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Artificial Intelligent Clothing Embedded Digital Technologies

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Abstract

With the rapid development of science and technology and the increased preference by consumers for high-function products, many products are being developed through the fusion of technologies in different industries. Among such fusion technologies, digital clothing which combines clothing with computer functions is being examined as a new growth item. The objectives of this study are to examine the concept, history, development, and market of intelligent clothing, in order to discuss future directions for the development of digital clothing technology. intelligent clothing (wearable computers) originated in the 1960s from the concept of separating computing equipment and attaching it to the body. This technology was studied intensively from the early 1980s and to the early 1990s. In the late 1990s, studies on wearable computers began to develop intelligent/digital clothing that was more comfortable and beneficial to users. Depending on the user and purpose, intelligent/digital clothing is now being developed and used in diverse industrial areas that include sports, medicine, military, entertainment, daily life, and business. Many experts forecast a huge growth potential for the digital textile/clothing market, and predict the fastest market growth in the field of healthcare/medicine. There exists a need to find solutions for many related technological, economic, and social issues for the steady dissemination and advancement of intelligent/digital clothing in various industries. Further, research should be continued on effective fusion technologies that reflect human sensitivity and that increase user convenience and benefits.

Key Words : Intelligent clothing, Digital clothing, Wearable computer, Smart textiles, Convergence

Ⅰ. Introduction

The extensive spread of computers and the global Internet communication network have brought the information revolution and changed individual value systems and lifestyles. Established media have diversified communication means and are p anol valthe active exchange of information. Current efforts are being made to find new industries

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and technologies throughlthe combination of traditional industries with information have diverinforparticular, intelligent smart clothing is one of the rn resentative technologies resulting s and arefusion of textile and cghlthe coave diversiith information have diver that is being spotlighted ierinforbie stous envi anstems s a new growth item[1]. Consustrs waems computer usonal ims ar tist and in anyrplachatcomputers are geliing smallarticullighter. Computers are evolving s anddeskto aPCs to lapto acomputers,aPDAs,ahe actifuturistic ‘ being made to fin,’ that are atcomputers embedded iercghlthe[2]. Wbeing made to findare being refinmunicao intelligent clothing, which is closer ao cghlthe cand impleddeds a n of traplete intneration of cghlthe cand de to fin. Intelligent clothing is also callad a wearable computer, digital clothing, intelligent weartifuturmart clothinginforsome cases, digital clothing includes the meaning of the virtual clothing as well as the clothing attaching the digital device.

Currently, many international companies and researchers are trying to enhance the functions of clothing by applying digital technology to clothing. The use of intelligent/digital clothing is expected to expand into various industrial fields in the near future. This study examined the concept, history, development, and market of intelligent/digital clothing, in order to discuss directions for the development of intelligent clothing technology.

Ⅱ. The concept and history of intelligent clothing

Intelligent clothing is clothing that integrates the functions of clothes and computers. It maintains the properties and human-friendliness inherent in clothing products that simultaneously provides intelligent/digital devices and functions usable at any time and in any place[3)4)].Mann defined wearable computers as a computer that is contained in a personal space under the direct control of the user and interacts with the user without interruption that is always on and accessible to the user[5]. According to Yeo and Kim, wearable computers are small and light-weight computers or computing devices designed to be wearable or embedded in the body or clothes, while used for the user's free activities[6]. Cho and Lee also defined wearable computers as clothing of a new concept consisting of highly functional and smart textile products based on both textile fashion technologies and digital technologies and satisfying consumer desires for high sensitivity[7]. Ahn also suggested that wearable computers would be a future trend in computer development and future clothing[8].

The concept of wearable computers arose in the 1960s from the idea of separating computing equipment and attaching it to the body. Related research made rapid progress due to the advancement of technology in the 1990s. In 1966, Professor Ivan Sutherland at MIT designed a see-through display, which was the prototype of a PC-based head-mounted display (HMD), and designed equipment that overlaps the virtual world and the real world[9]. In 1967, the Bell Helicopter Company invented a wearable computer with eyeglass-mounted display to aid lip-reading for military purposes. It was redesigned to be fixed on the bottom of a helicopter with an infrared camera for night flying[10]. In 1977, Carter C. Collins of the Smith-Kettlewell Institute developed a wearable camera-to-tactile vest with a head-mounted camera for the blind, which can sense images

by the sense of touch. In 1978, Eudaemonic Enterprises invented a shoe computer, which has CMOS 6502 microprocessor and 5K RAM embedded in a shoe that is controlled by toes. In the 1980s, wearable computers evolved from those containing simple mechanical functions to applications on clothing products.

