Wearable Tech: Why Architectures Matter

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This paper explores the issues surrounding the evolution of wearable technology and the principle of taking a platform based approach and what could be done to make wearable technology easier to develop and more accessible. The paper suggests definitions of where the boundary lies between what constitutes wearable technology and technology that is carried rather than worn. The main areas highlighted for discussion came about as a result of the research into the issues surrounding wearable technology development. The two principle technology based issues are the generation, storage and transfer of electrical power, and the safety, security and storage of Data. The third main issue is the social framework in which wearable technology is developing and how acceptable the use of technology is in today's society. This paper concludes by highlighting the issues in these three areas with a view to encouraging the technology manufacturers to develop solutions to the power and data questions, whilst in the meantime encouraging society as a whole to reflect and see what technology means to our future social architecture.

Wearable Technology, Human Integration, Wearable Architecture, Social Architectures.

1. INTRODUCTION

Wearable Technology is a significant growth area that is seeing particularly strong development growth, particularly in the health and fitness domains. With products having been developed such as FitBit, Google Glass, Apple Watch, Pebble and other devices, the wearable market is expanding at pace in different market sectors.

This paper brings together the results of state of the art reviews, technology appraisals and results from focus groups and debates (Kirby, 2015), and goes on to summarise the exploration of key development areas for wearable technology while highlighting the key questions with a view to determining what could be achieved if these questions were prioritised.

As the technology becomes more robust and the scale of incremental capability change decreases, the sales of mobile devices, whilst still growing, are looking to plateau in the near future (Kelly, 2014). From the smart watches, glasses to e-textiles, the new generation of wearable technologies require energy, data and integration to function. Most devices are being developed in a device centric manor that means that, while some standards are being followed and used for convenience (e.g. Bluetooth) there is no overall thought about how a wide variety of devices can be used together to their optimum potential for the future.

The definition this paper uses for wearable Technology is: "Technology that is used on or close to the body" (Kirby, 2015). While the definition is largely non-contentious, the boundaries of when a technology can be classed as wearable may be blurred and will become more so in the future. For clarity, Table 1 highlights the four boundaries that are suggested.

<table>
<thead>
<tr>
<th>Level</th>
<th>Boundary</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embedded</td>
<td>Implanted within the body</td>
<td>Pacemaker</td>
</tr>
<tr>
<td>Intimate</td>
<td>Attached to the body in such a way that could be deemed indistinguishable</td>
<td>Contact Lens, Prosthesis</td>
</tr>
<tr>
<td>Mounted</td>
<td>Attached to the body, non-covert</td>
<td>Smart Watch, Head Mounted Display</td>
</tr>
<tr>
<td>Carried</td>
<td>A device that is carried and used close to the body</td>
<td>Smart Phone</td>
</tr>
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Table 1: Levels of Wearable Technology

The proposed external boundary is labelled "Carried", i.e. a smart phone. This is defined as distinctly different to a tablet type device, as the phone is carried close to the body and now seen as
a common adornment, mainly due to size. The Tablet is bigger and not expected to be carried on a regular basis. However, as Smart Phones are growing in size (e.g. iPhone 6s plus, Samsung Galaxy) and tablets are shrinking (e.g. Ipad Mini, Galaxy Nexus) this boundary is going to be further blurred as the social burden of carrying a larger device is accepted and becomes commonplace.

In looking at this from the perspective of a platform, many platforms (cars, aeroplanes, ships) have developed over a significant number of years from a simple platform and technology through to a fully integrated platform. Historically, the transport platform was developed and the sensors, controls and communications equipment was integrated subsequently, with a large emphasis on the user to transfer information between them. Over a number of years, the evolution of platform has progressed to see the development of common data and power buses. This has led to platforms being able to highlight commonly available data items and power sources, with specifications on how they can be accessed, therefore leaving the technology developer to focus on their capability rather than the more common integration aspects.

This paper identifies that integration between wearable devices requires greater development and it outlines the physical, data, energy as well as social challenges that currently impede integration from being fully realised in today’s market place.

As wearable technology develops the type of data that wearable devices collect is set to expand. For example, the data that wearable devices collect are not limited to people’s personal biomedical information but also their geographical location, social interactions, and the vast number of high resolution photos and videos that are now in common usage for most social media platforms.

