Tampere University

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# WEARABLE DEVICE AND THE DISPLAY IN THE SOCIETY

Bachelor Thesis
Faculty of Engineering and
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# ABSTRACT

Thien Vinh Tran: Wearable device and the display in the society
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This thesis study about the wearable device and the device display of it. The aim of the thesis is to give out the overall look about what is wearable device and how many kinds of them are there in today's commercial worlds. Moreover, it also brings out more knowledge about how the information and data are display on the wearable device.

As a literature review, many articles and reports are studied to bring out the most identical and overall look about the wearable device. As there are many different kind of the wearable device base on their shapes and usages, the thesis bring out one scaling to specify them into three main groups base on the place the sensor are put.

Moreover, based on the basic principle of the wearable device and the work of studying more reports, the thesis gives out the most common advantages and challenges of the wearable device and an overall look about its daily application. Many challenges are found with the limited technology and industry nowadays but as many reports have given out many solution, the future of the wearable device will be bright.

Keywords: wearable device, wearable device display

# PREFACE

This thesis is written based on the interest of understanding how new technology such as Apple Watch and VR glasses interact with people in the society and how they can

Petit for supporting me in my affect their daily habits

I would like to thank my supervisor Thomas Olsson in helping me writing this thesis. I would also like to thank Laeticia first phase of the thesis writing.

Tampere, 26 April 2022

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# Table of Contents

# LIST OF SYMBOLS AND ABBREVIATIONS

| | |
|---|---|
| GPEs | Gel Materials |
| MEMS | Micro-electronic system |
| AF | Atrial Fibrillation |
| PPG | Photoplethysmography |
| KB | Kardia Band |
| LED | Light Emitting diodes |
| LCD | Liquid crystal display |

# 1 Introduction

Wearable device is a technology device which has a sensor device on its body. The wearable device usage is quite simple where you just need to put them on one of your clothes such as T-shirt or trouser. Moreover, wearable device can be worn as watch or accessory or even directly implant into your own body.[1]

The goal of this thesis is to understand the background of wearable device which is common in today market. Moreover, the thesis also represents the advantage and dis-advantage of each kind of wearable device and come up with some self – reflection solution.

The thesis will begin with the overall definition of wearable device and the division into different types of. Following by describing the critical facts of each type, the thesis will separate wearable device into groups and determined their advantage and drawbacks. Finally, it will give out some solution based on resources and literature that has been found.

## 1.1 History of wearable device

The wearable device was first started around 13$^{th}$ century by English friar Roger Bacon. He had written some scientific principles about the corrective lenses that he used in his Opus Majus [16].

