		Accessories / smart jewelry					
Device		NFC Ring	Smarty Ring	Nod	Motiv Ring	Bellabeat Leaf	CliMate Clip-on
Price	Cheap	X					
	Moderately expensive						
	Expensive						
	Very expensive				X	X	
Security	Low	X	X	X	X	X	
	Medium						
	High						
Size	Small	X	X		X	X	X
	Medium			X			
	Big						

Table 6 – Smart jewelry

Type/subtype		E-textile / Smart clothes					
Device		Hug Shirt	T Jacket	Solar Shirt	Hovding	Athos	OmSignal
Connectivity	BLE						
	BT	X	X			X	X
	Wifi						
	NFC						
Battery duration	Short		X		X		X
	Medium						
	Long					X	
Application	Health and medicine	X	X			X	X
	Industrial			X	X		
	Military						
	Tourism						
Price	Information					X	
	Cheap						X
	Moderately expensive				X	X	
	Expensive						
Security	Very expensive		X				
	Low						
	Medium					X	
	High						
Size	Small		X	X			
	Medium					X	
	Big	X			X		X

Table 7 – Smart clothes

Type/subtype		e-patches / Smart patches				
Device		Chrono Therapeutics	Proteus Health Patch	Health Patch MD	Thync	Valedo Back Therapy
Connectivity	BLE				X	
	BT					X
	Wifi			X		
	NFC					
Battery duration	Short			X	X	X
	Medium		X			
	Long	X				
Application	Health and medicine	X	X	X	X	X
	Industrial					
	Military					
	Tourism					
	Information					
Price	Cheap					
	Moderately expensive					
	Expensive					
	Very expensive				X	X
Security	Low					
	Medium					
	High		X			
Size	Small	X				
	Medium		X	X	X	X
	Big					

Table 8 – Smart patches

Type/subtype		E-textile / smart shoes, gloves and socks				
Device		ProGlove	GPS Smartsole	Sensoria	Owlet Smart Sock	Samsung IOFIT
Connectivity	BLE					
	BT			X	X	X
	Wifi	X			X	
	NFC					
	GPS		X			

Type/subtype		E-textile / smart shoes, gloves and socks				
Device		ProGlove	GPS Smartsole	Sensoria	Owlet Smart Sock	Samsung IOFIT
Battery duration	Short	X	X	X		
	Medium					X
	Long				X	
Application	Health and medicine			X	X	X
	Industrial	X				
	Military					
	Tourism					
	Information		X			
Price	Cheap					
	Moderately expensive					X
	Expensive		X		X	
	Very expensive			X		
Security	Low					
	Medium		X			
	High	X				
Size	Small		X	X		
	Medium					X
	Big	X			X	

Tabla 9 – Smart shoes, gloves and socks

6. Analysis of results

The results that the research shows are the following: Table 3 indicates that there is a great similarity in security and prices between Apple Watch, Samsung Gear S2 and Huawei Watch. Table 4 indicates that the Mi Band 2 is the most expensive accessory. Table 5 shows that Google Glass is the security. In table 6 can see that all smart jewelry has a very low level of security. Table 7, 8 and 9 show us that smart clothes and patches are used more frequently in health and medicine. These findings can facilitate the decision to purchase for personal, academic or research use of each wearable device based on its characteristics

7. Conclusions

As time passes wearable devices have been introduced little by little in the commercial, industrial, health and communication markets. The arrival of these devices creates interesting

challenges that must be resolved, such as battery life and communication security, which were analyzed in this document and that are intended to be improved to help create greater confidence in the adoption of a device. The different applications provided by the devices make their adoption more feasible, however, the price factor is one of the most worrying for users. The document covers the topics of WBAN, their main uses and characteristics, as well as portable devices in which they show their definition, classification and types.

The weakest link when talking about wearable devices is the connection to the mobile phone. This is because it is usual for both devices to be paired through a short-range wireless connection known as Bluetooth. Malicious people can introduce malware and use malicious applications to do a variety of things from calling, sending and receiving texts and extracting personal information, etc. They can also know what the location is through GPS and record any health problems that have put in the wearable device. The danger is: once they have access to another person's mobile device, they will have control and a large number of resources at their fingertips. Two tips to implement security are: first, use a personal identification number (PIN), all mobile devices should have a PIN; secondly, set limits on the information to be shared.

We have given an idea and we have clarified the panorama to people, working groups, entities and others so that they can choose the best option of wearable device according to the requirement or the existing need. In this article, easy-to-read and interpretable comparison tables were created for wearable devices that are worn on the wrist as smart watches and used on the head and face as smart glasses, each comparing them by the same type of device, along with the analyzed factors such as connectivity, battery life, price, security, size and application. Finally, we hope that this article optimizes the selection of a wearable device and helps future research on related topics.

Currently, with the rapid growth of the Internet of Things (IoT), wearable technologies have begun to be used in various scenarios such as research, health, etc. In the field of learning, Azzabi, Kouki and Jemni (2018) present a framework for mobile learning using wearable technology. Despite the importance of these technologies to improve learning experiences, they are not well explored yet in educational situations. In this context, the findings of this study can help researchers and professionals to better design educational experiences based on the individual characteristics of each wearable device.

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