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A Systems View of Wearable Technology in Today's World

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ABSTRACT

The paper provides an insight into Wearable Technology and a brief about the wide range of applications of wearable technology in today's world, bringing "system thinking" perspective into the subject. Wearable technology is the technology of the future and has the fastest growing market in the world. Instead of going to a device to getting one's work done, these devices are worn by individuals. The device then works for the individual all round the clock. A small, portable and light weight device can be designed in such a way that it can be easily integrated into one's daily wear. Applications using this technology are increasing day by day. Wearable technology is used in many fields from sports, health, lifestyle, gaming etc. But other question arise due to the immense popularity increase of these small devices. e.g. (1) How is this advancement going to improve human life in due course? (2) Can these achievements lead us to some chaotic situation? (3) Are there enough studies about how these technologies are going to evolve different systems (like, medical, legal, economical etc.) in future?

In this paper we delve into two such applications - (1) Health monitoring device and (2) Crime fighting device in detail and outline the probable impacts with regards to the system thinking interpretation. We view the two applications as individual systems and analyze the factors that affect them.

KEYWORDS

Wearable Technology, System Thinking, Casual loops, Stock and Flow

1 INTRODUCTION

"Small is beautiful" has always been in vogue right from the Charles Babbage's computational computer to today's PDA (Personal Digital Assistant). Technology has manifested itself into micro miniature forms with the power and processing speeds. In today's busy life, everything is getting automated. A newer version is being upgraded each day. The dream about a device that a person can wear all day long to track a plethora of activities and health has become true and the popularity of these devices are increasing than ever before. In recent decades, wearable technology has ignited a new type of human-computer interaction with the rapid development of information and communication technology. Wearable technology assigns the attributes of mobility and connectivity to users so that users can access on- line information conveniently and communicate with others (or other things) immediately while moving [5]. The technology is characterized by "wearable", as its name implies in contrast with the concepts of simply holding portable compact computing devices. Wearable computers are inherently different from portable com- puters such as sufficiently small laptops or separated desktop computers; accordingly, it is highly important to understand the value that can be acquired from using wearable technology by users. An early experimental study conducted by Steve Mann, one of the pioneers in wearable technology, started by strolling around the street carrying a computer and wireless equipment that looked cumbersome and heavy [18, 19, 21]. In contrast with current wearable devices, which are light, unnoticeable, and beautiful, early wearable devices looked entirely different, but the wearable concept was clearly exhibited by "wearing" the devices on the user's body to extend the user's mind and body practically [19].

Pulsar's Calculator Wristwatch can be considered as the first consumer wearable device to achieve global success. In 2000, the first Bluetooth headset was sold and in 2004, the first GoPro was launched. Google Glass, released in 2013, was the first voice-operated optical head-mounted display product to combine hands-free internet access with augmented reality and the ability

to capture images. The wearable market is promising, as the number of connected wearable devices worldwide is expected to jump from an estimate of 325 million in 2016 to over 830 million in 2020 [2].

Inspite of gaining popularity, wearable technology is facing some critical challenges. In contrast with the positive prospects of wearables from various sectors in its early days when wearable technology started be- ing commercialized, many survey results show that its proliferation rate into public society has not met expectations [10, 12, 15, 16]. The results found that one-third of American consumers who have owned a wearable product stopped using it within six months. Moreover, a large number of people no longer use it even after owning some form of wearable devices. Here comes the basic question what is the problem with wearables? To expand its use with the public, it is necessary to pay attention to the essential principle related wearablesâĂŤthat they should be closer to users' daily lives than any other devices. Nonetheless, the meaning of the term "wearable" tends to be mentioned as only the restrictive definition, which is fitness tracking devices that are accessorily used to maintain individual health status worn on a wrist. Major wearable devices such as smartwatches and fitness bands that have launched in the market up un- til today include the features of activity tracking and the functional sensing of biometric information such as the heart rate and body temperature. Services provided by wearable devices can display not only the current heart rate and activity but also how many times the user turned over during sleeping. However, apart from whether these functions and services are universal requirements from a user's perspective, it is not yet clear whether these functions and services are appropriate applications for the effectiveness of wearable devices.

