CHAPTER 2
WEARABLE ELECTRONICS REVIEW

2.1 INTRODUCTION

The wearable electronic textiles arena has generated an abundance of literature, especially trade literature. The literature suggests the merge of electronics and textiles will offer significant opportunities for both industries. These opportunities stem from increased consumer demand for lightweight mobile electronics. Technological advances have enabled electronics to become smaller and more powerful. Many industry experts are seeking to take this one step further by integrating electronics into textiles to increase user mobility and comfort. This involves understanding available technologies and how they can be used to develop interactive electronic textiles. The firms that understand how to incorporate these emerging technologies into their business strategy will establish and sustain financial and competitive advantages within their industry. This research provides a better understanding of the current work and foci in the wearable electronic textiles arena and may potentially open the area to new concepts and ideas. When a research study can provide information to assist industry with further understanding of a new emerging area, it proves to be worthwhile and relevant.

J. Kay’s invention of the flying shuttle in 1733 sparked the first Industrial Revolution, which led to the transformation of industry and subsequently of civilization itself. Yet another invention in the field of textiles is the Jacquard head by J.M. Jacquard, which was the first binary information
processor. At any given point, the thread in a woven fabric can be in one of two states or positions: on the face or on the back of the fabric. The cards were punched or cut according to the required fabric design. A hole in the card signified that the thread would appear on the face of the fabric, while a blank meant that the end would be left down and appear on the back of the fabric. The Jacquard head was used on the weaving loom or machine for raising and lowering the warp threads to form desired patterns based on the lifting plan or program embedded in the cards. Thus, the Jacquard mechanism set the stage for modern-day binary information processing. A. Lovelace, the benefactor for C. Babbage who worked on the analytical engine (the predecessor to the modern-day computer), is said to have re-marked, “The Analytical Engine weaves algebraic patterns just as the Jacquard loom weaves flowers and leaves.” The Jacquard mechanism that inspired Babbage and spawned the Hollerith punched card has been instrumental in bringing about one of the most profound technological advancements known to humans, namely, the second Industrial Revolution also known as the Information Processing Revolution (Jayaraman 1990). In fact, when Intel introduced its Pentium class of microprocessors, one of the advertisements had a “fabric of chips” emerging from a weaving machine; this picture eloquently captured the essence of chip making, a true blending of art and science, much like the design and production of textiles. Nowadays, more than two centuries later, researchers are finding themselves looking at the possibility of integrating textiles and electronics, but in a different way.

Humans are used to wearing clothes from the day they are born and, in general, no special “training” is required to wear them, i.e., to use the interface. In fact, it is probably the most universal of human–computer interfaces and is one that humans need, use, have familiarity with, and which can be easily customized (Marculescu et al 2003). Moreover, humans enjoy clothing and this universal interface of clothing can be “tailored” to fit the
individual’s preferences, needs, and tastes including body dimensions, budgets, occasions, and moods. Textiles can also be designed to accommodate the constraints imposed by the ambient environment in which the user interacts, i.e., different climates or operating requirements. In addition to these two dimensions of functionality (or protection) and aesthetics, if “intelligence” can be embedded or integrated into textiles as a third dimension, it would lead to the realization of clothing as a personalized and flexible wearable information infrastructure (Park and Jayaraman 2001).

Wearable Electronics are an emerging interdisciplinary field of research that brings together specialists in information technology, microsystems, materials, and textiles. The focus of this new area is on developing the enabling technologies and fabrication techniques for the economical production of flexible, conformable and, optionally, large-area textile-based information systems that are expected to have unique applications for both civilian and military sectors. The synergistic relationship between computing and textiles can also be characterized by specific challenges and needs that must be addressed in the context of electronic textile-based computing.

2.2 TEXTILES AND INFORMATION PROCESSING

A well-designed information processing system should facilitate the access of information Anytime, Anyplace by Anyone—the three As. The “ultimate” information processing system should not only provide for large bandwidths, but also have the ability to see, feel, think, and act. In other words, the system should be totally “customizable” and be in tune with the human. Of course, clothing is probably the only element that is “always there” and in complete harmony with the individual. Also, textiles provide the ultimate flexibility in system design by virtue of the broad range of fibres, yarns, fabrics, and manufacturing techniques that can be deployed to create
products for desired end-use applications. Moreover, fabrics provide “large” surface areas that may be needed for “hosting” the large numbers of sensors and processors that might be needed for deployment over large terrains, e.g., a battlefield. The opportunities to build in redundancies for fault tolerance make textiles an “ideal” platform for information processing.

2.3 DEFINITION OF WEARABLE ELECTRONICS

An “intelligent” garment differs from a traditional garment primarily in this capacity to receive input from its wearer or from its environment, and use that input to activate or change the state of an associated technology. A garment may be more or less intelligent based on the number of sensors and their ability to detect context, synthesize input, or cause change. The field of intelligent clothing is characterized by the fusion of two distinct fields: functional clothing design and portable technology. These two fields have developed separately but both are necessary for the successful design of intelligent clothing.

2.4 CHRONOLOGY OF WEARABLE ELECTRONICS

The concept of wearable computing (wearables) emerged in the mid 1990’s at a time when carrying an ‘always-on’ computer combined with a head-mounted display and control interface first became a practical possibility. In July 1996 a workshop, ‘Wearables in 2005’ was sponsored by the U.S. Defense Advanced Research Projects Agency. This was attended by industrial, university and military visionaries to work on the common theme of delivering computing to the individual. They defined wearable computing as "data gathering and disseminating devices which enable the user to operate more efficiently. These devices are carried or worn by the user during normal execution of his/her tasks" (DARPA 1996). One of the first advocates and adopters of this form of computer usage, Steve Mann, further defined
wearable computing and arrived at three fundamental properties (Mann 1994). Firstly a wearable computer is worn, not carried, in such a way as it can be regarded as being part of the user; secondly it is user controllable, not necessarily involving conscious thought or effort; and, lastly it operates in real time - it is always active (though it may have a sleep mode) and be able to interact with the user at any time (Mann 1997 b).

Using these definitions it was possible to retrospectively recognize early applications of wearable computing. These included the shoe mounted roulette wheel prediction system by Thorp and Shannon, first implemented in 1961, subsequently successfully developed and used by the 'Eudemons' and by 1983 commercialized by Keith Taft and others (Thorp 1998) (Bass 1985). Dive computers, which first became common in the 1980's, are also worn, are user controllable, and have sensors which operate in real time. In the art world Stelarc has experimented with body sensors and actuators (Stelarc 1997), and many artists have developed unusual musical controllers. These wearable interfaces used sensor systems affixed to the body or clothing of a performer measuring movement and/or body functions such as heart rate or skin resistance. The interfaces connected to audio equipment such as midi devices and sound synthesizers, sometimes also worn on the body. Joe Paradiso at M.I.T. has taken a particular interest in these and, as well as creating his own devices, provided a comprehensive overview of this field in an IEEE Spectrum article 'New Ways to Play: Electronic Music Interfaces' (Paradiso 1997).