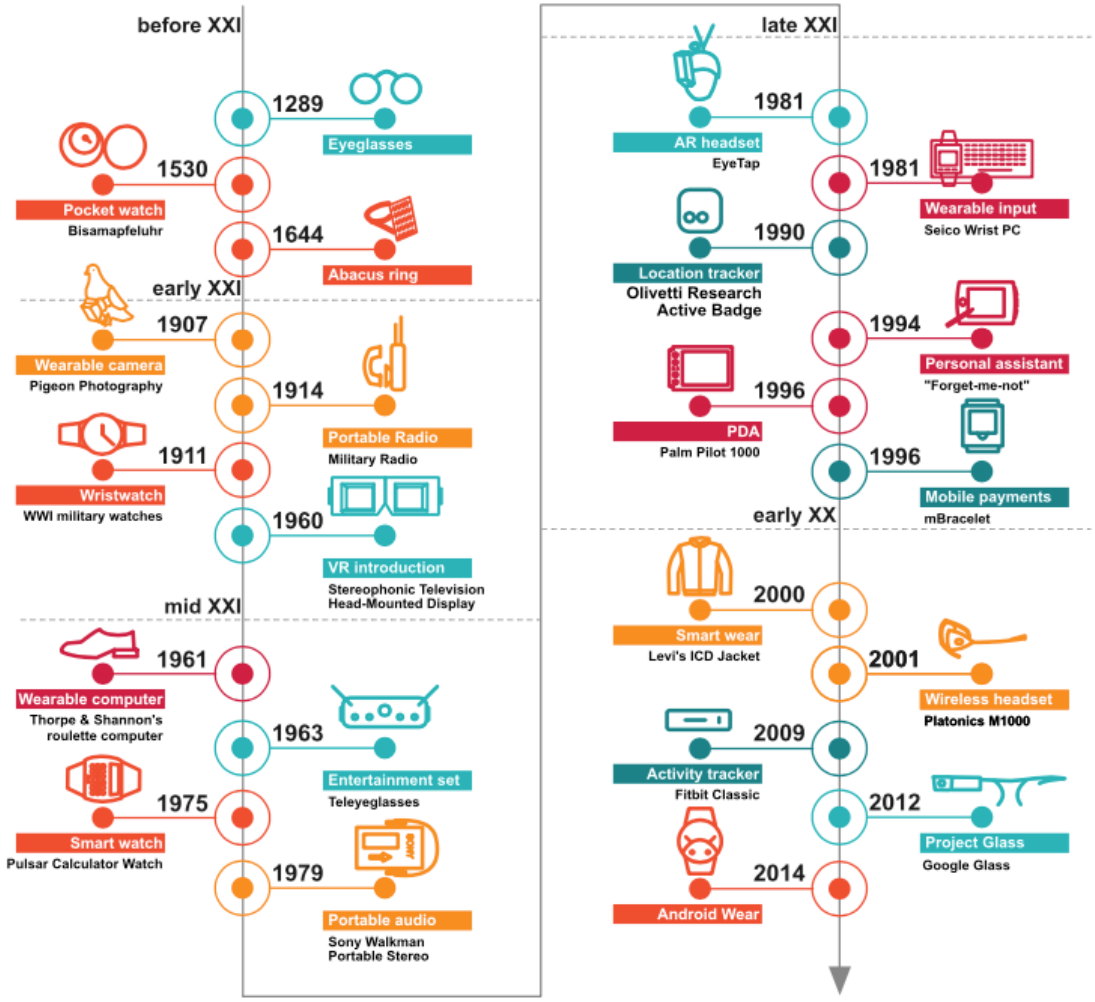


**Figure 1**: The history milestone of wearable device

Based on the Figure 1 and article [15], in the early of 20th century, the first idea of portable camera was introduced by Pigeon camera which was operated by Julius Neubrommer. This was considered to be the breakthrough in the wearable device industry as the camera was invented in the period of World War I, it appeared not only taking the movement of the pigeon but also catching up the military demands. As the additional function of the camera, it then developed into military camera and was widely used in the rest of World War I and the World War II. After World War II, another breakthroughs was brough when Morton Hellig successfully developed VR technology and VR simulation technology.

In the middle of 20th century, researchers from MIT – Edward O.Thrope and Claude Shannon presented a timer in a shoe which can predict the position of roulette balls. This device was considered to be the first hidden and wearing device and marked a big milestone in the development of wearable device industry.

In the end of 20th century, the industry was even more developed when Steve Mann introduced the EyeTap project and a back-pack like computer in 1981. This device will collect and process data from a next – to - eye – mounted camera and present it in a form of a glasses. This hit a big step and gave out the basic for the development of AR glasses nowadays and Google Glasses.

Later on, in the early of 21st century, clothing was brought into the wearable device industry by Levi. They introduced a jacket made by the technological material with a system of electronic gadget inside. After that in 2001 , one of the first wireless headset – M100 was introduced with the combination of Bluetooth technology opened a bright future for wearable devices development until todays.

## 1.2 Wearable devices principles

In this part of the thesis, a brief introduction about what principles is needed for the wearable device is discussed. As wearable computers are small and wrist – mounted, it requires to satisfy three main goals to support users.[15]

- The first goal is the flexibility and mobility of the device. Since the shape of a device is simple and small, it should be carried where the user brings them with the most convenient and the least complexity.
- The second goal of the wearable device is to have a reality augmented which means that all the environment images, sound need to be overlaying generated. This will support the devices to fully function in different situation and different environment status
- The last goal of the device is to provide as much context sensitivity as possible. As the device is carried by users' and can be aware by many surroundings and environment, developing such a context sensitivity application can help in exploiting the intimacy between people, device and surrounding's

# 2 Wearable device

In this chapter, the thesis will give out the brief introduction about wearable device and what materials, usage and sensor modes there are in different kind of devices.