For example, although collected information is displayed in some applications that work with smartphones, merely listing the measured data is not sufficient to maintain the use of wearable devices. The issue of the effectiveness of wearables is one of the claims raised from the early days of noticeable product launches in the market up until now. Donald Norman, a cognitive scientist and pioneer in applying human cognition to design, mentioned that "much of what is being done with wearable devices is happening simply because it can be done [23]". What Norman pointed out is that the current wearable technology trend mainly focuses on core technology development while ignoring practical extensions of mind and body through technology, which is an essential inherent objective of wearable technology. Nonetheless, it is now quite promising that more researchers and companies are focusing on researching wearable applications and services that can provide the best value from the users' perspective.

In this paper, we try to encompass all the relevant circumstances that have potential to dictate the fate of two specific type of werable devices in future. We discuss how the 'Health Monitoring Chip' and 'Smart Hair Clip' can evolve in this thriving era of wearable technology from a system thinker's point of view.

2 BACKGROUND

2.1 Wearable Technology

The terms "wearable technology", "wearable devices", and "wearables" all refer to electronic technologies or computers that are incorporated into items of clothing and accessories which can comfortably be worn on the body [27]. These wearable devices can perform many of the same computing tasks as mobile phones and laptop computers; however, in some cases, wearable technology can outperform these hand-held devices entirely. Wearable technology tends to be more sophisticated than hand-held technology available in the market today because it can provide sensory and scanning features not typically seen in mobile and laptop devices, such as biofeedback and tracking of physiological function. Wearable technology has some form of communication capability and allows the wearer to access real time information. Data-input capabilities are also a feature of such devices, as is local storage. Examples of wearable devices include watches, glasses, contact lenses, e-textiles and smart fabrics, headbands, beanies and caps, jewelry such as rings, bracelets, and hearing aid-like devices that are designed to look like earrings.

Wearable device consists of a small chip with built-in wi-fi and Bluetooth with the power consisting of tiny embedded systems that transmit information via Bluetooth / wi-fi to other devices. The chip has inbuilt sensors which sense all movement in human body including pressure, light, temperature etc. and can be attached anywhere in human body (in a dress, jacket, clip or even a pendant). Once it senses the changes in human body it starts transmitting all information to the device to which it is configured. This wearable technology can be configured to any device like smart phone, wrist watches, laptops etc. [13].

The chip that is used in the wearable technology and the circuit embedded in the chip is shown in Figure. 1).

The market potential of wearable devices is huge. The worldwide number of connected wearable devices from 2016 to 2021 are shown in Figure 2. In all of 2016 wearable device shipments amounted to almost 100 million units [2]. According to GlobalWebIndex 71 percent of those aged between 16 to 24 years prefer to use wearable technology [1].

Figure 1: Chip used in WT

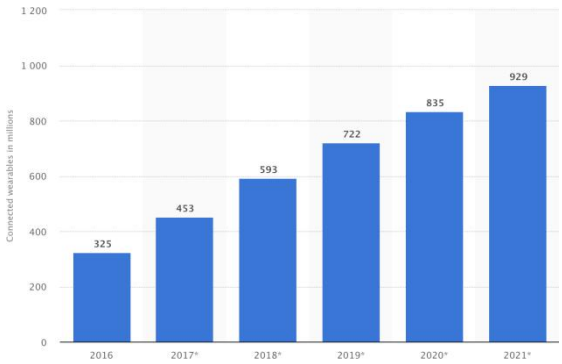

Figure 2: This graph shows the number of connected wearable devices worldwide from 2016 to 2021

2.2 System Thinking

2.2.1 Casual Loops. Now we provide breif background on the Systems thinking concepts that are used later in the paper in the context of wearable technology. One of the keys to analyze a system is to be able to recognize a circular causal behavior of system components. Causal loop diagrams help in analyzing any system by demonstrating the ways different components can affect each other as well as the system as a whole [3]. A link in a causal loop can either be positive or negative. A positive link describes a positive effect of one component on another. For example, population growth can cause an increase in food supply. On the other hand, a negative link shows an opposite effect. For instance, an increase in goods production may cause a price drop.