Many other inventive backroom constructors also produced wearable systems, most notably Mann with his WearCam and WearComp devices. Originally starting by building a wearable 'photographer's assistant', he developed a series of wearable from the 1970's to the present day featuring body mounted cameras and lighting, head mounted displays, audio interfaces
and many of the other features commonly associated with wearable computing (Mann 1997b). As the development of the wearable computer was originally inspired by the availability of battery powered head mounted displays, it has been closely linked to this technology. An overview of the challenges presented by these displays was summarized in the paper described by Duchamp et al 1991. These were the hassle of the head gear, low-resolution, eye fatigue, and the requirement for dim lighting conditions.

The health and well-being of service personnel also require special attention. The sensate liner developed at Georgia Institute of Technology was designed specifically to monitor the vital signs of combat casualties, as well as automatically detect and characterize a wound in real time using bullet entry detection (Lind et al 1997). The applications described previously have used position sensing technology to assist in a variety of tasks. The knowledge of where the user is located clearly provides the basis for many wearable designs. Wearable can also be designed to monitor well-being and activity - the how and what of the user. This form of context sensing has been put to use in wearable computers for medical and health applications and has met with more success than in any other field. Body invasive devices, such as heart pacemakers, have become common place. However as these devices is generally not user controllable they do not fall into our definition of wearable computers. Wearable have the potential to monitor health to assist with improving performance e.g. sports; prevention and detection of illness through diagnosis; and even treatment, though this usually involves some invasive procedure. Examples of treatment by a wearable are insulin pump therapy for diabetics (Doyle et al 2004) and a brain implant to facilitate communication with speech-incapable patients (Bakay and Kennedy 1999).

Textiles are ubiquitous in our society, and provide the ideal base or support for wearable monitoring electronics. Because textile garments or
accessories can be worn close to the skin, integrating electronics within the textiles gives benefits unrivalled by other systems. Measurements of data requiring close contact with the skin are possible; with minimal effects on the comfort of the wearer, and with minimal disruption to his/her day-to-day activities. To date, a number of wearable electronic textiles have been developed. Many are multi-layer systems, consisting of at least an internal layer (in contact with the skin) and an external one, with connected electronics and circuitry. The torso garment of Dunne et al. (Dunne 2004) is an example of a double-layer prototype. The paper by Stylios and Luo (2003) described a multiple layer system consisting of an innermost layer for comfort, an electromagnetic mask layer to shield the body from radiation, an electronic layer and an outermost layer, where power management systems such as solar cells can be incorporated. The paper by Rantanen and HaoNnnikaoNinen (2005) described a three-layer system, consisting of a skin layer for physiological measurements, an inner clothing layer as a platform for the electronic components and an outer layer for environmental and positioning sensors and equipment. Structurally, both knitted and woven fabrics have been used for wearable electronic clothing for monitoring applications.

The main advantage with textiles is their flexibility, which relates to some extent to wearing comfort. Knitted fabrics have the advantage of being stretchable and deformable to some extent, and have been used where the fabrics need to be close to the body, or close fitting, such as for leotards or other sportswear. Comparatively, woven fabrics provide more dimensional stability, and are more suitable where large movements of the body are not an essential factor to consider. Exploring the duality of functions, the interlacing of warp and weft in woven fabrics has been explored as networks for electrical circuits, in addition to being the supporting material for the integrated electronics (Dhawan 2004a). At this point in time, the influences of
fabric structure and geometrical construction and of fibre type on the monitoring performance and accuracy have not been considered to be of significance. Most of the research has instead focused on constructing systems and ensuring that it works efficiently. Fabrics of prototype monitoring garments have been made of various types of fibres as reported in the paper by Dunne 2005 prototype developed using natural fibres, the paper by De Rossi 2003 describes prototype development using polyester and acrylic fibres, the paper by Beith 2003 describes prototype development using elastane fibres, Dhawan et al 2004b describes prototype development using Nylon fibres and the paper by Dario et al 1982 elaborates prototypes developed using optical fibres.

2.5 APPLICATION GROUPS

This section gives a short overview on the major application groups of wearable electronics:

(a) Retailer support

A successful embedded electronics for retailer support should cover the needs in logistics, such as stock control, quality insurance control, and anti theft protection. For this purposes there are several integrated RF indent-tags already in use. These tags consist mainly of a RF antenna used to transfer energy to the indent-tag and to establish a communication link between the tag and the control equipment. The most primitive tags consist of a simple antenna-capacitor resonance circuit. The more complex ones contain simple microcontrollers and non-volatile memories.
(b) Service Support

Service support is of more importance in Europe than in the USA. Here consumer tends to sort clothes into different categories before washing. Therefore the washing machines are able to treat the clothes in very different ways. Naturally it happens sometime that a black sock is hiding in a white shirt. This results in colored shine on the originally white clothes. The consumer can avoid such accidents if the washing machine recognizes type, number and required optimal treatment of the clothes to be washed. In case of conflict an error message is generated.

(c) User convenience

Built-in electronics may control and support more advanced textile functionalities like temperature, moisture, etc. For that purpose secure heating and cooling elements are necessary.

(d) User interfacing

User interfacing enables the interfacing between the user and his electronic belongings or external (out of body) networks and terminals. Sound, gesture, and temperature may control such interfaces. Suitable components are microphones, loudspeaker, textile keyboards, flexible displays and more complex devices.

(e) Appliance networking

The networking between different electronic modules is a key feature necessary for the application of user interfaces. One scenario might be the connection of a cellular phone ported in the right pocket, with a PDA in the left pocket, Bluetooth interface in the trousers and the user interface integrated into the coat.
(f) Networking with external networks

The networking with external networks can be done in real time or by “batch processing”, online and offline. Another offline method might be the use of exchangeable storage elements like multimedia cards. Online external networking might be possible as a direct communication link established by Bluetooth, DECT, GSM or UMTS RF connections. They require a suitable TWRX RF part and a base-band processor handling all the necessary protocol work. Broadcasting applications are also viable. They might rely on standards like DVB-T or DAB. Here the system requires a tuner, demodulation stage, decompression and decryption unit. Common to all applications is the need for a power supply that enables relative long stand-by times and that can be recharged or refueled with high customer convenience.

Wearable computers have the potential to enhance the day-to-day activities of the user. Applications that support many specialized activities have been explored and demonstrated by Ockerman and Pritchett (1998). The Metronaut mobile computer developed by Smailagic and Siewiorek (1994) can able to sense information and locate position via bar code reader, provide wide range communications via two-way pager, supporting applications like navigation, messaging, and scheduling and still consuming less than one watt of power and weighing less than one pound.

Posture and gesture analysis, together with the monitoring of body kinematics, is a field of increasing interest in bioengineering and several connected disciplines. In the paper by Federico Lorussi et al (2004), they shown some typical features of distributed sensing systems are described, as well as a methodology to read signals from such systems. The paper by Zheng et al 2007 describes a wearable mobihealth care system aiming at providing long-term continuous monitoring of vital signs for high-risk cardiovascular patients. Owing to integrating fabric sensors and electrodes endowed with
electro-physical properties into the WS, long term continuous monitoring can be realized without making patients feel uncomfortable and restricting their mobility. The paper by Mazzoldi et al (2002) describes the implementation of truly wearable instrumented garments capable of recording biomechanical variables is crucial to several fields of application, from multi-media to physical rehabilitation, from sporting to artistic fields.