## 2.1 Materials of wearable device

As being designed to collect be easily worn and used by people, wearable device materials need to be light, soft and corrosion – resistant.[1].

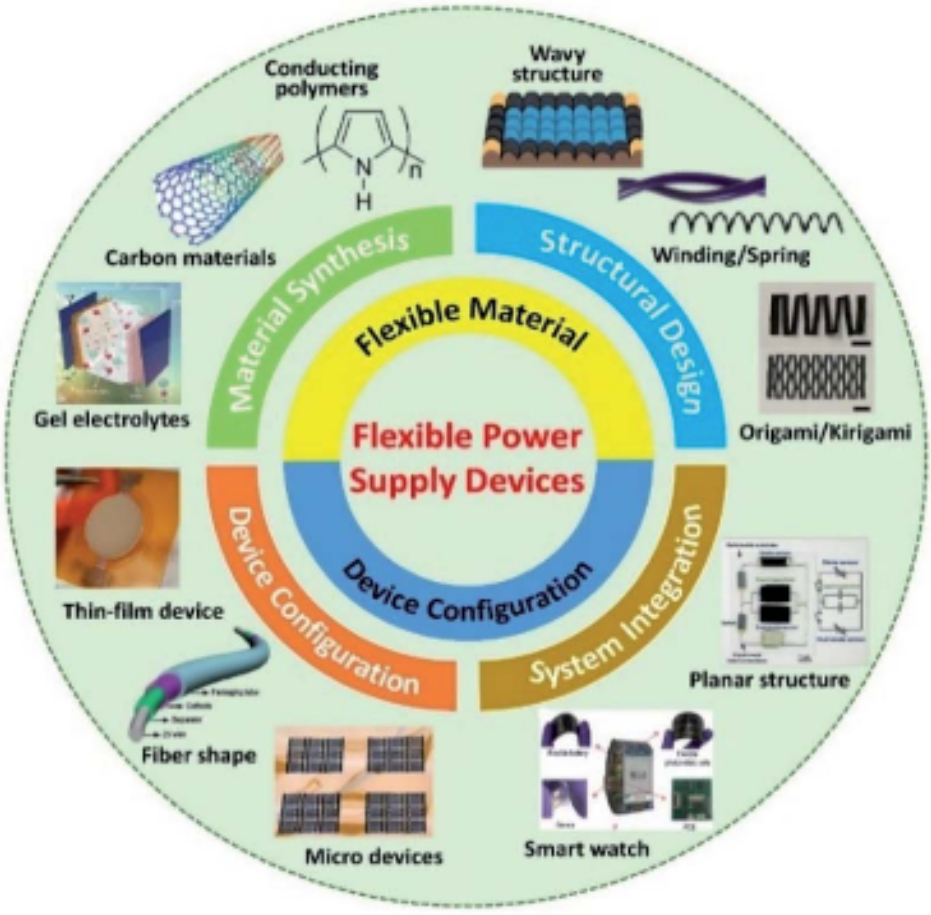


**Figure 2**: Materials used in wearable device

Based on Figure 1, there are two basic categories of the materials: fabrication of intrinsically flexible materials and construction of special architectures through ration structural design.[6] Moreover, as the technology are developing there is one more important materials type that can be used in implanted wearable device (discuss in part 2.2) which is called nanometre materials.[1]

### *2.1.1 Flexible materials*

The first type of fabrication materials is conducting polymer materials. They are very flexible, lightweight and conductive, which have been widely used to develop flexible energy storage devices. Apart from the polymer materials, carbon-based materials also play an important role in the structure of wearable device as they can serve either as an active components or as a conductive substrate. Gel materials (GPEs) in the order hand, are the combination of polymer molecules and liquid electrolyte making GPEs more stable and have higher ionic conductivity. As a result, GPEs place an important role in forming electrochemical power device and components that require strong stretching resistant. Lastly, packing materials play an important role in protecting the devices. However, based on the usage of protection, packing materials is less flexible than others. These type of materials are usually used in the combination with high mechanical stretchability materials such as aluminium plastics films or thermo shrinkable tubes to form a strong but flexible protection for not only the power source but the mechanical chip of the device.[6]