There are two types of causal loops: balancing and reinforcing [14]. Balancing loops are those that try to balance the system state throughout time, i.e. the loop keeps the system in equilibrium. For example, Figure 3 shows that increasing price of fish leads to higher magnitude of fishing activities, which in turn leads to increased

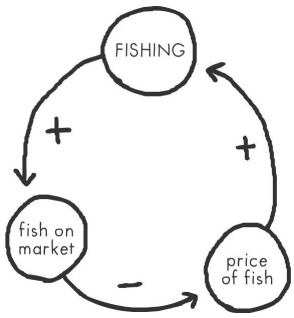

Figure 3: Example of Balancing Loop

supply of fish in the market. With more fish availability in the market the price of fish will go down. It is important to note that the loop has two positive links and one negative link. A system that can be represented with an odd number of negative links is a balanced one.

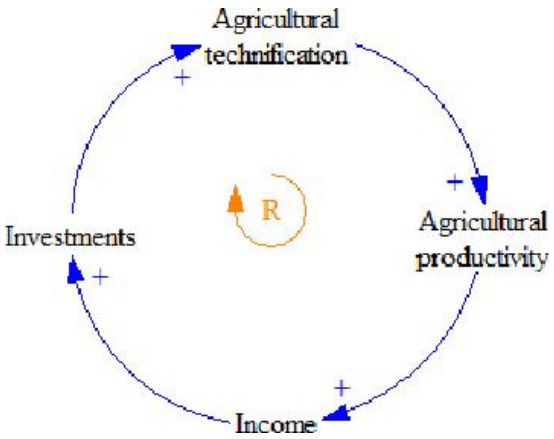

Figure 4: Example of Reinforcing Loop

On the other hand, reinforcing loops are usually in the systems where components encourage similar (positive or negative) behavior exponentially [22]. Reinforcing loops cause an accelerated growth or decline. For example, Figure 4 shows that with more investment for introducing modern technology in agriculture will improve agricultural techniques which in turn will increase the agricultural productivity which means more income from agriculture leading to a higher investment in agricultural modernization. This increasing trend goes on forever.

However, these examples of balancing and reinforcing loops do not consider external factors that may play a major role in systems behavior. For instance, in the

balancing loop example the fish price can be greatly affected by the buying capacity of the consumers.

2.2.2 Stock and Flow Approach. Another way to model a system is to use stock-and-flow diagrams where a system is described using stocks and flows. A stock is the base of any system that changes over time through the actions of a flow. A stock, then, is the present memory of the history of changing flows within the system. Stocks are the elements of the system that you can see, feel, count, or measure at any given time [8]. For example, a stock can be water in a bathtub or the money in a bank account. Stocks may go up or down based on inflows and outflows. Flows can be draining and filling, purchases and withdrawals etc. For instance, the capital in the market can be described as a stock and new investment and depreciation can be represented as the inflow and outflow respectively (Figure 5).