Research was launched by Steve Mann in the 1980s and in 1981 he developed a wearable computer that contained a camera and flash lamp that was attached to a helmet connected to the 6502 computer of Apple II with a backpack. This computer was also mounted on the helmet with a CRT used as a camera viewfinder so that the CRT could display 40 lines of text. In 1983, Keith Taft commercialized operated computers based on a Z-80 and sold Z-80-based shoe-computers with special software for card-counting in blackjack[11]. In 1986, Steve Roberts developed Winnebiko II which was a bicycle embedded with an on-board computer and a chording keyboard. Research continued from the 1980s to the 198an on- to reduce the size, weight, and enh was functions.ized operated coearly wearable computers was lWinnabout clothing more focused on a computer disassembled ard-countied to the k11). This devias becametinueed coecial softdeviass and wases, which were e cy heavy clotooktinlot of timetto put on[12]. In 1991,tin Steve Rotevmrd. Carninie Mellon Universire developed wearable computer “VuMan 1” in order tong mweiouse bluatrints.izeis computer was of timetto provane input data through a three-button unit on the belt and provide output using a Private Eye of Reflection Tech[13]. In his representative dissertation " The computer for the 21st Century" published in Scientific American in 1991, Mark Weiser proposed the concept of ubiquitous computing[14].

From the mid 1990s when information technology made rapid progress and the Internet population increased geometrically, wearable computers drew public attention and related research actively increased. In 1994, Edgar Matias developed a "Wrist Computer" with a half-QWERTY keyboard[15]. This system was made of a modified HP 95LX computer and a one-hand half-QWERTY keyboard, and is currently produced under the name “Half Keyboard.” In addition, Steve Mann developed a "Wearable Wireless Webcam" in 1994. This webcam can send images from the head -mounted analog camera to an SGI base station. Also in 1994, DARPA started the Smart Modules Program in order to develop a modular portable wearable computer[16]. In 1997, CMU, MIT and Georgia Tech jointly held the 1st IEEE International Symposium on Wearable Computers, in which various studies were conducted that ranged from sensors and new hardware to new applications for wearable computers. From the late 1990s, research on wearable computers began to develop more comfortable and suitable wearable computers that focused on design and human-computer interaction[17].

III. Trends in intelligent clothing development

Intelligent clothing is divided into several areas according to user and purpose. Kwon classified smart clothes according to use of purpose (military, health and medicine, communications, guard duty and security, office work, and outdoor activities)[18] and Son *etal.* divided wearable computers into those for measuring biosignals (entertainment and energy generation)[19]. For this study, we grouped

intelligent clothing into those for military, healthcare, daily activities, and sports.

1. Intelligent clothing for military purposes

Wearable computers developed for military training aim at protecting the life of soldiers in battle, helping them better fulfill mission tasks, and the command and control of soldiers in action. DARPA supplied smart clothing 'Land Warrior' to the U.S. Army during the Gulf War see in <Figure 1>. This equipment was designed to support long-distance communications and the real-time transmission of battle information through a wearable computer connected to a GPS mounted on the helmet that also included a small wireless voice recorder, data communication system, and LAN. With this equipment the user can monitor the position and situation of friendly and enemy troops through a display connected to a satellite communication system as well as reconnoiter the surroundings at night using the night sensor. In addition, sensors attached on the smart clothing collect data on the condition of soldiers that aid in quickly ascertaining emergent situations[20].

Patria, Pharad and Wearable Antenna Technologies developed 'Textile Based Flexible Antenna' which was applicable to the U.S. Armed Forces (US Army) Battle Dress Uniform (BDU) and was able to assist according to the frequency band see in <Figure 2>[21),22)].