### *2.1.2 Device configuration materials*

About the structural design configuration, the types of design are divided into three main kinds that are presented in the table below.

| | |
|---|---|
| Wave – shaped design | A 2D configuration that can be generated from a process of transferring rigid materials onto a pre - stretched elastomeric substrate |
| Winding shaped design | A highly stretchable electrode which is constructed by combining a winding or coil spring – like structural design to form a coil which act like a spiral spring. |
| Origami and kirigami inspired design | These are two traditional Japanese craft techniques. Origami is a folding of paper while Kirigami is a combination of paper folding and paper cutting. These way of constructed materials are used in nano |

| | |
|---|---|
| | technology and 2D or 3D designs to enable high stretchability. |

**Table 1**: List of device configuration materials

### *2.1.3 Nano Materials and Organic Materials*

Nano materials and organic materials are the materials used in specific kind of devices.

- Nano materials: carbon nanotubes, metal nanowires, metal oxide nanowires and conductive polymer nanowires. These materials are usually used in implanted devices to related with $H^+$ or $OH^-$ in order to detect the pH value in the user body.
- Organic materials: these materials are the organic semiconductors or conductive materials what are used in wearable device. The advantage of this kind of materials is the flexibility and extensibility with a low cost.

## 2.2 Contact wearable device

Contact wearable device follows the method of directly attaching the device to the skin surface through adhesive or adsorption force. With this method the easiest way to contact between human body and the device is through sweat. This skin fluid with provide not only human status but also related to human physiological status. Moreover, with a high developed technology, wearable devices are now programmed with signal transduction and the wireless transmission technology in order to display accurate information throw evaluating body sweat to users' mobile phone. This will help user to easily catch up with their own situation.[1]

According to Daniele Leonardis, contact wearable device works in sense of touch for interaction in virtual environments and teleoperation applications. Most of the haptic devices work basically on kinaesthetic feedback, others also make use of tactile stimulation, vibrotactile and electro – tactile simulation. Moreover, studies and research show that, cutaneous stimuli are the fundamental in recognizing shapes, integrating curvature and local surface orientation. This will improve the illusion of presence in both remote and virtual environments. [4]

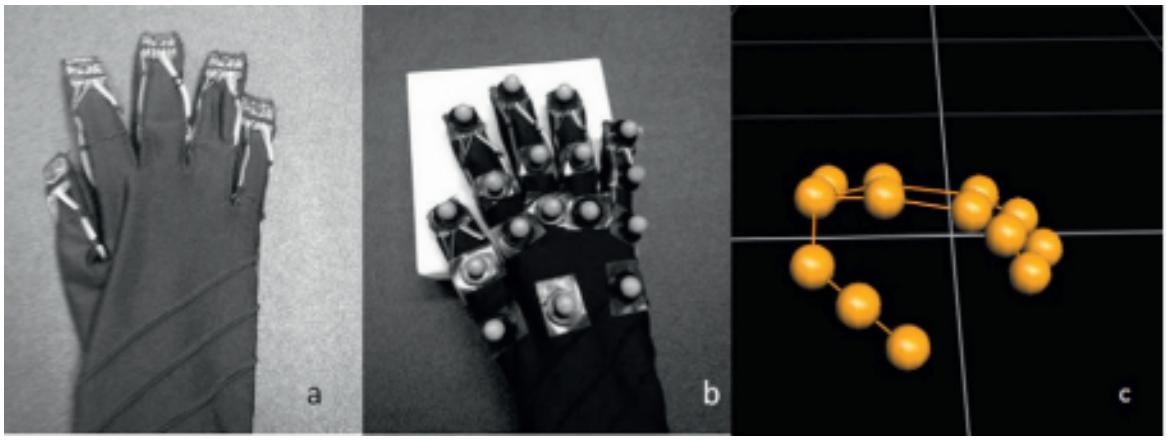


**Figure 3**: The sensor based gloved

In the Figure 1, the device is designed to extract higher order motion data from people hand movement. This device is designed in the goal of collecting anthropometric data from a human limb and avoiding collision between the linkage and the wearer's limb. The glove's sensor consists of tri-axis accelerometers which locates at the fingertip. Moreover, the optical markers are placed in accordance with a reduced marker protocol [5]. This example of a contact wearable device is one of the most important parts as it appears as a clothing at a visible display which will be discuss in chapter 3 of the thesis.