2.6 NEED FOR WEARABLE ELECTRONICS

The need for truly wearable body sensors is clear: while invasive, restrictive, uncomfortable sensors are the only choice, viable applications will remain restricted to those arenas (medical, military) where the body sensing function is crucial to the subject’s health or well-being. But the trade-offs for sensing accuracy must also be overcome to preserve the full range of possible applications. An understanding of the requirements for mainstream wearability is necessary to further wearable body-sensing research in this direction. The paper by Gerhard Tröster (2003) reflects the state-of-the-art in electronic textiles and presents first implementations. Depending on the application the electronic functionality can be fully integrated or a modular approach can be chosen, where clothing provides a kind of ‘platform’ for several possible modules. In order to achieve these objectives a close interdisciplinary cooperation in the fields of electrical, textile and clothing technology is necessary.

They are expected to measure and react in an intelligent way. They can monitor a person and his or her environment, and interpret such data. In cases where health problems or environmental threats are detected, a smart suit can send out a warning or even protect instantaneously. Consequently, they will become an important tool for prevention. In the long term, a smart suit can assist in the rehabilitation process by supplying of drugs, activation of muscles and many more.
Weber et al (2002) presented various technology components to enable the integration of electronics into textiles. Key elements are a packaging and interconnect technology for deep textile integration of electronics. An interconnect and packaging technology is demonstrated using a polyester narrow fabric with several warp threads replaced by copper wires which are coated with silver and polyester.

2.7 TEXTILE FIBRES USED FOR WEARABLE ELECTRONICS APPLICATIONS

Functional apparel design has historically sought to meet user needs with material properties and design features but now many of these needs can be met with more flexibility and control using powered technology. At the same time engineers in technology fields are turning their attention to increasingly portable devices and encountering the design challenges that are the province of functional apparel designers. Currently there are few functioning intelligent garments in the commercial arena despite the availability of facilitating technology. Existing garments are primarily designed for protective functions, including protection from extreme cold, physiological monitoring for emergency conditions, and wearer GPS information for emergency intervention. (The North Face 2001), (Rantanen and HaoNnnikaoNinen 2005), (Sensatex Inc. 2002).

Continuous miniaturisation of electronic components has made it possible to create smaller and smaller electrical devices which can be worn and carried all the time. Together with developing fibre and textile technologies, this has enabled the creation of truly usable smart clothes that resemble clothes more than wearable computing equipment. These intelligent clothes are worn like ordinary clothing and provide help in various situations according to the application area. The paper by Rantanen and HaoNnnikaoNinen (2005) describes the design and implementation of a
survival smart clothing prototype for the arctic environment. With the advancements in technology and science, electronics have been getting smaller and smaller, which enables researchers and scientist to weave the electronics and interconnections into the fabric. This new technology enables to establish a new concept called "Electronic-Textiles (e-Textiles)", which allows cost-effective and efficient solutions for various applications.

The blossoming research field of electronic textiles seeks to integrate ubiquitous electronic and computational elements into fabric. This section concerns one of the most challenging aspects of the design and construction of e-textile prototypes: namely, engineering the attachment of traditional hardware components to textiles. Three new techniques for attaching off-the-shelf electrical hardware to e-textiles were presented: (a) the design of fabric PCBs or iron-on circuits to attach electronics directly to a fabric substrate; (b) the use of electronic sequins to create wearable displays and other artifacts; and (c) the use of socket buttons to facilitate connecting pluggable devices to textiles.

The paper by Leah Buechley and Michael Eisenberg (2007) have focused on using easily obtained materials and developing user friendly techniques to develop methods that will make e-textile technology available to crafters, students, and hobbyists. The paper by Ivo Locher and Gerhard Troster (2007) describes transmission lines structures screen-printed on fabrics. Textile structures can be divided into a) woven, b) nonwoven or pressed fabric, and c) knitted fabrics. Woven fabrics are usually quite dense. Non-woven fabrics are less dense, weaker and lack a regular Structure. Knitted fabrics have a low density and are elastic. In each category a conducting fabric can be constructed either by incorporating conducting threads or by plating after textile has been formed.
**Woven conductor fabrics:** The early conducting thread woven fabrics were so poor they could not be used in a resonant antenna. Their performance will probably improve with further development.

**Knitted fabrics:** The interest in knitted cloth stems from their application as a stretchable fabric in constructing a laminated garment. Knitted fabrics can be constructed from pure copper. However using just metal threads tends to damage the knitting machines, and most samples have been constructed with at least 50% nylon. To date, no antennas constructed with knitted fabrics have had satisfactory performance characteristics. The reasons for the poor performance of the knitted fabrics have not yet been verified. Possible causes include: additional inductance due to using fine wire threads, poor contact between the knitted wires, and too little conducting surface in the material when compared with plain woven sheets.

Wireless communication and wearable computers coupled with clothing forms a new approach to wearable computing (Gerhard Troster et al 2003) (Yao et al 2005). This so-called “smart clothing” has become a potential alternative for a wide range of personal applications, including safety and entertainment as well as applications requiring privacy. The basis for smart clothes is ordinary clothing, which is augmented with electrical or non-electrical components. Also the fabric of the clothing may itself be intelligent. Based on these, an intelligent garment that can better fulfill its primary function as clothing, and also give some added value to a user can be developed. Electronically implemented intelligence in smart clothing includes electrical components such as processors, sensors and communication equipment which help the clothing to adapt to the changing environment and the user's needs. On the other hand, non-electrical functions may also provide necessary tools for the user to survive in uncommon situations. Mizell et al (1999) introduced the terms “Tool Model” and “Clothing Model” to
describe the different usage models of wearable systems. Steve Mann has carried out extensive work in the field of making computer systems wearable (Mann et al 1997).

Probably the best-known example of smart clothing is a textile keyboard and a synthesizer embedded into a denim jacket (Post and Orth 1997). Intelligence in the form of electrical components has also been embedded into other pieces of clothing, e.g. gloves (Perng et al 1999), ties (Schmidt et al 1999), suspenders (Gorlick et al 1999), undergarments (Mann et al 1996) and footwear (Paradiso and Feldmeier 2005). Electro Textiles Company Limited has adopted another view in the development of smart clothes. They started by introducing new functionality into textile material without compromising other clothing-like properties such as washability and flexibility. The Defence Clothing and Textile Agency has done research on material development for smart clothing. They have studied shape memory materials (Russell et al 2000), active ventilation, heat transfer through garments, and reactive waterproof materials (Elton et al 2000). Gore Leckenwalter et al (2000) has developed many new materials based on Polytetrafluoroethylene (PTFE) technology and has concentrated on waterproof, windproof, and breathable fabrics.

Du Pont developed the polymeric optical fibre in 1964, and Mitsubishi Rayon later introduced the technology for it as a commercial product. Tampere University of Technology studies POF manufacturing methods in the Technical Textiles laboratory of Fibre Material Science. Many electronic functions can be built into textiles based on low-tension electrical connection. However, limitations related to electromagnetic disturbances and moisture is evident. In contrast to the electric connections, light transmission is not affected by the defects of physical surroundings. The light wave-guides may be prepared of silica glass, which are very efficient for data transmission,
especially at long distances. In textile integration, POF is a reasonable choice because of its high mechanical flexibility and durability.