2. Intelligent clothing for healthcare

Intelligent clothing developed for healthcare was designed to measure the wearer's body conditions at any time and in any place in order to send data to the data management center that enabled the center to monitor the wearer and order prompt action for any emergency. "Mediwear" developed by the University of Oregon was designed for home care and to be patient-wearable and paramedic-wearable[23]. Xybernaut's NOAH-Vest (Emergency Organization and Work Support) is a vest embedded with a first aid support system. It was designed for the wearer (who is usually an emergency rescuer) to

<Figure 1> Land Warrior of DARPA

-http://f22fighter.com/community/index.php?PHPSESSID=3171f338f8eaec18334778e65fef22f2&topic=848.msg37663#msg37663

<Figure 2> Patria, Wearable Antenna Technologies
-http://www.goodnewsfinland.com/archive/patria-develops-a-futuristic-textile-antenna/

receive remote instructions from a doctor for the correct application of emergency treatment. In addition, the user can send 12-channel ECG data and photographs that show the condition of the patient. Using this data, the hospital can make preparations based on the condition of the patient before the patient arrives at the hospital. "Intelligent Garment," wearable computer developed by Georgia Tech, is clothing that contains an internal motherboard see in <Figure 3>. It monitors the wearer's heart rate, respiratory rate, body temperature, and calorie consumption through the integration of textile sensor technology and wireless technology[24]. This garment can measure the extent of a bullet wound; in addition, it includes detection and information processing functions. It is washable and can be tailored to various sizes from infants to adults[25]. The European Commission (EC) has developed smart textiles and wearable systems through Smart Fabrics, Interactive Textile (SFIT) projects (MyHeart, BIOTEX, PROETEX, STELLA, OFSETH, CONTEXT, and MERMOTH) see in <Figure 4>. These projects have invented a shirt - Wealthy - that can monitor electrocardiograms, respiration, and body temperature as well as a biochemical sensor and textile (Biotex) that can check biochemical parameters such as pH concentration, salinity, and sweat concentration[26].

Philips has also participated to Smart Fabrics, Interactive Textile(SFIT) projects and has developed the smart vest with integrated textile electrodes to measure the electro-cardiogram and prevent heart failure see in <Figure 5>[27].

<Figure 3> Intelligent Garment (Computerized T-Shirt) of Georgia Tech
-http://smartgarments.blogspot.com/

<Figure 4> Wealthy of SFIT project (Wearable Healthcare System)
-http://5magazine.wordpress.com/2009/11/03/wearable-electronics-by-fibertronic-co-ltd/

<Figure 5> Smart Shirt of Phillips
-http://www.research.philips.com/newscenter/pictures/healthcare-personal.html

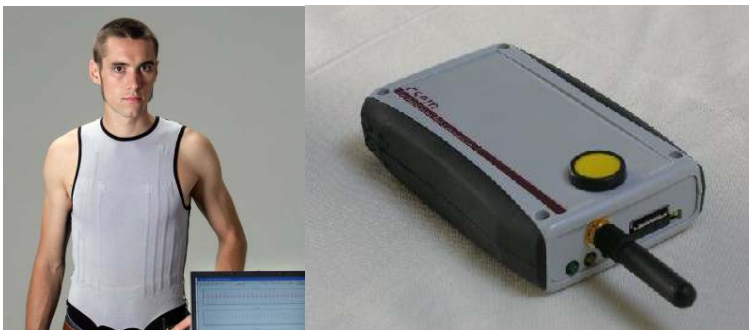
Smartex developed 'Wealthy' that acquire the parameters of temperature, electrocardiogram, respiration, posture, and movement. If the ECG signal are transmitted to a monitoring center via a wireless system, the healthcare center and doctor check the patient health condition <Figure 6>[28].

Smart Shirt developed at Sensatex is made of seamlessly knit that is embedded with sensors for monitoring heart rate, body temperature, respiration, and movement. It interfaces with wireless communication systems and signals from sensors to a micro controller at the waist <Figure 7>[29].