## 2.3 Implanted wearable device

According to Liu Feng et al., implanted wearable devices are used in body detection in the form of microneedles. The used of implanted wearable devices are used to detected glucose, lactic acid and alcohol through the channel of interstitial fluid. The shape of the implanted device is a microneedle one with the height of only a few hundred microns and the size of it will be very small in order not to damage the dermis.

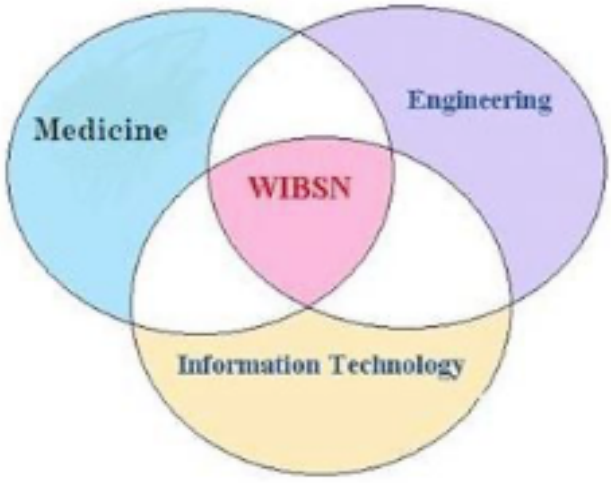

**Figure 3**: Interdisciplinary sciences

According to figure 3, the idea of bringing the engineering and information technology into medical research and healthcare has been brought out recently and come up with the implanted wearable device. The implantable devices are the integration of a large scale in the field of wireless telecommunication technologies such as 3G, Wi-Fi Mesh and Wimax. Ashraf Darwish also claimed that in the following year, the amount of implanted wearable device would rise strongly due to the development of micro-electro-mechanical systems (MEMS) technology, wireless communication and digital electronics.[7]

The sensor network is designed in two following ways [7]:

- Sensors can be placed far away from the observed occurrence. Large sensors with complicated algorithms for distinguishing objects from background noise are needed for this strategy.
- Sensors which perform sensing function will be deployed. These sensors and communications network topology will be carefully designed. The data which is collected by these sensors will be transmitted to the central nodes where the computations are performed and data are fusded

Finally, the usage of these kind of wearable device are used in military as a targeting system, environmental applications as a nature species and in health care with the patient tracking in both biological status and physiological status.

## 2.4 Wearable sensor

Wearable sensor is an item which is connected to a device item such as smart watch and glasses which are integrated with audio and visual image processing, recording equipment and wireless connection [1]. This way of combination will may not active fully function usage of the sensor, but it will be more flexible for user to bring it anywhere and tracking their status as a good display of the devices (the display will be discussed in chapter 3)


**Figure 4**: Apple watch display of function

For details, in an article about Apple Watch [8] and Figure 4, the authors have given some sensors that are used in the Apple Watch under the image of wearable sensor based on the AF (Atrial fibrillation) function.

- Photoplethysmography (PPG): PPG is the proportion of the volumetric difference in the heart by estimating light transmission or reflection. During systole, the ascent in pressure powers a forward beat into the vein. The gadget focuses light on the skin to distinguish a heartbeat by estimating the distinction in the amount of light reflected back to the sensor. The sensor is generally put on the skin in the region where the corridor is proximal to the skin. In this way, the pulse is estimated utilizing a calculation. PPG innovation can be utilized in actual sensors, brilliant watches, or even telephone applications to quantify pulse.
- Kardia Band (KB): KB is an item made by AliveCor intended to be utilized as an Apple Watch embellishment. It copies lead I and can record a cadence strip for

30 s. The KB application can then utilize a calculation to identify whether the strip shows atrial fibrillation (AF) or not.

- Handheld EKG devices: One more way Smartphones can be utilized as EKG screens is by communicating with peripherals, for example, an extraordinary cell phone case with installed terminals to obtain, store, and move single-channel EKG rhythms like AliveCor Heart Monitor (AHM), which has proactively been US Food and Drug Administration cleared and Conformite Europeenne (CE) checked, and My Diagnostick handheld EKG stick.Wearable device display

In the conclusion, this is one of the most common ways of attaching a sensor or a wearable device into a big shape of technology.