In the short to medium term, the ability to connect multiple devices to smart phones with a low energy consumption overhead will be a huge advantage. It must also be remembered that in the current networked paradigm, the main flow is from device to the cloud storage system, be that a storage facility such as Dropbox or a social platform such as Facebook.

The standardisation of hardware and software applications will lead to greater integration between wearable technology products. Today’s wearable technology devices communicate largely through Bluetooth and mainly in a client-server fashion with the Smartphone acting as a server. There are some instances of a peer to peer relationship and Google Glass is a good example of the growing requirement of larger data bandwidth requirements meaning that both Bluetooth and Wi-Fi is utilised. These devices have to integrate multiple communication technologies from Wi-Fi to Bluetooth to meet software applications needs with low transmission rates and while not consuming too much power.

The data bus is the framework in which all the wearable peripherals should be able to join to share data. The use of data bus technology has enormous precedent when integrating platforms. Platforms form aircraft such as the Harrier, Tornado and Typhoon, as well as civilian versions, as well as land vehicle architecture that is being developed on platforms such as Ajax. The key here is to treat the human as a bearer, as a platform in which the data needs to be distributed and accessible. It is an exact correlation to the way the human senses already work, where the brain and spine connecting to connectivity to the senses and function control.
This viewpoint of enabling the extension of the metaphor highlights just what wearables are, the extension of the human senses and control functions. The data bus acts like to the human spine.

In many respects this is not a new idea. The notion of a 'wearable motherboard' has been around for years (Park et al, 1999). A notable early example is the Georgia Tech Wearable Motherboard (GTWM) which provided a versatile framework for the incorporation of sensing, monitoring and information processing devices. The Wearable Motherboard provided an inconspicuous way of observing the user's vital signs. However, smart clothes require further development and until advances are made in this area and they become a vital commercial commodity and not a special product, the idea of having a physical network that connects several wearable technology devices may just not be practical. Key factors distinguish wearable networks from other kinds of wireless networks:

(i) Energy Consumption: Wearable devices are commonly powered by small batteries which poses a significant challenge. Wireless network radios will need to operate at significantly lower power levels than for mainstream networks. Today, Wi-Fi and even Bluetooth often cannot be used on body area networks. Bluetooth commonly consumes ten times as much power as desired for a wearable, and Wi-Fi requires much more.

(ii) Reliability: Reliable communication is essential for many wearable devices, particularly those that are used for medical applications. Outages on Body Area Networks (BAN) can potentially have life threatening consequences. Contingency networks may be required.

(iii) Durability: Body Area Networks have to be durable enough to withstand exposure to the weather, water, direct sunlight and extreme temperatures.

(iv) Interference: Signal interference between wearable devices and other kinds of wireless networks also present a challenge. Several wearable devices maybe carried in close proximity to each other increasing the network traffic. Devices will have connected through Body Area Networks will have to recognise each other and network capacity will have to be well managed (Mitchell, 2014).

Wireless Personal Area Networks (WPANs) (also referred to as Body Area Networks) could provide a more pragmatic answer. Initially developed by the medical industry, WPANs provide health professionals an inexpensive and continuous means of monitoring the health of their patient by providing real-time updates of medical records through the Internet. Wireless Personal Area Networks consist of handheld or wearable devices that link and control the user's immediate environment. The devices upload commands and key data to the cloud that are then used by the user's personal applications.

Data requires the transfer of information between devices to enable collaboration. Greater standardisation between devices and applications may be required. Manufactures of wearable technology products are increasingly calling for data standardisation in the industry (Hammond, 2014). At present there are no standard platforms in wearable technology. Some commentators have suggested that wearable software should be hardware-agnostic. There has also been call for more collaboration between wearable designers and software developers which could lead to platform standardisation for software systems (Armada, 2014).

Security experts are warning that the data that wearable technology produces is a gold mine for hackers (Curtis, 2014). This is a major problem because data created by wearable devices can be extremely personal revealing a person's location, regular movements, communications and habits. Indeed, wearable devices collect more detailed data than that produced by smart phones.