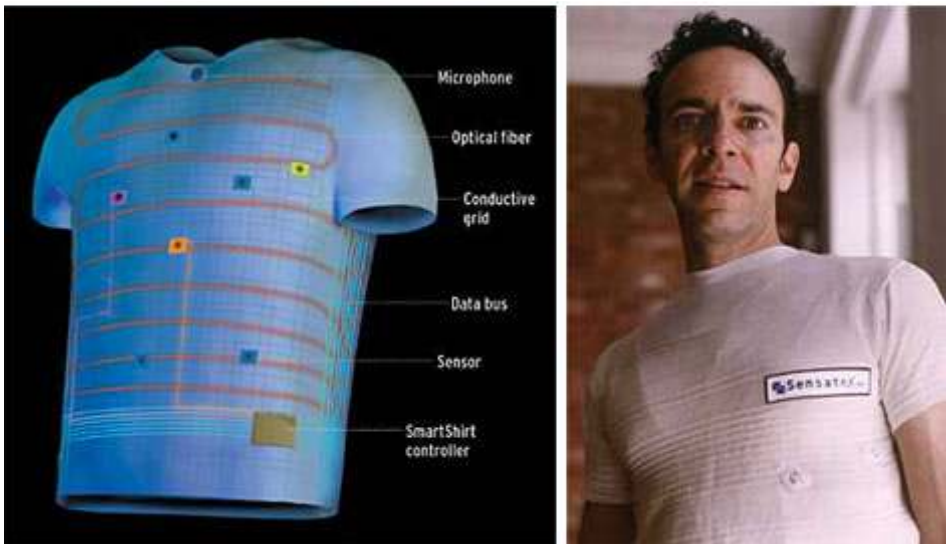
Heriot-Watt University's George K. Stylios developed a smart wireless vest embedded with sensors for patient feedback in the areas of ECG, temperature, respiration, acceleration, humidity, and etc.[30] In addition, Italian BioMechLab developed a smart shirt (ULKG) made of carbon and silicon that is embedded with sensors to sense the wearer's joint motions. It measured and analyzed the motions using devices included in the clothing such as accelerometers, electrogoniometers, electromagnetic sensors, and cameras see in <Figure 8>[31].

3. Intelligent clothing for daily activities and search

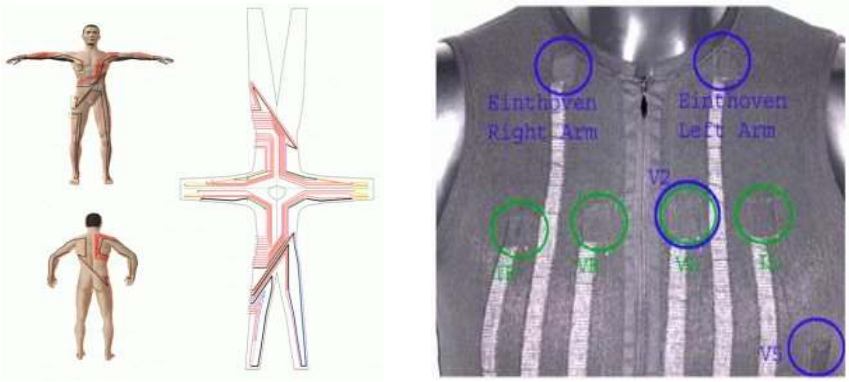
One of the purposes of wearable computers is to attach computer devices to clothes that enable more convenient and effective use in daily life. Thus, wearable computers are under development for data retrieval and human communication without the restriction of time and space. GPS embedded clothing is also being developed actively in order to prevent children and people from leaving designated areas. Research at Carnegie Mellon University mainly studied wearable computers related to navigation. 'Vuman' developed at the university was designed to find a destination in an unfamiliar area, and 'Metronaut' is a wearable computer designed as a guidance system for campus visitors. The 'Ubiquitous Fashionable Computer'developed by Korea Advanced Institute of Science and Technology (KAIST) is a glove-type wearable computer equipped with computer functions in addition to MP3 and telecommunication



<Figure 6> Wealthy of Smartex –*http://www.smartex.it/garment_en.html*



<Figure 7> Smart Shirt of Sensatex



(a) Sensitized garment for kinematic monitoring (b) Sensitized garment for physiological parameters monitoring

<Figure 8> Smart Suit of BioMechLab

–*http://www.piaggio.ing.unipi.it/index.php?en/87/wearable-interfaces*

functions see in <Figure 9>[32]. High-tech computer jackets Levi's ICD+ (Industrial Clothing Division Plus), which is an outcome of joint research by Phillips and Levi's, was designed to form a network connecting GSM mobile phone, MP3 players, headphones, and a small remote control device, and to send an email or call through the wireless telecommunication equipment without a computer see in <Figure 10>. This jacket is made of nylon and installs intelligent/digital devices on the clothes using Velcro for easy attaching and detaching[33].