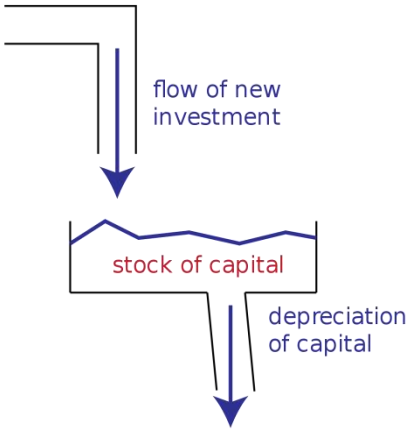

Figure 5: Example of Stocks and Flows diagram

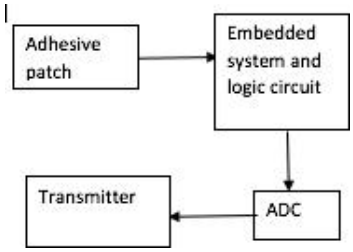

Figure 6: Blocks in the Transmission System.

In this paper we utilize both of the above mentioned system thinking tools (stock-flow diagram, casual loops) to analyze the future of Wearable Technology.

3 SYSTEM'S THINKING OF WEARABLE TECHNOLOGY DEVICES

We apply the System's thinking approach in two wearable technolgoy device. Now we describe the functioning and the use of these two devices.

3.1 Health Monitoring Device

Wearable technology provides an integral part of the solution for providing health care to a growing world population. By providing a means to conduct telemedicine-the monitoring, recording, and transmission of physiological signals from outside of the hospital-wearable technology solutions can ease the burden on healthcare personnel and use hospital space for more emergent or responsive care. This state of the art, high precision device can be worn on a person's finger. It can monitor anything starting from a person's blood type, hemoglobin content to someone's brain signals. In addition, using wearable technology in professions where workers are exposed to dangers or hazards can help save their lives [9].

In today's modern world, people are so busy with their day today activity that they don't even have time to take care of their own health. As time goes by the number and intensity of diseases is rapidly increasing. Such a device that can monitor someone's health can be designed by using wearable technology. These wearables in medicine allow continuous physiological monitoring with reduced manual intervention at low cost. They can be integrated into various accessories such as garments, hats, wrist bands, socks, shoes, eyeglasses and other devices such as wristwatches, headphones and smart phones. Wearable technology enables constant monitoring and data collection, thus allowing providers to look at data over time and understand patterns of patient behavior. A deeper understanding of patient behavior is one of the keys to improving health, especially in managing chronic conditions that are primarily driven by leading an unhealthy lifestyle [17].

Whereas a diagnosis is mostly based on a patient's account of events and symptoms experienced, wearable technology offers an additional source of information, which improves the providers' ability to diagnose their patients. Such applications are particularly useful when the patient may not be able to directly provide information to the physician.

3.1.1 Example: Skin Chip. This is a small, self-adhesive patch that a person wears on his skin and it instantly transmits all of his vital healthcare data directly to the doctor - before he even gets to the exam room. Figure 6 represents a logical view of it's operation technique. This

Figure 7: Wearable Chip attached to skin.

Figure 8: Transmission of Signals to the Conftg-ured Device

is the future potential of flexible electronics in wearable medical devices: to free both patient and doctor from the bulky and unwieldy technology of the past. When most of us think of electronics on a printed circuit board, we think of a rigid, stiff device. However, advances in electronics, flexible materials and technology are driving development of new wearable electronics that can bend and fold just like paper. Flexible electronics are lightweight, portable and so thin and supple that they can conform to the human body. They represent a fast-growing industry. Recent advances in flexible electronics technology has allowed researchers to devise a way to print devices directly onto the skin allowing people to go about normal daily activities for an extended period of time. Such systems could be used to track medical conditions and monitor healing near the skin's surface.

The adhesive patch can be configured to a smart phone or any other device. Once the adhesive patch in stuck on to a person's skin (Fig. 7), it transmits the information regarding his body to the device that it has been configured to as shown in the Figure 8. This can be used to monitor all the functions of a person's body right from blood flow to heart beat with the help of sensors that are built into the circuit [24]. These sensors sense the blood flow, pulse, heart rate etc. and sends it to the device that it has been configured to using the concept of Bluetooth.