# 3 Device Display Technology

## 3.1 Device display technology

Contact wearable device display can be divided into main categories:

- Devices that can emit light on their own
- Devices that alter how light is reflected

According to Florian Heller, Kashyap Todi and Kris Luyten,[2] there are two main type of devices that can emit light on their own which are light – emitting diodes (LEDs) and Liquid crystal display (LCDs) while devices that reflected lights are electrochromic inks, thermochromic inks and electrophoretic display.

## 3.2 Device Display Design

Based on [2], the shapes of contact wearable device can be form in different shapes and ranges. According to Schneegass et al., the spaces design of wearable device needs to acquire a wide range of input and output modalities and a high screen resolution. These two aspects with directly affect how a device interacts with the user in term of information announce and receive.[3]

In order to give out the best user experience for contact wearable device, Florian Heller suggested two overarching aspects for the display of it:

(1) On – body placement: considering the device as an attachment to the user body, the display of it will heavily influence user moment and physical properties. This will lead to the idea of making them as accessories, clothing or on – body attachment.

(2) Display content: wearable device contents and information are considered to be one of the most important parts considering if the wearable device is user – friendly. As this result the display of content need to be taken a heavy responsibility on. The display is divided based on display properties and information density.

### *3.2.1 On – body placement*

According to [2], there are three main way of space design for the wearable device among people body. The first one is accessories design, the second one is clothing and the las one is skin and body.

First way of body placement is about accessories where body places are “desks” that put the wearable device on.