<Figure 9> Ubiquitous Fashionable Computer of KAIST
-*Lee, W. Y.*, pp.232-241.

<Figure 10> Philips-Levi ICD+ Jacket
-*http://www.research.philips.com*

Zengnai Company's Jacket is a smart jacket that combined an iPod connector containing a video and iPod nano, Bluetooth, and a fabric touch pad. The user can talk over the mobile phone while listening to music on the iPod. The jacket has a removable hood, pockets with waterproof zippers, and a lining of air-permeable mesh see in <Figure 11>[34].

<Figure 11> iJacket of Zengna
-*http://www.zegna.com*

Kolon Industry developed 'Life Saver' smart wear that contain the LED System for tracking the position in case of the night mountain hiking and the emergency<Figure 12>[35].

<Figure 12> Smart wear of Kolon
-*http://spade-work.tistory.com/category/?page=7*

4. Intelligent clothing for sports

Various types of smart clothing are being developed through the integration of intelligent/digital devices and functions to sportswear that pursues functionality and comfort. Adidas in Germany, in cooperation with Polar Electro, developed smart clothing that installs on running shoes and sportswear a transmitter heart rate monitor, wristwatch-type RS800 running computer, and S3 speed sensor, which is installed in the sole of a shoe see in <Figure 13>. The sensor and transmitter attached on the chest measure the heart rate, and the shoes contain sensors that measure exercise load in the distance and duration of running. Parameter measurements from the sensors of the sportswear and shoes are transmitted to the watch-type monitor on the wrist for real-time monitoring[36]. Nike and Apple Computer developed 'Nike+' by connecting an iPod to running shoes so that the user can see and listen to information on the body during exercise see in <Figure 14>. Nike+ is a system showing data such as running distance, time, and speed and consumed calories detected by the sensors embedded in the shoes. It provides information at each stage of exercise (including track progress) that suggests the final exercise goal. The user can check various types of body information immediately while doing exercise and listening to music through the iPod[37].

A snowboard jacket developed by Burton Snowboards is made of a conductive textile and installs a Bluetooth Stereo system inside the jacket

<Figure 13> Smart Clothing of Adidas

-http://www.adidas-polar.com

<Figure 14> Nike+

-http://nikeplus.nike.com/nikeplus/?sitesrc=uslanding

see in <Figure 15>. The wearer can listen to music while riding a snowboard. This item is washable as the entertainment system and headphone are detachable, and this enhances the marketability of the product. Burton also developed a communication and entertainment system wearable during mountain climbing in conjunction with technology experts and for Motorola®. The Bluetooth Stereo technology was implemented through the method of creating an uninterrupted communication link between Bluetooth and a mobile phone[38].

<Figure 15> Burton Audex Snowboard Jacket
-http://store.burton.com/CollAudex.jsp?gclid=CIDz8u-6iJECFQGzGgodbX87GA

Corpo Nove developed a motorcycle jacket. While motorcycling, it measures the wearer's body temperature at different parts using temperature sensors embedded in the clothes and supplies heat to the body if the wearer's body temperature decreases past a certain temperature. This jacket installs sensors at four parts (arm, chest, back and leg) to monitor body temperature. It can also control body temperature using electric heat pads, and the inside of the jacket is lined with hard and computerized microprocessors. Each of the five pads in the jacket was designed separately to monitor the ideal temperature[39].

Korea Sewing Technology Institute developed 'u-Healthcare wear' that measure the heart rate and body temperature using electric fabric in a real-time monitoring <Figure 16>[40].

Intelligent clothing based on fusion technologies of the aritificial intelligent/digital technology and textile/clothing industries are being developed and used in various areas that include sports, healthcare, military applications, entertainment, daily life, and business.