2.8 WEARABLE SENSORS

Clothing is a basic need of human kind besides food and shelter. About six thousand years ago, man started to replace the inflexible animal skin by manufactured textiles. The body protection functionality has been enlarged by aesthetic attributes. Beyond their protective and aesthetic functions, clothes as our second skin have the potential to acquire an additional functionality as a personalized and flexible information platform (Park and Jayaraman 2001). Wearable Computing will change the mobile computing landscape provided that the unobtrusive integration of electronics in our daily outfit becomes feasible.

Today people are actively involved in their health and increasing their activity-level to prevent health risk factors. Applications in the medical field are highly accepted by customers because of personal benefits provided like extending active lifetime by disease prevention or disease management based on objective measures. Vital signs like ECG, EEG or respiration monitor almost continuously can give information about the cardio-vascular system of a patient. A recent approach is to investigate concepts in which sensors are integrated into clothing for monitoring purposes measuring signals of movements, temperature, galvanic skin response and patient’s activities. To pick up electrical signals by intelligent textiles one essential component of a system design is using an appropriate electrode-design.

Permanent monitoring, which will become possible with textile sensors, opens up new perspectives for traditional parameters too. Permanent monitoring supported by self-learning devices will allow the set-up of personal profiles for each individual, so that conditions deviating from the
normal state can be traced as soon as possible. There are a variety of sensing technologies that could be envisioned for context recognition for instance audio, video, photography, acceleration, light, air and body temperature, heat flux, humidity, pressure, heart rate, strain gauges, galvanic skin response, electrocardiograms or electromyograms. Streaming video is overly expensive on bandwidth and many physiology sensors require skin contact or special outfits. There is clearly a tradeoff between informative and unobtrusive sensing.

The AMON (Advanced Medical Monitor) system is a next generation wearable medical monitoring computer that has been developed by a European Union (AMON 2001). It provides complex monitoring, data analysis and communication capabilities in a single wrist worn unit. AMON has been conceived as a clinical device for high risk patients requiring constant monitoring, logging and analysis of their vital signs. Belardinelli et al (1998) and Jovanov et al (2000) presented a wrist worn medical monitoring computer designed to free high risk patient from the constraints of stationary monitoring equipment. The system combines complex medical monitoring, data analysis and communication capabilities in a truly wearable watch like form. The paper by Jens Mühlsteff (2004) describes and characterizes dry electrodes based on silicone rubber concerning their usability for functional clothes.

Health monitoring applications were initially explored for military purposes with the objective of remotely determining the physical status of troops in the field. The Personnel Status Monitor was designed to predict when a soldier is either injured or fatigued using a wide range of sensors, processing boards and a wristwatch display (Satava 1997). A simpler low-cost, lightweight, noninvasive and adaptable system employed a single neck mounted acoustic sensor to listen to the sounds of blood flow, respiration and
the voice, while minimizing ambient sound (Siuru 1997). The sensor can collect information related to the function of the heart, lungs, and digestive tract or it can detect changes in voice or sleep patterns, other activities, and mobility. Extensive testing with soldiers and firefighters has demonstrated the effectiveness of this design to help understand the interrelations between physiology, the task at hand, and the surrounding environment. More recently health monitoring wearable has become commercially available in the form of the Bodyscan product range (Bodyscan). This is based around an armband design with sensors for detecting movement, heat flux, skin temperature, near-body temperature, and galvanic skin response. Data can be either viewed in real time via a wireless link, or downloaded for analysis using the Internet.

Meanwhile academic research continues with health monitoring wearable such as the University of Birmingham's Sensvest for monitoring sports activity (Knight et al 2005); the WEALTHY Wearable Health Care System which seeks to improve the comfort of wearable systems by integrating sensors with the fabric of the users clothes; and the GRID enabled system which can display live data, historical data, or perform data mining developed by the University of Nottingham (Crowe et al 2004). Providing assistance for people with special needs has become an important role for wearable. Many systems have been explored to provide the visually impaired with guidance. Early examples of this were developed at the University of California, Santa Barbara using GPS (Loomis 1985). Evolving from a bulky backpack design, the current system weighs only a few pounds and is worn in a pack slung over the shoulder. A radically different approach was taken by the University of Bristol (Campbell et al 1995) in which real-time video from a body worn camera produced images in which areas such as pavements were classified, identified and presented to the visually impaired user as registered colour coded areas on a head mounted display.
Interaction and communication in this field can also be assisted by wearable, for instance with the deaf using MIT's American Sign Language Recogniser (Starner and Paradiso 2004); and the forwarding of images from body worn cameras at accident scenes to hospitals from medics while talking to the waiting doctors using British Telecom's CamNet system (Garner et al 1997). The continuing challenge of medical wearable is the achievement of interfaces which can be worn, and will operate reliably, without the conscious involvement of the user. Perhaps more than in any other wearable computing field it is important that the wearable augments and assists daily life and does not interfere with the normal functions, especially for users who may have special needs. Elise Co explored computational fashion in her Masters thesis at MIT with creations featuring bio- and movement sensors controlling displays in the garments structure (Co 2000). There is undoubted appeal for such fashion items and products are starting to become available commercially (Enlighted).

The first physiological parameter measured using intelligent textiles is the heart activity. Heart signals are one of the basic parameters in health care. The heart is a muscle controlled by the brain through electrical impulses (Clark 1998). Since the body is a vessel filled with aqueous electrolyte, these signals can be detected in all of its parts. The generated difference in electrical potential can be measured on different spots on the skin. This signal is the electrocardiogram or ECG. The ECG of a normal person at rest has a fundamental frequency of about 1.2Hz (Golden et al 1973). Priniotakis et al (2007) paper demonstrates electrochemical impedance spectroscopy is a useful technique to measure the properties of textile electrodes in an accurate and repeatable way.

Several wireless ECG monitoring systems have been proposed (Otto 1998), (Lo 2005), (Joshua Proulx 2006), (Rune Fensli 2005), (Eugene
Shih 2004), (Victor Shnayder 2005). The paper by Victor Shnayder et al (2005) presented a description and evaluation of a wireless version of a system based on these innovative ECG sensors. Experimental results show that the wireless interface will add minimal size and weight to the system while providing reliable operation. The development of an active implantable device for measuring electrocardiogram (ECG) is presented in Jarno Riistama et al (2007). To measure ECG and blood pressure the subject attention is required. An unobtrusive and wearable, multi-parameter ambulatory physiological monitoring system for space and terrestrial application, termed LifeGuard (Mundt et al 2005) has been developed. The system uses the conventional electrodes to acquire ECG and interfaces a separate non-invasive cuff-based blood pressure monitor and wires from the sensors to the data acquisition hardware are routed around the subject. The U.S. Army Medical Research and Material Command has developed the War fighter Physiological Status Monitoring (WPSM) system (Hoyt et al 2002), which is intended to be a next-generation combat uniform featuring a configurable array of miniaturized sensors. These sensors acquire various physiological data and transmit them to a central hub device so as to be stored, analyzed using life sign decision support algorithms (Savell et al 2004) and sent to command communication networks when desired. The project CodeBlue from Harvard University is a wireless infrastructure, which is intended for deployment in emergency medical care; integrating low power, wireless vital sensors, PDA and PC (Lorincz et al 2004). VivometricsTM an US based company has developed ‘Life Shirt’ to acquire a number of physiological parameters (Carter et al 2004) (Wilhelm et al 2006). This system uses the conventional electrodes to acquire ECG and there is no online analysis of data. A wireless sensor network for smart electronics shirt has been developed which allows the monitoring of individual biomedical data and is transmitted wireless for further processing using a wireless link (Carmo et al 2005). A novel wearable cardio respiratory signal sensor device for monitoring sleep
condition at home using a belt-type with conductive fabric sheets and a PVDF film is developed (Choi and Jiang 2006). A wearable system with sensing bio-clothes for monitoring five leads of ECG signal and body gesture/posture without transmission are reported in (Paradiso et al 2005) (Pacelli et al 2006). Ambulatory health status monitoring consisting of multiple sensor nodes that monitor motion and heart activity by a personal server is reported (Otto et al 2006). Smart sensors for continuous detection of vital physiological such as ECG, heart rate and blood pressure and physical gait signals with Bluetooth wireless transmission for determination of fall to prevent injury has been developed (Choon Po et al 2006).