Devices such as smart watches and fitness trackers predominately transfer data to an external device wirelessly, via Bluetooth or Wi-Fi, which can be targeted by online criminals. Wearable devices can act as a gateway to other devices such as smart phones, pcs and tablets. The need to strengthen security for wearable technology is literally a matter of life and death. In 2012, a security researcher, Barnaby Jack reverse-engineered a pacemaker to deliver an 830-volt shock to a person's device from 50 feet away. The same researcher also showed that through wireless networks it was possible to affect the way insulin pumps function, without even knowing the device identification numbers (Curtis, 2014).

For example, many wearable devices are unable to connect to the internet independently. Often they require Bluetooth to connect to internet through internet devices such as smartphones. However, the device may still collect and store data even when it does not have a connection to the internet. User's concerned about security may want to determine which wireless networks their devices connect to.

The challenge of collating and transferring data comes down to having multiple devices that connect in a secure and accurate way, whilst still
being invisible to the user for both day-to-day operation and maintenance.

3. POWER

At present wearable devices all have different power requirements. Devices all require some form of electric charge. Currently the vast majority of wearable devices that are available on the market, such as smart watches or fitness bands, all have their own on-board power supplies that need to be charged on a regular basis, depending on their energy consumption. Similar to smartphones, a wearable devices’ energy consumption is dependent on how the device sends and receives data and the frequency in which the device is used. Wireless data exchange technologies such as Bluetooth, Wi-Fi as well as cellular technology can be energy hungry and require the user to recharge their wearable device on regular basis from once every 2-3 hours to once every 7 days. Reducing the need to recharge a device increases its utility.

How wearable devices are charged varies from product to product. Smart watch devices such as Sony Smart Watch 2, the Samsung Galaxy Gear™ and the Pebble all rely on USB charging. This comes with some clear advantages and disadvantages. Advantages are that USB cords have become the most popular way in which users connect devices to their computers. The simultaneous charging that USB cords provide added convenience for the user and enables the user power their devices in a range of different locations providing they have the appropriate USB cord with them. Whereas disadvantages include the fact USB ports make wearable devices vulnerable to water and moisture.

Wireless charging could provide the answer. Smartphones, such as the Nexus already use induction charging that does not require a wire to be connected to the device. Electric tooth brushes commonly work on such system. Another charging method is trickle charging which is a commonly used method of charging modern smartphones and MP3 players. A trickle charger can provide a device with a continuous charge effectively ‘topping up’ a device’s battery without overcharging. By providing a small amount of power, trickle chargers can keep a battery’s power between 95-98% without overcharging the battery. Trickle charging can prevent a devices’ battery from becoming depleted and could be incorporated in everyday wearable technology. However, this charging method has been proven to damage lithium or nickel-metal hydride batteries and shorten their life span (Evans, Accessed 2014). Lithium-ion batteries that are often used in smartphones will become less effective if they are continuously charged. With this in mind the potential utility of trickle charging in the development technology cannot be easily dismissed requires further development. If trickle charging can be incorporated into a wearable technology product that can harvest its power from a renewable energy resource such as solar power or kinetic energy, then wearable devices could become less cumbersome to the user and be more of integrated part of the user’s everyday life. If developers cannot prevent the damage trickle charging can cause batteries that wearable technologies utilities, it may place an added burden of the user who will have replace prematurely aged batteries from time to time.

How to prevent overcharging will be a key challenge in the development of wearable technology. The next generation of batteries for wearable technology must be able maintain their battery capacity over the life span of the product without requiring replacement.

The growth of technology sophistication within wearable devices is rapidly increasing and is another example of Moore’s law in action. This technological growth is not without significant consequence though as more processing performance leads to a significant growth in power demand. This highlights one of the biggest issues, in that the development of battery technology has not been able to keep the same pace of performance to keep abreast of the computing performance. This means that a significant restriction in the wearable technology market is the physical size and weight of the on-board battery technology and the charging mechanism (Costa, 2014).

Energy harvesting, the ability of wearable devices to collect and store energy from its immediate surroundings and transform into exploitable electric charge, is another frontier that designers will have to break through if wearable technology is to become fully integrated into everyday life. Energy harvesting would allow generation of power through movement or thermal energy. Hence energy harvesting solutions are critical to making wearable technology feel like a natural, consistent part of our lives (Defeo, 2013). Solar power could also help developers overcome the energy challenge facing wearable technology. Using tiny solar panels that could provide enough energy to power wearable devices. One obvious drawback is that solar panels have to be exposed to direct sunlight. If a solar panel is cover by something like a shirt sleeve, then the device will not charge. Nonetheless, solar energy could provide an exciting opportunity for smart clothes, where durable solar cells could be integrated into a garment. Yet significant developments in solar cells will be required.