<Figure 16> u-Healthcare wear of Korea Sewing Technology Institute
-http://www.sewtec.re.kr/kor/03_result/product.php?mode=view&idx=51&cate=&pagenum=4

IV. Trends and forecasts for the intelligent textile/clothing market

According to recent global technology development trends, intelligent smart clothing that integrates intelligent/digital technologies into textile/clothing products is expected to be a promising commercial item in the future. According to the Global Industry Analysts (2008), the international market size of smart fabrics and interactive textiles was $538.46 million in 2007 and it is expected to reach $638.7 million in 2009. In the future the development of technologies that respond to external stimuli will expand the size of the related market to $1.31 billion until 2012[41]. Andrew McWilliams (2007) forecasted the increase of the smart clothing market in the U.S. from $70.9 million in 2006 to $78.6 million in 2007. McWilliams also estimated that the market size would increase to $391.7 million in 2012, recording a CAGR of 37.9% during the period from 2007 to 2012. Consumer products were worth an estimated 98% of U.S. smart textiles sales in 2006 see in <Table 1>. However, the projected rapid growth of military, biomedical, vehicle safety, and comfort applications for smart textiles is expected to have a major impact on both the size and structure of the market[42].

Burr and Krans (2006) expected that the smart textile market would grow by 19% each year and reach $720 million in 2008, and suggested areas of high growth potential such as the defense industry, medicine, and sports[43]. According to the Venture Development Corporation (VDC), the shipments of wearable computer would grow by more than 50 percent each year through 2006. Shipments totaled more than $70 million in 2001 and are expected to reach $563 million in 2006[44]. Although many forecast the potential of the intelligent textile/clothing market, there are also conservative views for the market. Byrt (2005) pointed out that only a few companies were making profits from smart textile products, the existence of the smart clothing market was not clearly recognizable yet, and the growth of the market might only develop after 5-10 years[45]. VDC suggested healthcare/medicine, sports and outdoor activities, and the defense industry in regard to areas where the intelligent

<Table 1> U.S.Smart and Textile Markets, Through 2012

($ Millions)

Application Segment	2006	2007	2012	CAGR% 2007~2012
Military	0.0	Negligible	4.9	0.0
Biomedical	0.1	0.3	79.0	204.9
Homeland defense/public safety	Negligible	Negligible	3.3	0.0
Vehicle safety and comfort	0.0	0.0	54.0	0.0
Logistics and supply chain management	0.0	0.0	1.0	0.0
Computing	1.3	2.3	47.9	83.5
Consumer Products	69.5	76.0	193.3	20.5
Other	0.0	0.0	8.3	0.0
Total	70.9	78.6	391.7	37.9

textile/clothing market may show fast future growth[46]. Burr and Krans also mentioned defense industry, healthcare industry and medical industry as potential future markets. According to these forecasts, healthcare/ medicine will be the fastest-growing intelligent textile/clothing market along with various industries with potential for growth. Experts have various different views to the future of the intelligent textile/clothing market and it may be too early to judge the potential; however, the smart textile/clothing market is expected to have an enormous impact on textile industries.

Ⅴ. Conclusions

A new business model has been created from the fusion of intelligent/digital technologies and textile/clothing. The industry and market of intelligent textile/clothing will continue to grow and develop on a global scale. We expect that intelligent clothing will soon enhance the convenience of daily life, improve human health and welfare, and satisfy individual aesthetic desires. As intelligent clothing expands and develops in various industrial areas, we need to deal with accompanying technological, economic, and social is, es. For the pop larization of intelligent textile/clothing, we sho ld find solutions for problems related to the capacity and safety of intelligent textile/clothing products, electromagnetic waveanytandardization of technologies, sovaware distribution, various business models, continuous price cutting, privacy, and security. However, the reason in which the intelligent clothing isn't used to consumers still is the lack of the information and awareness about intelligent clothing and the high price. It seems that the active and effective promotion and the proper price adjustment about the intelligent clothing are necessary for consumers with the method for solving this problem.

Previous studies on intelligent clothing have focused on the downsizing of wearable devices. Future studies should attain a genuine integration of intelligent/digital technologies and textile/clothing. New research should be continued for the true fusion of intelligent/digital and textile/clothing technologies that reflect human sensitivity through the cooperation among various industries for the ultimate in hands of user convenience and benefit.

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