Though the above systems use new innovative sensors, but they lack in terms of the number of vital parameters being monitored. A number of wearable physiological monitoring systems have been put into practical use for health monitoring of the wearer in hospital and real life situations and their performances have been reported. The Armband SenseWear (BodyMedia Inc, Pittsburgh, PA USA) wearable body monitor has been used to study bodily movement and energy expenditure in normal subjects and chronic obstructive pulmonary disease (COPD) subjects. Pandian et al (2008) describe the wearable physiological monitoring system, which uses an array of sensors connected to a central processing unit with firmware for continuously monitoring physiological signals. The data collected can be correlated to produce an overall picture of the wearer’s health.

Smart textiles with wireless communication to monitor the bio-signals are increasing in the last few years. For the purpose of acquiring the exact signals, commercial electrodes are usually used, especially on the exercise ECG application (Healey and Logan 2005). In addition, fabric-based electrodes are also studied (Scilingo et al 2005). In the study by Chien-Lung Shen et al (2006), a wearable fabric-based sensing band is developed.
Combining with the textile structure design and the processing algorithm, any mechanical signals resulted from exercise can be eliminated and the ECG signals are cleared from motion artifacts.

Locher et al (2004) presented a smart fabric system with temperature sensing capability. The woven structure of the hybrid fabric itself represents an array of temperature sensors that can be utilized to measure the temperature profile of a surface (Jan De Vries et al 1993). Currently, many research labs concentrate on the side of signal transmission (Jung et al 2003). Temperature measurement is one option, but fabrics have the capacity to integrate other sensing functionality. The paper by Lorussi et al (2004) describe the work on fabric-based strain sensors in order to track body postures. Companies such as Softswitch, Eleksen and ITP investigate in fabric pressure sensors.

2.9 BIOMONITORING DEVICES

Multifunctional electroactive fibres and fabrics will give the traditional textile industry a new additional value, the possibility of making daily life healthier, safer and more comfortable, bringing technological advances closer to the public through the use of easy-to-use interfaces between humans measuring devices and actuators. The fabrication of such multifunctional interactive fabrics represents a potentially important tool for promoting progress, sustainable development and competitiveness in several disciplines such as health monitoring, rehabilitation, ergonomics, disability compensation, sport medicine, telemedicine and teleoperation.

The paper by Danilo De Rossi et al (2003) give a picture of the potential use of smart materials in the realization of sensing strain fabrics and of actuating systems. In particular, the early stage implementation and preliminary testing of fabric-based wearable interfaces are illustrated with
reference to a functionalized shirt capable of recording several human vital signs and wearable motion-capture systems. The implementation of truly wearable, instrumented garments which are capable of recording biomechanical variables is crucial in several fields of application, from multimedia to rehabilitation, from sport to artistic fields. Danilo De Rossi et al 2003 discussed about wearable devices which can read and record the vital signs and movements of a subject wearing the system. Chen et al 1999 described monitoring of multiple vital signs based on mobile telephony and internet. The overarching goal of this Wearable Biomonitor project by Bozena Kaminska et al (2004) is to create solutions that will optimize lifetime wellness of a person, thereby enhancing quality of life, permit independent living as long as possible, provide real-time support and advice as an electronic "health companion", and reduce the overall life cycle cost of health and medical care.

Knight et al (2007) paper describes the use of accelerometers in wearable systems for a number of applications. In particular, systems for the detection of activity status, assessment of performance and for teaching were explored. Knight et al 2007 suggested that a trace of accelerometer data can be used as a referent model to improve technique for skilled performance. This may be best achieved if the trace can easily be dissected into the constituent actions of the whole activity. Anastopoulou (2004) suggested that for future teaching uses, movements for investigation should be less rapid, and less specific, to allow open-ended investigation by the student. Dario and de Rossi (1985) described the development and applications of an artificial, flexible, force sensitive skin that can measure the spatial distribution and magnitude of forces perpendicular to the sensing area. Various sensor structures have been developed for this purpose based on piezoresistive, piezoelectric, optoelectronic or capacitive force sensing technologies on silicon, printed circuit boards or flexible substrates (Minbang and Heping
1991) (Snyder and Clair 1978) (Dario et al 1982) (Mei et al 1999) (Lumelsky et al 2001). The paper by Dario et al (1985) describes a novel force sensing mechanism along with the smart skin fabrication process, the accompanying electronics and representative applications. The novel force sensing mechanism of contact piezoresistance has been used to create a versatile, flexible, smart skin Berry et al (2004). The work by Murat Guler and Seniz Ertugrul (2003) describes monitoring vital body signs by placing the electronic devices into a garment in a compact way.

2.10 INTERFACING CIRCUITS AND GARMENTS

The integration of digital components into clothing is becoming an increasingly important segment in wearable computing research. The first indications for this trend are the incorporation of existing mobile technologies, such as personal digital assistants (PDAs) or mobile phones, into jackets via flexible textile circuits. Post and Orth (2000) introduces a functioning prototype of such a flexible network that not only allows communication between wearable components, but is also able to supply power to them. They propose an arrangement of layered textiles as opposed to the more traditional routed circuitry layout, which results in a novel approach towards the concept of a flexible clothing network.

Weaving integrates yarns of different colors into a large variety of complex two-dimensional and three-dimensional patterns (Adanur 2001). Techniques derived from weaving could furnish new approaches to interconnecting and integrating electronic components. Textile-like electronics (e-textiles), by being drapeable and conformable, could also become a new class of human/machine interfaces (Park and Jayaraman 2003), (Wagner et al 2003). Eitan Bonderover et al (2004) described the weaving of an electronic circuit from component fibres. Multiple and single (Lee et al 2003) transistors on Fibre have been made recently. Thin-film transistors
(TFTs) of amorphous silicon made on substrates of 0.5mm thick polyimide foil (Gleskova et al 1999) keep functioning while bent (Gleskova et al 2003) to radii of curvature as small as 0.5 mm.

Eitan Bonderover et al (2004) presented a new type of electronic circuits: e-textiles. Such circuits are made by weaving together specialized component fibres. The fibres have electronic components integrated onto them. Various circuits can be formed by weaving these fibres in various patterns. Connections between fibres are made using contact pads, which are free to move against each other, thus keeping the fabric flexible. They made an inverter circuit by weaving component fibres to make a fabric. To keep the fabric flexible, electrical connections between fibres are made by pressure contacts. Also they have demonstrated that an e-textile with a specific electronic function can be woven from generic component fibres. Fuller exploitation of this concept awaits advances in technology for making component fibres.