3.2 System Thinking for Health Monitoring Devices

Due to the ease of use, the wearable health monitoring devices are most likely to gain huge popularity in near future. If we analyse the healthcare system in depth, we will be able to find a number of effects that amplifies the changes and encourage more people to use the system [11]. Moreover, health care is undergoing a dramatic shift. As the tech industry becomes more and more healthcare-focused, patients are becoming increasingly aware of their own health. The emergence of mobile health apps and innovative wearable technologies has created a demand for a healthcare system driven by an engaged consumer demanding the right quality of care that is safe and cost-effective.

Figure 9 shows the causal loop diagram of the use of health monitoring device as a system. There are three loops in the system. One balancing loop (B1) and two reinforcing loops (R1 and R2).

3.2.1 Reinforcing loop R1. With the deinstitutionalisation of health monitoring system it will be much easier to track the health situations of a patient continuously without hampering his other daily routine. Hence the doctor will be able to reach him as soon as the chip senses any medical emergency. The treatment will be more accurate with the help of the huge monitored data. On the other hand it will save a lot of time that is generally wasted just for some basic physical check up(like measuring blood pressure, blood sugar etc) prior to original treatment. With mass usage of this device the quality of care provided by any health system will rise upto a few notch just by reacting assertively to any medical need within a short time. The reduced rate of different health hazards will further enhance all these components of the system. This loop has four positive links:

- More use giving rise to ease of monitoring patients.
- Easy monitoring giving rise to more timely treatments.
- More timely treatments will increase the ease of treatments.
- Easier and timely treatements will increase the quality of care.

The loop has two negative links:

- Good quality of ehalthcare will reduce the health hazards.
- Decreased health hazard will in turn increase the popularity of the device.

3.2.2 Reinforcement loop R2. The more people use this technology, it will be easier to get more medical data required for different research (like, data analytics, medical research etc) purposes thereby creating improved welfare technologies for mankind. Imroved health technology will in turn help to reduce the health hazards as well as it will boost the use of wearable devices. This loop has three positive links and two negative links, making it a reinforcing loop.

3.2.3 Balancing loop B1. As every reinforcing loop has a limit of growth, to balance the overall system, there has to be a presence of a balancing loop in the system. The effect that can acutally work against all these reinforcing predictions and hence can balance the use of this device is the increased tendency of avoiding organisational treatments among people. As people themselves will get their health data regularly a habit of self treatment can grow in many of them and there can always be a risk in this practice. Hence it has the potential to lead to even more hazardous medical situations which will discourage people to use such devices. This loop has one negative link and three positive links, therefore it is a balancing loop.

3.3 Smart Hair Clip for Crime Fighting

The hair clip is a tiny accessory a person can clip on his/her hair or clothing, knows when he/she could be in danger and sends signals for help. This device raises an alarm in case of any assault. When the wearer is physically attacked in any way, it raises an alarm and can be configured to alert close relatives or friends [26].

The smart Hair Clip (Figure 10) features a mobile application that automatically calls for help and begins to collect evidence at the first sign of an emergency. The Hair Clips automatic alarm is activated when forces associated with a violent attack impacts like slapping, punching, or aggressive movements are detected [4]. Though self-defense classes and pepper sprays form part of a solution, their value becomes questionable if the perpetrator is already known to the victim or attacks by surprise. The Hair Clip fitted with security sensors, is designed to not only send out a cry for help, but gather up evidence to ensure the attacker is brought to justice.

The clip contains a gyroscope, 3-axis accelerometer, Bluetooth, microphone, manual alarm trigger, micro-USB charger and a lithium-polymer battery, which will have the ability to sense any aggressivemovements together that may someday protect your life.

It may be hard to believe that a simple hair clip can save a person's life but that's exactly what this 'smart pin' does. The most obvious question is whether the clip could distinguish between a legitimate attack and an innocuous bump on the head. But fortunately, False alarms are very rare.