Another option could be a thermoelectric solution. By transforming heat into electric energy, the human body could potentially power the next
generation of wearable technology. Electrical energy is produced the Seebeck effect which is when semiconductors produce an electrical current whenever a temperature gradient occurs so whenever one side is warmer than the other. The human body, which is constantly emitting heat, might be used as the hot side of the equation while the surroundings can pose the cooler side that is needed for thermoelectric harvesting. The amount of energy produced will depend on the variation between high and low temperatures. This could be an ideal solution for devices that have direct contact with the human body and could provide a constant source of energy.

A further solution may be found in piezoelectric systems which convert vibrations or shocks into electrical energy. In what is known as the piezo effect, energy is generated whenever the element is vibrated or shaken. When applied, wearable devices could be powered by the vibrations from walking and moving about. However, this energy solution required significant development this solution generates comparably small amounts of energy and could struggle to power the wearable devices. Interestingly scientists are now developing polymeric piezoelectric fibres which are durable and could be integrated into clothes (Schumacher, 2014).

The new generation of wearable and flexible gadgets, such as smart watches, glasses, and fitness trackers, all require batteries that are flexible and small enough to fit into these devices. This could give a big boost to the prospects for thin film and printed batteries, but it’s not yet clear which companies will benefit most. Existing thin film (TF) battery suppliers may be able to leverage their expertise, but OEMs are pursuing wearable applications and developing their own batteries, posing a threat to the TF battery suppliers.

Circuit Lithium-Ceramic Battery (FLCB) technology has been highlighted as a possible solution. Flexible in its design and capable of producing an electrical charge even after it has been cut, punctured and exposed (Etenjitv, 2012). This type of battery, are thin, flexible and light and importantly do not require protective casing. This means that this technology can be amalgamated with previously unusable areas of a device such as its protective casing. With further development the company ProLogium has suggested that the technology could power wearable technology fabrics (Mohney, 2013). The potential of FLCB technology has given rise to a range of ideas about how such batteries can be stored on the human body. Power belts, power bags and power cloth are just a few ideas that have been suggested by commentators seeking to find a solution for wearable technologies. Researchers at Rice University have developed a new lightweight battery that combines the flexibility of graphene with the high storage capacity of inorganic metal compounds (Williams, 2014).

Despite these challenges, flexible, thin and light batteries are seen by designers as part of the storage solution of increasing the compatibility and utility of wearable technology on humans. Therefore, developers are looking to alternative battery materials, other than Lithium, that can provide the flexibility required. Super-capacitors and graphene show lots of potential and they might significantly improve the efficiency of batteries and capacitors, and consequently improve the overall performance technology. Such structural capacitors might manage turning the casing and other wearable components into an energy store thus reducing the amount of space needed for a separate battery.

The growth of wearable technology is largely restricted by the energy needs of the devices. As the battery technology innovates, then the wearable technology itself will expand its durability.

4. SOCIAL INTEGRATION

Wearable technology has been around for many years, since the 1980’s and despite the availability of Smart watches, E-textiles, Fitness trackers and Google glass in the market place wearable technologies are yet to become part of mainstream society. There are physical and social challenges that are preventing technologies from becoming a part of everyday life for most people.

Manufactures of wearable technology products have to balance the functionality of their product with aesthetic demands and expectations of their consumer. This delicate balance between functionality and style poses a key challenge for wearable technology producers. Today’s wearable technology products are a result of manufactures focusing on the technological function of their product more than the wearable aspect of the product. In short, aesthetics and ergonomics of the product are sacrificed for functionality.

Manufactures of wearable technology products know their devices will be more appealing to the consumer if they offer more functionality. This means that the race is on to offer functionality matched with aesthetic appeal. The consumer wants and expects wearable technology to be small and highly functioning. How devices process, exchange and present data will be the key to meeting this challenge.