Wearable technology has the potential of allowing clinicians to track patient status over extended periods of time. This capability could have a significant impact on clinical applications in cardiology, orthopedics, neurology, and other clinical fields. The application of wearable technology would lead to significant improvements in patient management in the field of rehabilitation medicine. In the recent past, researchers have focused their work on two types of wearable systems: 1) wireless body sensor networks and 2) special garments with embedded sensors. (Gibbs and Asada 2005) (Tognetti et al 2005). Wearable systems for continuous monitoring of patient status could positively affect the quality of patient management in rehabilitation hospitals.

Christopher Einsmann et al (2005) have realized that there is a difficult set of related problems that must be addressed if e-textiles are to
reach their full potential for wearable computing: an e-textile garment must be able to sense the shape of the garment, the location of sensors on the garment, and the user’s motions (Jones et al 2002). The integration into woven structures has been presented in Kallmayer et al (2003). Temporary contacts and embroidered circuitry with conductive yarn have been introduced in Linz et al (2005b) Building embroidered electrical interconnection with a simple embroidery machine has been presented in Linz et al (2005a). The research by Post et al (2000), concentrated on the creation of conductive embroidered circuits. The usefulness of textile-integrated electronics stands out in applications where a distributed sensing, computing or energy sourcing is an indispensable part of the system.

E-Textiles are envisioned to be useful for applications in human monitoring, wearable computing, and large area sensor networks. Various examples and techniques for creation of e-textile systems are introduced in Marculescu et al (2002). Fibre form components offer intrinsic integration into textiles for added concealment and comfort; such fibre components include batteries (Kim et al 2000) and acoustic sensors (Piezo Film Sensors 2003). Piezo-electric material was used in (Edmison et al 2002) to sense the movement of the fingers while being integrated in a glove. The Georgia Tech Wearable Motherboard (GTWM) (Firoozbakhsh et al 2000) is to be used in a combat situation to assess the seriousness of a soldier’s wound and communicate this data. The interconnections in this fabric will determine the location of a bullet penetration. The GTWM can be used as a PAN (Personal Area Network) where the devices carried by the user can interact and share data. The sensor algorithms that run on e-textiles, for example the acoustic beam forming algorithm discussed in Riley et al (2002), require information from sensors at specific physical locations, yet the flexibility of fabric means that the relative and absolute locations of elements on the fabric will change. Given this, the communication scheme must support location-specific rather
than node specific communication and addressing. Note that the implementation should take advantage of the fact that the physical connections on the fabric are inherently a two-dimensional grid that, absent faults, does not change even as the locations of elements change. Finally, standalone e-textiles must be power-efficient, requiring computational elements to sleep whenever possible. Communication must account for the cost of activating and routing around such nodes.

The Token Grid network presented in (Todd. et al 1992) (Todd et al 1997) will be modified for use as the interconnection network. Other types of networks were examined for feasibility, but do not necessarily map well to e-textiles. For example, in an e-textile system the number of nodes to be connected is not known a priori and that number is expected to change throughout the lifetime of the system. The node degree increases linearly with an increase in the dimension of a hypercube (Hwang 1993); this poor scalability factor renders architectures similar to the hypercube unsuitable for e-textiles. Tree-type architectures rely heavily on specific nodes for connections between different branches, which does not map well to the faulty environments of e-textile applications. The scalability and fault tolerance of the token grid are the primary attractive features.

2.11 COMMUNICATION BETWEEN CIRCUITS AND GARMENTS

There are certain professions in which one may have to be highly active and are prone to dangers, such as a soldier fighting the enemy, fire fighters, law enforcement personnel, miners, deep-sea divers and astronauts in space. Considering the mobility and vulnerability, it is very important to monitor the health status and geo-location of the personnel to ensure the safety and effective completion of the assigned job. Hence, there has been a significant shift in the development of the clothing by way of introduction of
the sensors into the clothing worn by the personnel. In conventional monitoring systems there are too many hampering wires, which are meant for acquiring physiological signals, and the system is too bulky to be used for wearable applications (Martin et al 2000).

The uses of existing technologies and demands for new functions constantly increase, contributing opportunities for further development and incorporation of new technologies. The people have become highly dependent on various forms of technology: in the office, in our cars, and at home. The need for continuous communication and access to information has led to the development of portable technologies, devices that have connected us to an electronic world of data. The portability of technology has increased significantly in the last decade, with the development of sleek palm-sized cell phones from the bulky cordless phones of the 80s, and pocket sized personal digital assistants from computers that occupied most of desktop and originally occupied whole rooms. These advances are the result of miniaturization of electronics. Computing power has been reduced to the nano-scale allowing devices to occupy a fraction of the space they once did. The next logical step is wearability. Wearable technology is more than an easily carried device. Clothes are not carried, they are worn. They are more intimately connected to us than hand held devices, so they are not treated as a separate item.

Wearable technology is specifically intended to be worn close to the body for extended periods of time. Thus it must take into account factors related to human-machine interaction: issues of comfort, mobility, usability and aesthetics. A specific category of wearable technology is emerging, is that of intelligent clothing. Intelligent or “smart” clothing has augmented functions that are derived from new technologies. It is a sub-group of wearable technology, characterized by its emphasis on the integration of technology into ordinary garments, so that the technology becomes part of a
garment or garment system. The functions that it fills are generally those traditionally performed by clothing and garment systems, functions that can be augmented to operate more powerfully with technology. The user interface is subtle and relies on sensor input from both user and environment to automate tasks. Intelligent clothing is designed to be unobtrusive. It is also designed to reduce the intentional demands on the user through automation of functions.

Future clothing may have a variety of consumer electronics products built into the garments. Physical locations of people and objects are the most widely used context information in context-aware applications. To enable location-aware applications in indoor environments, many indoor location systems such as Active Badge (Want et al 1992), Active Bat (Harter et al 1999), Cricket (Priyantha et al 2000), Smart Floor (Orr and Abowd 2000), RADAR (Bahl and Padmanabhan 2000), (Ekahau 2003) were proposed in the past decade. However, there is no widespread adoption of such systems in everyday environments. The main obstacle is the level of system infrastructural support required in the deployment including hardware, installation, calibration, maintenance, etc. Significantly reducing the needed system infrastructure serves as our primary motivation to design and prototype a new footstep location system.

Shun-yuan Yeh et al (2007) adapted dead reckoning to track human footsteps from a starting point, such as the entrance of an indoor facility. A wearable location tracker is an important advantage over infrastructure-based indoor location systems. There is a growing body of research on sensor network data management. CodeBlue is a wireless communications infrastructure for medical care applications. It is based on publish/subscribe data delivery where sensors worn by patients publish streams of vital signs and geographic locations to which PDAs or PCs accessed by medical
personnel can subscribe. Secure and ad hoc communication, prioritization of critical data, and effective allocation of emergency personnel in case of mass casualty events are major emphases of this project. In this project a challenging sensor network application which can highly benefit from various data management strategies have been studied.