First, Sign Hair Clip sends a distress signal to authorities when under attack and also gathers valuable evidence from the phone's camera and microphone. That is as soon as a harsh movement occurs the microphone in the clip starts recording, and the First Sign app will use Bluetooth to access the phone's GPS, camera and microphone to gather evidence, wearer's location, level of impact, pictures taken intermittently from the camera, audio recorded via microphone and other details and alerts the emergency contacts and first responders. Emergency contacts are also notified and the phone automatically dials emergency services for help. Law enforcement or medical services first on the scene are then aided by the evidence gathered. The hair clip is worn in the hair or even on clothes close enough to accurately measure impacts. When under assault, the accelerometer and gyroscope detect the impacts. If you haven't turned the hair clip off after 15 seconds, the information is then sent to a monitoring station and alert nearby emergency contacts and first respondents to your current location.

This smart hair clip will be a great companion for women when exercising alone, while travelling or driving alone, for elderly parents or anytime one might feel unsafe in a specific environment [20].

3.4 System Thinking of Smart Clip

If we consider the smart clip as a system and analyze the feedback loops, we get a reinforcing as well as a balancing loop (Figure 11).

As more people understand the significance of the technology, the usage increases. With more usage of this device the identification of criminals becomes easier for the legal system which in turn makes penalisation faster and more assured. The fear of punishment will reduce the crime rate. Though in long term reduced crime rate can make people reluctant to use this technology any more. As people tend not to use it, the crime rate will go up making the significance of the device evident thereby creating a balancing loop and the cycle would go on [7].

4 WEARABLE TECHNOLOGY AS A SYSTEM

In this section, we consider the applications of wearable technology as an entire system and describe it using a stock and flow diagram (Figure 5) [25]. We get the following scenario.

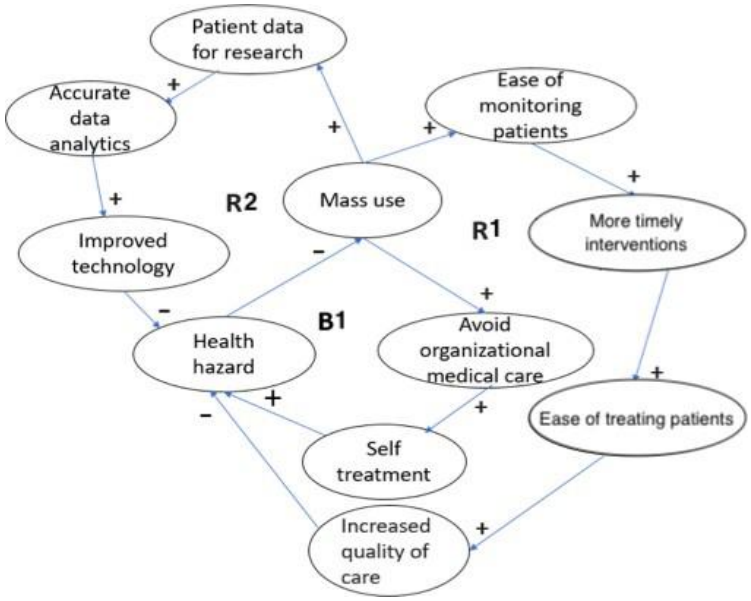

Figure 9: Casual loop diagram for the healthcare technology

Figure 10: Smart Clips

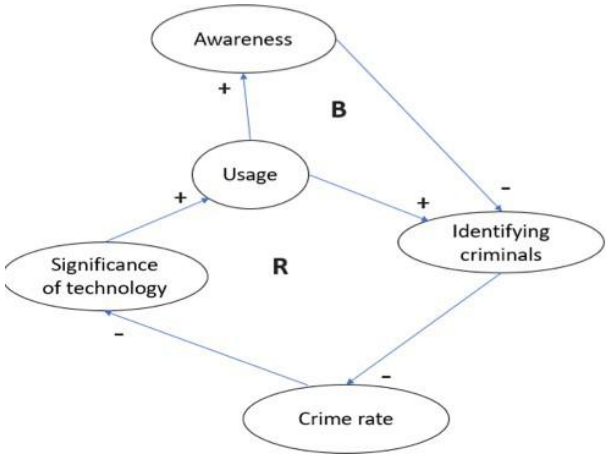

Figure 11: Casual Loop Diagram of Crime Fighting System

We consider four stocks in this system:

