4.0 Applications of Wearable Devices

Perhaps the earliest form of wearable computer was a device created for the noblest of pursuits: gambling (Hong and Baker, 2014; Randell, 2005; Sözüdoğru and Tuncay, 2019; Yadav et al, 2020). Ed Thorp considered the possibility of applying mathematics to beat roulette. Working with renowned scientist Claude Shannon, they built a device that could be strapped around the waist, with the tap of the shoe as input and a small earpiece as output. The shoe input was used to mark a reference point for the roulette ball, and the audio was used to signal one of eight possible quadrants where the ball was most likely to land. During tests in a lab, the pair found that the device could give them a 44 percent edge, which led them to try out the device in a real casino.

Areas that different researchers have applied wearable computing as highlighted by (Hong and Baker, 2014) include:

i. Animated sweater: had different designs, all having a clever pocket for holding a smartphone. The smartphone showed different animations like a fireplace with a lively fire or a cat that can move its eyes around, with the running of an application. A creative use of wearable computing wherein the wearer simply puts his or her smartphone in the right place, runs an app, and instantly has animated clothes.

ii. A smart wig: It has a built-in laser pointer and offers some input capabilities for advancing slides.

iii. The navigation wig: uses GPS and vibration to guide wearers

iv. Sensing Wig: used to sense data such as temperature and blood pressure (Hong and Baker, 2014).

v. The teeth-embedded sensors that can measure and model a variety of oral activities, including chewing, drinking, speaking, and coughing.

vi. **Zackees**: these are gloves with LEDs in them that can be activated using a simple contact switch between the thumb and index finger. The LEDs are positioned to form a left and right arrow on the left and right gloves respectively as shown in fig.1. The electronics are also protected so that the gloves can be washed normally. They can be used for signalling in bicycling or skateboarding and increasing visibility at nighttime while jogging.

Figure 1.Animated Clothes and Zackees (Hong and Baker, 2014).

4.1 Wearables for Health Monitoring.

Wearable technologies provide support for continuous health monitoring of people with a wide range of diseases including psychological and physical. Wearables in the health care domain are the most advanced, and with the highest number of production implementations, (Domb, 2019). According to

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Tahir et al (2018) wearable devices often operate in a group setting. That is, a single device can be categorized into two or more domains of life. In Lind et al, (1997), considering that the health and well-being of military service personnel are paramount and require special attention, the sensate liner developed at the Georgia Institute of Technology was designed to specifically monitor the vital signs of combat casualties, as well as automatically detect and characterize a wound in real-time using bullet entry detection.

Health monitoring wearables seem to be the most ubiquitous wearable computing technologies. **The SensVest** is one of such wearables, Woolley, et al (2003)**.** It is a wearable data logging system that senses and records body motion, heart rate and temperature.

Figure 2: The SensVest - Left the vest and right the electronic enclosure and cable kit. (Woolley, et al, 2003)**.**

The data processing is carried out by a 16-bit microcontroller, the Mitsubishi M16C. As shown in Figure 6, the SensVest electronics are contained in a lightweight aluminium case with a simple menu LCD interface system. It can connect directly to a PC or other RS232 serial device, or PDA. The vest has pockets to hold the modules, and tubes for the wiring. The weight is distributed over the back with the lion's share of the weight on the shoulder blades for comfortable use.

In recent times health monitoring wearables are in vogue in the form of Body media range of products. Jhajharia et al, (2014) highlighted wearables that are based around an armband, designed with sensors for detecting movement, heat flux, skin temperature, near-body temperature, and galvanic skin response. Data can be viewed either in real-time via a wireless link or downloaded for analysis using the Internet. A new healthcare system that is aimed at prevention is the Metria Wearable Sensor. The wearer attaches the wearable sensor, which uses "skin-friendly" cohesive; the sensor collects data, such as the breaths per minute and number of hours slept and breaths per minute. Another health monitoring wearable is The Remote Monitoring System (RMS) which was developed in collaboration with Mayo Clinic. It uses designs to support remote monitoring of patients with cardiac problems. Examples include the Electroencephalography (EEG), BodyTel Products and BioMan t-shirt.