A potential research direction involves treating sensor readings as continuous waveforms with integrity constraints. If recent heart rate readings suggest that the heart rate could not have gone beyond normal threshold since the last reading, then not need to receive a new heart rate report. WPSM-IC is currently concerned with dismounted warriors and the management of their personal area networks. The goal at this point is to create a summary of the soldier's physiological state at the hub. In the future, this state information would be disseminated to other battlefield units. The information that is uploaded beyond the individual soldier would be used for some form of remote triage. The remote triage problem, of course, comes with its own technical challenges.

Recent technological advances in wireless networking, microelectronics integration and miniaturization, sensors, and the Internet allow us to fundamentally modernize and change the way health care services are deployed and delivered. Focus on prevention and early detection of disease or optimal maintenance of chronic conditions promise to augment existing health care systems that are mostly structured and optimized for reacting to crisis and managing illness rather than wellness (Dishman 2004).

Wearable systems for continuous health monitoring are a key technology in helping the transition to more proactive and affordable healthcare. They allow an individual to closely monitor changes in her or his vital signs and provide feedback to help maintain an optimal health status. If integrated into a telemedical system, these systems can even alert medical
personnel when life-threatening changes occur. In addition, the wearable systems can be used for health monitoring of patients in ambulatory settings (Istepanian et al 2004). For example, they can be used as a part of a diagnostic procedure, optimal maintenance of a chronic condition, a supervised recovery from an acute event or surgical procedure, to monitor adherence to treatment guidelines (e.g., regular cardiovascular exercise), or to monitor effects of drug therapy.

During the last few years there has been a significant increase in the number and variety of wearable health monitoring devices, ranging from simple pulse monitors, activity monitors, and portable Holter monitors, to sophisticated and expensive implantable sensors. However, wider acceptance of the existing systems is still limited by the following important restrictions. Traditionally, personal medical monitoring systems, such as Holter monitors, have been used only to collect data. Data processing and analysis are performed offline, making such devices impractical for continual monitoring and early detection of medical disorders. Systems with multiple sensors for physical rehabilitation often feature unwieldy wires between the sensors and the monitoring system. These wires may limit the patient's activity and level of comfort and thus negatively influence the measured results. In addition, individual sensors often operate as stand-alone systems and usually do not offer flexibility and integration with third-party devices. Finally, the existing systems are rarely made affordable.

One of the most promising approaches in building wearable health monitoring systems utilizes emerging wireless body area networks (WBANs) (Jovanov et al 2005). A WBAN consists of multiple sensor nodes, each capable of sampling, processing, and communicating one or more vital signs (heart rate, blood pressure, oxygen saturation, activity) or environmental parameters (location, temperature, humidity, light). Typically, these sensors
are placed strategically on the human body as tiny patches or hidden in users’ clothes allowing ubiquitous health monitoring in their native environment for extended periods of time.

A number of recent research efforts focus on wearable systems for health monitoring. Researchers at the MIT Media Lab have developed MITHril, a wearable computing platform compatible with both custom and off-the-shelf sensors. The MITHril includes ECG, skin temperature, and galvanic skin response (GSR) sensors. In addition, they demonstrated step and gait analysis using 3-axis accelerometers, rate gyros, and pressure sensors (Pentland et al 2004). MITHril is being used to research human behaviour recognition and to create context-aware computing interfaces (DeVaul et al 2003).

Current wearable applications still have several problems to be worked out before mass market. Many of them are related to the maintenance of the device, e.g. machine washing, recharging of batteries and customer service. Bringing a function close to the body can often be of more service than merely delivering hands free operating, but interfacing the wearable devices can be complicated. If the wearable device requires both input and output and needs to be operated on-the-go, an integrated wearable user interface may cause more problems than it solves. First of all the usability may suffer if for example text input, or any multi-key input must be used; constructing a soft washable keypad is possible (Post et al 1997) but efficient typing may be difficult for lack of suitable rigid surfaces on the body against which to press the keys. Secondly, for the same reasons high resolution display output is not yet an option as the flexible displays still really are not flexible and tough enough to withstand regular garment wear (Moore 2002). Woven optical Fibre displays (Gould 2003) are softer in feel and lighter, but so far do not offer needed resolution or brightness. Thirdly, hard objects
larger than a button or a zipper in soft textile are likely to damage the fabric in machine wash. Constructing them waterproof and rigid enough to be able to take a washing cycle is expensive and time-consuming. Finding a perfect location for the display and a keypad is hard from a usability and ergonomic point of view (Thomas et al 2002). By making the mobile phone a part of the system the toughest problems of added manufacturing (and purchasing) costs and the maintenance of the garment-integrated electronics could be solved.

2.12 SOFTWARE DEVELOPMENT

The decreasing portion of money the consumers spend for clothing increases the textile manufacturers’ demand for new differentiation potentials. Integrating electronic intelligence into clothes is one possibility. Several institutions have presented research studies on wearable electronics based on already existing consumer devices like cellular phones, MP3-players, etc. Electronic textiles or e-textiles are a new emerging interdisciplinary field of research which brings together specialists in information technology, microsystems, materials, and textiles. The focus of this new area is on developing the enabling technologies and fabrication techniques for the economical manufacture of large-area; flexible, conformable information systems that are expected to have unique applications for both consumer electronics and military industry.

E-textiles offer new challenges for designers and CAD tool developers due to their unique requirements, cutting across from the system to the device and technology.

- The need for a new model of computation intended to support widely distributed applications, with highly unreliable behavior, but with stringent constraints on longevity of the system.
• Reconfigurability and adaptability with low computational overhead. E-textiles rely on simple computing elements embedded into fabric or directly into active yarns. As operating conditions change (environmental, battery lifetime, etc.), the system has to adapt and reconfigure on-the-fly to achieve a better functionality.

• Device and technology challenges imposed by embedding simple computational elements into fabric, by building yarns with computational capabilities, or by the need of unconventional power sources and their manufacturing in filament or yarn form.

There have been a handful of attempt to design and build prototype computational textiles. In particular, if medical assistance can be provided to an injured soldier within the so-called "golden hour", mortality can be significantly reduced. Teleintimation garment can serve as a monitoring system for soldiers that are capable of alerting the medical triage unit when a soldier is shot, along with information on the soldier's condition characterizing the extent of injury and the soldier's vital signs. This garment can be used for the continuous monitoring of the vital signs of athletes to help them track and enhance their performance. In team sports, the coach can track the vital signs and the performance of the player on the field and make desired changes in the players on the field depending on the condition of the player. The knowledge to be gained from medical experiments in space will lead to new discoveries and the advancement of the understanding of space.

Monitoring the vital signs of those engaged in mission critical or hazardous activities, such as pilots, miners, sailors, and nuclear engineers. Special-purpose sensors that can detect the presence of hazardous materials can be integrated into the garment and enhance the occupational safety of the
individuals. Combining the teleintimation garment with a GPS (Global Positioning System) and monitoring the well-being of public safety officials (firefighters, police officers, etc.), their location and vital signs at all times, thereby increasing the safety and ability of these personnel to operate in remote and challenging conditions.

2.13 POWER SYSTEM

After Alessandro Volta invented the battery in 1799, predating Michael Faraday’s dynamo by 32 years, batteries provided the world’s first practical electricity source until the wiring of cities in the late 1800s relegated batteries to mobile applications. Despite vacuum tube electronics’ weight and large associated battery, people living in the early 1900s lugged such enormous “portable” radios to picnics and other events off the power grid. As electronics became smaller and required less power, batteries could grow smaller, enabling today’s wireless and mobile applications explosion. Although economical batteries are a prime agent behind this expansion, they also limit its penetration; ubiquitous computing dream of wireless sensors everywhere is accompanied by the nightmare of battery replacement and disposal.