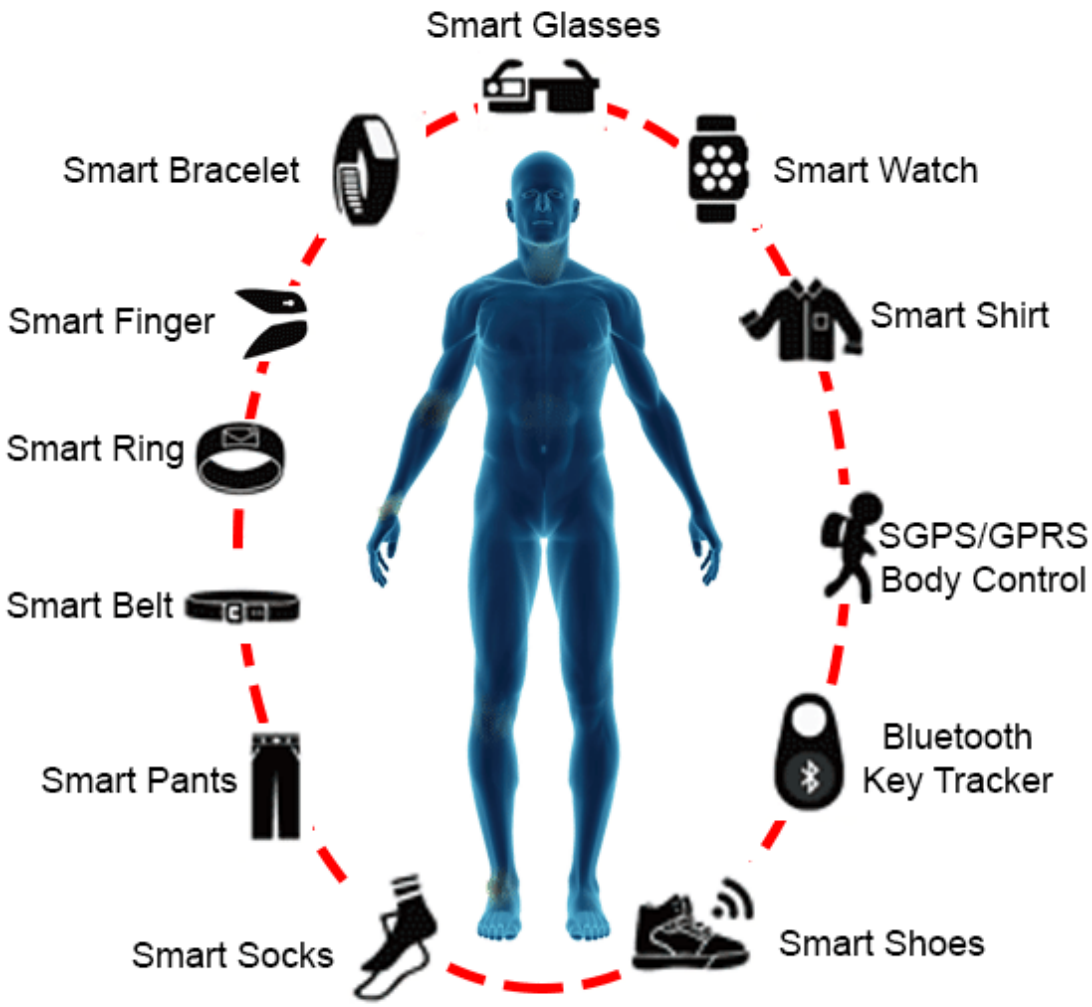


**Figure 5**: Body placement

Based on the figure 5, there are some basic factors for wearable device placement:

- Eyewear: this is the place where people vision at so the main way of design for wearable device should be glasses. The advantage of this way is that glasses or nowadays called smart glasses display the information directly to user vision.

This method will help user to catch up with the information in no time at all. However, these types of devices will cause distraction and distortion without purpose for the users. One of the most common examples of this type is VR glasses. They provide information 360 degrees around users however they have many distractions.

- Headwear: this way of design is similar to eyewear as the aim of this is to have the information delivered directly to user sight. One more advantage of the headwear comparing to the eyewear is that it has environmental contacts (for example helmets).
- Watches and Bracelets: these way of design bases on the wrist placement. This is one of the most common and important way for putting wearable device as it is easy to interact and get information. The first generation of watches and bracelets design are the Nike and Fuel Band which track user fitness and biological status. However, this kind of tracking is combined with smartwatches which have more functionality than a single bracelet one.
- Jewellery: this is one of the most challenging ways in attaching a wearable device. Taking an example of rings which require the littlest impression. It will have communication with surrounding areas through LED. Besides, chains and Neckbands are not as limited in their size, and can in this manner increment the showcase size or arrive at a higher data thickness
- Gloves: gloves design which is mentioned in chapter 2 is one of the basic form when designing for a wearable device. This offers many movements and interaction not only in public – outside the hand but also private one – inside hand. The challenge of this prototype is that the sensor system needs to be arranged in a way that information from 2 different source are clear.

The second way of placement that can be considered for display is that the clothing. This is a flexible way to design such a display for wearable device. However, as clothing requires many criteria such as wearability, fashion ability and breathability which will make the work of creating hardware for seamless integration and adding components for the wearable device harder. In the summary, the thesis produces a table about clothing

**Table 2:** Clothing design factors for wearable device

| | |
|---|---|
| Shirts and tops | Communicate information about users and surrounding environment. |
| Jackets and suits | Jackets and suits act as the protection layer against external effect. |
| Buttons and zippers | This is the small object which is exposed visual and landmarks on the garment |
| Skirts | Comparing with shirts or tops, skirt provide more integrate displays surface |
| Dress | Dress has many common aspect comparing to skirts and shirts but it requires a more complexity and technology when designing basing on this factor |

### *3.2.2 Display content*

Based on the display criteria of wearable device [2]. There are three main type of render which determine the display of the device: intended viewer, temporal aspects of the display and information density. In this part of chapter 3 we will discuss about the aspect of display content that are used in wearable device.

- Audience: the audience aspect is very important toward the displays as basing on the place of the wearable device, the display need to be easy to catch an eye on. Moreover,
- Temporal Aspects: this aspect refer to the time that the device gives out the content and update them. This is one of the first criteria when considering in the temporal aspect. The second one that can be considered is that constancy of the contents when there are no power.
- Information Density: this part relates to the information range that can be perform by the device. The more the information are collected the more lights and technology are needed to perform it and deliver it as accurate as possible.

# 4 Wearable device in society

In this chapter, the thesis will discuss about both advantage and challenge of the wearable device. Moreover, it will give out the overall look of how user and devices interact with each other.