Leutheuser, (2019) in his thesis presented three different wearable computing applications aimed at addressing different non-communicable diseases which include: mobile breathing analysis; mobile electrocardiogram (ECG) analysis and inertial measurement unit (IMU)-based activity recognition. The introduction of wearables is a potential solution to addressing non-communicable diseases.

Respiratory inductance plethysmography (RIP) provides an unobtrusive and mobile method for measuring breathing characteristics, avoiding the measurement with flowmeters (FMs) as with them the natural breathing pattern is altered.

Liu and Hong, (2019) discussed the use of strain and pressure sensors, which correspond to two main mechanical stimuli. According to them among the different types of sensors available such as single functional sensors like temperature, pressure, strain, optical, and electrochemical sensors, to multifunctional sensors like tactile and electronic skin, wearable electromechanical sensors including strain and pressure sensors have attracted more and more attentions due to their simple mechanism, low cost, low power consumption, and high performance. Watanabe and Terada (2020) proposed a framework to manipulate auditory perception which is one of the most important human senses. They focused on earphone-type wearable computers (hearable devices) that not only have speakers but also microphones. A hearable device is a new kind of wearable computer that uses earphones. It is designed for multiple purposes ranging from listening to music to medical monitoring, fitness tracking, translation, and personal identification.

Yadav et al, (2020*)* proposed a new architecture of a wearable computer where all possible devices are wirelessly interfaced using a central Internal Processing unit (I.P.U.). According to them the I.P.U. with a proposed internal life of 20 years, will be surgically planted in the body, and would become an integral part of the human being supplementing his capabilities in big and small ways.

4.2 Wearables for Military and Security

Wearable devices play an important role in improving the capabilities of soldiers. The rising need for soldiers' coordination, training and health, increase in asymmetric warfare, suspected geopolitical conflicts and soldiers' modernization programs, are among some of the factors fueling the growth of military wearable devices (Sharma et al, 2020). Hence, it has become imperative to develop wearable devices with diverse functions for the military. Soldiers have become point nodes of information collection and resource control on the battlefield with the growth of the Internet of Battlefield Things (IoBT) which involves the full realization of ubiquitous sensing, communication, and computing (Shi et al, 2019).

In Randell, (2005) a Quantum3D Expedition that uses augmented reality to provide a wearable computing training resource for the military was presented. Using accurate simulations of fabricated situations, including visuals, sound, and voice command, the Expedition wearable computer design provides immersive training for the armed services and emergency response workers.

Figure 3. The Quantum3D Expedition (Randell, 2005).

Kodam et al, (2020) in their paper reviewed the application of smart wearables using WSN (Wireless Sensor Network) technology to provide safety for soldiers in the battlefield. These smart wearables Smart Vest, Smart Helmet and Smart Strap, equipped with Body Sensor Network (BSN) are able to determine the various psychological parameters and mental state of the soldiers. In addition to monitoring the health of the soldiers, they have the ability to track the live location in real-time, by this, information about an injured soldier can be transmitted to the control unit in no time using LoRaWAN (Long Range Wide Area Networking) and to the nearby soldiers using Zigbee module by forming a Mobile Ad-hoc Network (MANET), so that the control unit can take necessary actions for saving the life of the soldier.

4.3 Wearables for Sports and Fitness

In sports and fitness wearables have been largely influenced by passion and interest. Optimum performance monitoring and management, activity tracking, goal management, direction data and location sharing are some of the typical functions of such wearables. The BioHarness is a compact monitoring module that enables the transmission and capture of physiological data from the wearer via mobile and fixed data networks enabling genuine remote monitoring of human performance and condition in the real world (Johnstone, 2012). The Smart Training Shoes is another example of a next-generation wearable computer. It is an athletic shoe with radio frequency identification (RFID) tags, motion sensors and accelerometers allowing the user to customize the looks, fit and responsiveness of their kicks. It is also fitted with an activity tracker(Jhajharia et al, 2014). Other wearables for sports include sports sunglasses and headgears like sportii that gives the athlete real-time performance feedback like heartrate, miles etc; lumo lift which vibrates as a warning alert to you when your posture is wrong; the swimming tracker that gives audio feedback; smart socks for taking the physiological parameters in running; sweatband for heart rate monitoring; cycling wearable coach; boxing wearable that keeps track of the number of punches, smart pants, wearable pods and wearables on the wrist (Apac Business, 2022).