The need to make the technology robust is an ongoing challenge. One particular issue that is raised is the need to waterproof technology. This needs to include the ports and other connections (Sacco, 2014). Both the Micro-USB and the Apple
lightning connector and associated device ports are not waterproof. The way this is currently generally overcome is through the aftersales market of device covers which can provide robust and waterproof capabilities.

The social acceptance of wearable technology is going through a rather turbulent time due mainly to Google Glass being brought to market. It is the closest to mainstream head mounted wearable technology which is very much on "display" when it used. Within a week of launch in the UK, it was banned in all UK Cinemas (Child, 2014) and the Department of Transport banned it even before it was launched (Vincent, 2013). This highlights that wearable technology needs to consider the social environment that it is developing into. While many people may be early adopters and digital adapters, there is a significant section of society who are concerned about various aspects of technology and that they view the development of personal/wearable technology with mistrust. In 2013, a study by the University of London highlighted that 1 in 5 UK residents wanted to see Google Glass banned, 12 months before UK release (Austin, 2013). 51% had concerns over privacy and two thirds calling for regulation.

The general acceptance of wearable technology in society may occur naturally over time. The current market for Wearable Technology is the Early Adopter and the Digital adapters, but as time goes on, the younger generations are much more accepting and in many cases reliant on technology. These Digital Adopters will see the use of wearable technology as a natural evolution of technology and, if previous technology paths are to be followed, then society will evolve with technology regardless of the current attitudes. The evolution of the Digital Natives will be much more accepting of technology as an essential part of life, both functionally and aesthetically, and therefore will broaden the acceptance and include it in their social norms.

There is a big issue regarding personal security and, in particular, physical security. With wearable technology being keenly priced many people are walking around with quite a valuable amount of technology on them. This leads to an increased risk of physical robbery and associated assault (Curtis, 2014). Along with this, the increased risk of identity fraud and hacking of personal networks.

In recent years, there has been a clear divide between online and offline activity. As time has progressed the divide has begun to blur, and wearable technology has accelerated that blurring of the divide (Breed, 2014). The way people are using wearable technology to reflect what they are doing on a day to day basis, such as exercise tracking, taking photos and video and then posting all the information on social networks such as Facebook and Twitter to share with their online community demonstrates this.

The issue of third-parties accessing a user's data, including their location and biometric information, has sparked debate and controversy. Manufactures and software providers have yet to set the limits on how data can be used and Governments have been cautious about regulating how such data is used when collected by a wearable device (Costa, 2014).

The increasing numbers of consumers buying wearable products suggest concerns regarding privacy and security are not dissuading people away from these products. Although recent survey conducted by PwC in the United States reports that 82% of Americans claim they are worried that wearable technology will invade their privacy (Welsh, 2014). In today’s marketplace consumers have to decide for themselves whether the benefits of owning and using a wearable device outweighs the potential security risks and privacy concerns.

The social acceptance of wearable technology is the most significant enabler (or barrier) to its future technology. The technology needs to take into account aesthetics as well as be open about the usage of personal data and data security.

5. CONCLUSIONS

While wearable technology has been around for a number of years and some products are quite a considerable way down their technology lifecycle, on the whole wearable technology is still in the early phase of technology development.

There is clearly a need for greater standardisation of data platforms that will enable several wearable devices to exchange data. The design and security of Wireless Body Area Networks also requires further development in order that the use of wearable devices might become commonplace in industries such as medicine or by the military and law enforcement.

Battery life and the durability of wearable devices that are exposed to the everyday world needs to be greatly improved. Batteries need to become smaller, more flexible, more robust and, importantly, more efficient. Similarly, how batteries are charged needs to be further explored.

Socially, there remains physical and cultural barriers that are deterring people from using wearable devices in their everyday lives. Privacy concerns need to be addressed by both software designers, preferably without the need for Government regulation. Equally the design of wearable devices has to be aesthetically acceptable. Square and bulky products will not succeed and manufacture will have to balance
functionality with aesthetic appeal. What is clear is that wearable devices should integrate with the human body and be fashionable accessories that the people find desirable to wear.

Wearable devices will become more appealing when they offer more functionality and when they become less alien to the public. The challenges that manufacturers and designers face are immense because the technology is still young, but its potential utility in our everyday lives is great.

6. REFERENCES