## 4.1 Advantage of Wearable Device

As comparing in the health care criteria, the wearable device has many advantages towards the laboratory devices and hospital one in the flexible discipline. According to Bijan Najafi, while laboratory instrument requires a controlled space, wearable devices can work independently at almost any situation and anywhere. As this result, it will help to track patients' symptoms even when they are not under control of the doctors which eventually help both the user and the doctors to get up with the information as soon as possible.

Based on the clinical cardiology experiment [14], the wearable devices have a higher speed in diagnosis symptom. Moreover, as fast diagnosis, it provides such a great opportunity to put the tracking on a large amount of people.

Moreover, according to the article [15], wearable device shows a big perspective in boosting up productivity. Taking the example of Boeing Computer Services, before using the wearable device, the problem solving requires many complex steps from problems detecting then looking for manual and then trying to diagnosis problems and finally fixing it. This will may take many times causing the planes to retrieve themselves. However, after considering the benefits of wearable computer, they equip many of them which can directly access to all the plane's documentation from both storage and wireless. As a result, the mechanics as well as the engineer can easily access to what they want to find and boost up the working and benefits. One more benefits that the wearable brings is that it allows user to have such a hand-free task for multiple problems.

In a nut shell, most of the advantages almost come from the flexibility and the convenient that the wearable device brings to the user. However, there are some disadvantage that the wearable device has which will be discussed in 4.2.

## 4.2 Challenge of Wearable Device

Based on the research conducting by Bijan Najafi [11], one challenge that the wearable sensors has is that it is hard for those to extract clinical data when being put in such a system with a large number of sensors. For example, when some data is collected base on the complexity of the sensor systems or the device management, the health tracking application of itself will be limited. One more challenge for the wearable device is that the way devices sensor would face more challenge as it has to cooperate with the user daily life. This requires the devices to be as comfortable as possible when being carried by the user.

According to [14], one of the most important disadvantages about the wearable device is the data and information flow is so huge which will cause some limitation in working process of a device. As Bijan Najafi mention in his article, the complexity of the system and the load of data that the sensor can collect may overwhelming the ability to analysis and reports. Moreover, as a requirement of a wearable device is strict, the challenge for display to deliver as much information as possible toward user is already a big question.

## 4.3 Application of Wearable Device


**Figure 6**: The application of wearable device

According to [9] and [7] and figure 6, there are many different applications that wearable device can provide in our working days:

- Medical health care: this is the application of monitoring patients' health and making diagnosis as well as prediction in order to prevent deathly disease such as cancer. This application usually appears in implanted wearable device as it is the one which gets inside patients' body and making internal diagnosis.
- Home application: household applications such as micro-wave, refrigerators or vacuum cleaners can be added with outstanding technology like smart sensor. This will help the user to communicate with the applications easier and controlling them with the external network when they are not currently at home
- Education: with education, wearable device acts the same function as medical health care as it is monitoring stress levels and health conditions from the data that is extracted from the study curriculum.

- Sports: this application is considered to be one of the most common one when considering wearable device application as in sport activity, biology and physical status of a sport player changes every second. They need to catch up with every second changes to determine the best solution or practice curriculum for each person.

# 5 Conclusion

First of all, the thesis introduces the history of the wearable device from when it was just an idea on paper and research then having many breakthrough in some specific time until nowadays.

Moreover, the thesis gives out basic information about the definition of wearable device and its display. By dividing wearable device into many different types, the thesis gives out an overall look of the advantage and challenge of each time. Many criteria are given out to be considered as the challenge because when deciding to put functionalities into everyday equipment, the most important things is to make them comfortable for both user daily activity and user experience.

Moreover, when considering about the advantages and challenge of the wearable device, the principles of it makes up to with both the advantages and challenge. First of all as the goal of being flexible, the materials of the wearable device must as flexible as possible leading to the display technology to be as the same level. Next, when considering all of the situation and environment that the device needs to face when such a accessories or clothing parts of the user being, the challenge of having enough energy and sensor to catch up all of the changes and making records appears.

The last one in thesis following the claims from the article [8] which emphasises that although there are many big challenges, wearable device technology is said to be the future of devices and clothing in the future.

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