Figure 4: Nike Smart Training Shoes. (Jhajharia et al, 2014)

4.4 Other Wearable devices

Safety on the road cannot be overemphasized, hence Kyung et al, (2011) proposed a versatile wearable computer for drivers (VWCD) which is a promising solution to provide safety-related information for drivers using wearable devices mounted on or integrated into eyeglasses. Kunze et al.(2014) proposed wearable devices for adults.

Figure 5: VWCD Prototype. Kyung et al, (2011)

5.0 Wearability, Vulnerability and security of wearable devices.

Wearable devices are hurriedly being marketed in an attempt to capture an existing market(Tahir et al, 2018). Sequel to this, some devices do not adequately address the need for security. Knight et al (2006) developed a methodology for assessing the wearability of any wearable computer. According to the authors, physical effects that should be assessed to determine the wearability of a device include physiological energy expenditure, the biomechanical effects due to changes in movement patterns, posture and perceptions of localized pain and discomfort due to musculoskeletal loading, and perceptions of wellbeing through comfort assessment.

To protect personal integrity and privacy, confidentiality in information and communications wearable devices require a high level of information security. As regards security, wearables have limited processing power, memory, local storage facilities and possibilities for add-ons making it herculean to set up a security baseline for needed security services as would be required by the users' organizational IT/information security policy. Shrestha and Saxena (2017) provided an exposition of the security and privacy of wearable computing, studying dual aspects, that is, both attacks and defenses. They concluded that though wearables remain almost constantly attached to the body of the wearer, they have also raised unique security and privacy vulnerabilities.

Wearables pose various security and privacy threats, such as unfettered access, sensor sniffing and side-channel attacks, wearers' and bystanders' privacy risks, and information leakage through social media and other channels. These threats have raised the demand for the design and implementation of appropriate defense mechanisms on wearable devices to mitigate, if not eliminate, the risks due to the existence of such threats. While wearables introduce new security and privacy vulnerabilities, they also promise to improve the existing security, privacy, and safety paradigms in unique ways while preserving the system's usability, especially in the context of authentication and user safety.

6.0 Challenges to the increase in Wearable Devices

As Woolley, et al (2003) puts it, in spite of all the advances in wearable computing, there are still numerous engineering challenges yet to be addressed. Consumer wearable devices are expected to perform a wide range of tasks within stringent area and energy constraints. When computers are networked, there is the potential that information could be compromised. Some of the challenges affecting the growth of the wearable computer market include issues of size, weight, safety, privacy and security (Knight et al, 2006). Some obstacles posed by factors like battery life, processor power, display brightness, network coverage and form factor have led to a delay in the widespread introduction and application of wearable computers (Jhajharia et al, 2014). The risk of hacking is a serious security concern for wireless network communication. One of the most important design considerations of mobile devices is power consumption. The size of a wearable device is often a design limitation, which means that the size of the batteries is also constrained together with the heat dissipation that becomes a problem as the size decreases. However, recent progress in Lithium-polymer cell chemistry technology offers greater possibilities because a battery base is no longer needed and the cell can be flat, very light and robust. This opens up an interesting idea of embedding the batteries into clothing or other irregular shapes.

7.0 Conclusion

Wearable devices perform numerous everyday functions described as mobile information processing like emailing, fitness tracking, navigation, health monitoring and so on. Essentially wearable computers have become an integral part of our daily space, redefining our activities in seamless fascinating ways. The user is the focus of the design of a wearable computing device, therefore portability, safety and security are a major concern in their use. As widely acceptable as wearables are becoming, certain constraints like energy management and effective wireless communication devoid of hacking has been a major drawback in its full implementation. As advancement in research and technology continue to grow, we will in the nearest future see to a surmounting of these challenges for a widespread introduction and application of wearable computing to virtually every domain of life.

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