- The number of wearable technolgoy users.
- The number of different ways of using wearable technologies.
- The different misuses of wearable technology.
- The public concern about privacy issues arising from sharing personal data over the internet.

If the users of wearable technology can be considered as stocks then significance of wearable devices will increase the number of users and after the market gets saturated with the use of wearable devices, less number of people will be interested in buying new devices.

Wearable technologies can be used for a wide range of purposes for instance, health monitoring, crime fighting etc. New inventions will be act as the inflow to the stock of wearabale technolgy usages. On contrary, new technologies will inevitably invite some complications hence policies will be made to regulate such technologies and few technologies will get obsolete with time. These things will reduce the stock of wearable technologies.

A lot of personal data are generated through wearable devices that can be misused and the privacy can be breached which will lead to strict regulations on wearable technologies as well as to their obsoletion.

The inflows and outflows of these four stocks also can influence each other.

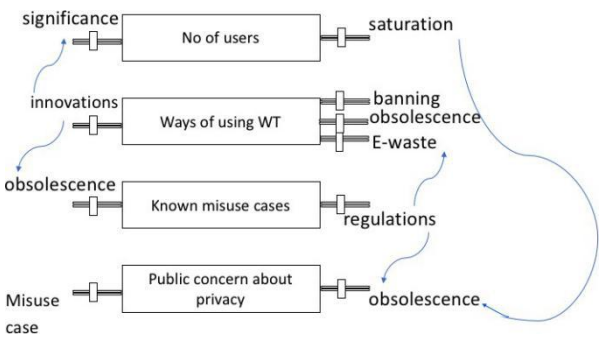

Figure 12: Stocks and Flows Representation of Wearable Technology

- New innovations will lead to increased significance of wearable technology.
- New innovations will lead to obsolescenece of older wearbale devices.
- Due to strict regulations, a lot of data generated by the devices will become inusable, increasing the amount of e-waste.
- New policies can lead to obsolescence of some wearable devices.

5 FUTURE WORK

The implications and uses of wearable technology are far reaching and can influence the fields of health and medicine, fitness, aging, disabilities, education, transportation, enterprise, finance, gaming and music to a very great unimaginable extent. The goal of wearable technologies in each of these fields will be to smoothly incorporate functional, portable electronics and computers into individuals' daily lives. Augmented reality and wearable technology can combine to create a much more realistic and immersive environment in real time Extensive research and development work at various centers have ensured that these wonderful devices will change our lives dramatically in the near future. They share the vision of interweaving technology into the everyday life, of making technology pervasive and interaction friction less. Wearable technology will very quickly change the technological and cultural landscapes once again, and may even change the nature of mobile phones and other hand-held devices entirely. As a future work, we tend to incorporate these aspects of wearable technolgy in the system diagram. We plan to analyse more wearable technolgoy devices from the System's thinking point of view.

6 CONCLUSION

The WT (Wearable Technology) is the pioneer and worldwide leading innovation and market development platform for technologies worn close to or on the body [6]. Several commercial vendors have started manufacturing and marketing these devices. In this paper, we provide a System's thinking point of view of two wearable devices: (1) a health monitoring chip and (2) a smart clip for crime fighting. With computers as close as shirts on our backs, interaction will become more natural. This will improve the ability to do track things while standing, sitting or walking. Therefore we foresee the importance of analysing the impact of these technolgies on human society by imposing the concept of system's thinking on them.

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