Exploiting renewable energy resources in the device’s environment, however, offers a power source limited by the device’s physical survival rather than an adjunct energy store. Energy harvesting’s true legacy dates to the water wheel and windmill, and credible approaches that scavenge energy from waste heat or vibration have been around for many decades. Nonetheless, the field has encountered renewed interest as low-power electronics, wireless standards, and miniaturization conspire to populate the world with sensor networks and mobile devices.
Energy recovery from wasted or unused power has been a topic of discussion in recent times. Unused power exists in various forms such as industrial machines, human activity, vehicles, structures and environment sources. Among these, some of the promising sources for recovering energy are periodic vibrations generated by rotating machinery or engines. Primarily, the selection of the energy harvester as compared to other alternatives such as battery depends on two main factors cost effectiveness and reliability. In recent years, several energy harvesting approaches have been proposed using solar, thermoelectric, electromagnetic, piezoelectric, and capacitive schemes which can be simply classified in two categories (1) power harvesting for sensor networks using MEMS/thin/thick film approach, and (2) power harvesting for electronic devices using bulk approach Snyder (1985). The small portable FM radio or walkman requires a small power level of 30 and 60 mW. These magnitudes of power are possible to be continuously harvested from human and industrial activity (Choon Po et al 2006). Shashank Priya (2007) review article provides a comprehensive coverage of the recent developments in the area of piezoelectric energy harvesting using low profile transducers and provides the results for various energy harvesting prototype devices.

Power source is one of the key elements for pervasive sensing. It often dominates the size and lifetime of the sensors. Thus far, battery remains the main source of energy for sensor nodes. In order to provide a constant energy supply; power scavenging is an actively pursued research topic. A number of power scavenging sources have currently been proposed, which include motion, vibration, air flow, temperature difference, ambient electromagnetic fields, light and infra-red radiation. For instance, Mitcheson et al (2004) developed a vibration based generator designed for wearable/implantable devices.
With the need for an alternative source of power comes many solutions that although seem plausible on paper in reality do not operate as required. The human body experiences many different motions that could in theory be converted into electrical power Mitcheson et al (2004). But most of this power is not at a usable level. Studies have shown that out of all the energy-dissipated areas on the body the foot experiences the largest amount (Stner 1996). The energy/power that is dissipated while walking/running is large enough to be converted to a usable electrical level. The work by Kendall (1998) has focused on implementing piezoelectric materials embedded in the sole of shoes, and although this work has shown a lot of promise it does have its limitations. The performance of electromagnetic generators designed for integration in a person's shoes is described by Damien Carroll and Maeve Duffy (2005).

There has been a steady increase in the technology worn and carried by the individual soldier. Today’s soldier carries a wide array of electronic devices such as computers, communications equipment, enhanced sensory devices and weapon systems. all requiring portable power. The increasing demand for power required by these electronic devices, coupled with a requirement to function as a distinct military system, has significantly increased the weight of the load carried by the individual soldier. The Army is aware of the situation and has identified problem areas of battery weight, space and power density for the current rechargeable power sources carried by the soldier. One area identified for further study is the potential benefits that rechargeable lithium-ion polymer batteries can achieve in both increased energy density and ergonomic packaging. The objective of this study is to evaluate and demonstrate novel approaches to packaging a rechargeable battery in a man wearable configuration for integration into specific military applications. A silicon-based micromachined thermoelectric generator chip for energy harvesting from body heat was proposed by Weber et al (2002)
Mobile and wireless electronic devices are increasingly popular and rapidly developing. Entertainment, voice and data communication, medical and emergency needs foster the further diversification of applications, devices and services, Whereas continuously evolving wireless protocols enable all sorts of services and communications, a sustainable wireless power supply is obviously rather difficult to accomplish. Clothing integrated photovoltaic, however, can solve this problem by providing sufficiently large areas in the range of several 100 cm² up to about 2,000 cm², directly on garments or accessories. The integration of photovoltaic into clothes imposes some novel challenges and restrictions which are uncommon to standard photovoltaic. Wemer et al (2003) presented the status and recent progress in all components for clothing integrated photovoltaic. In parallel to the development of flexible solar cells, they have demonstrated first prototypes of integrated photovoltaic garments, equipped with commercial amorphous silicon cells and realized in cooperation with our partners from clothing industry. However, as the system performance is increased and the system functionality improves the total power requirements are higher. The energy necessary to power such systems is stored in batteries. Batteries are a significant source of size, weight and inconvenience to present-day portable, hand held and wearable systems.

Integration of flexible solar cells into clothing can provide power for portable electronic devices. Photovoltaic is the most advanced way of providing electricity far from any mains supply, although it suffers from the limits of ambient light intensity. But the energy demand of portable devices is now low enough that clothing-integrated solar cells are able to power most mobile electronics.

Since 2000, design studies on solar cells integrated into clothing have been regularly presented at fairs and exhibitions on ‘smart textiles’ Christine Kallmayer et al 2005 or ‘smart clothes’, e.g. the Avantex fairs in
Frankfurt, Germany, the Nixdorf Innovation Forum Axisa (2005) in 2000, Hartmann et al (2000) presented a vision of high-tech fashion including the use of photovoltaic power. Although consumers and the clothing industry seem to be very interested in clothing-integrated photovoltaic, the advent of real products in the market has been hindered and delayed by the limited availability and performance of flexible solar cells Leckenwalter (2000).

From a customer point of view, a clothing integrated photo voltaic system should be easy to use, comfortable and reliable, offer a universal socket for the countless different charging adapters and devices, and, of course, deliver plenty of energy at an affordable price. If parts of the system need to be visible, they should be attractive and integrate well with the particular design of the garments. Connecting wires, charge controllers, and batteries ought to be invisible, lightweight, and maintenance free. As an additional requirement, clothing with integrated electronics and photovoltaic should be as washable as every other textile. The most decisive and restricting demand, however, is the conformal flexibility of solar cells used for clothing integration. Existing cells on plastic or metal foils with protective laminates can only bend in one direction rather than exhibiting full conformal flexibility like a woven textile.

Since the idea of a ubiquitous power supply from the photovoltaic conversion of ambient light is very appealing, one needs to investigate how much energy is harvested during a cloudy or rainy day, or during indoor use of integrated photovoltaic. Because of a considerable lack of data in the literature, Gleskova et al (2002) performed a detailed study to link empirical, long-term data on the incident solar radiation that reaches the earth’s surface under different weather conditions, as well as various indoor illumination scenarios, with the spectral and intensity dependence of different types of solar cells.
The interest in flexible solar cells is steadily increasing, since high altitude platforms, satellites for telecommunications, and deep-space missions would benefit from rollable or foldable solar generators. The integration of photovoltaic with textiles is not only interesting for powering portable devices, but also opens a wealth of opportunities for the integration of electronic features with architectural fabrics. The US company United Solar Ovonic manufactures flexible triple junction a-Si-based modules on steel foil for building integration with a total power output above 45 MW per year. Since these modules are designed for long-term outdoor stability, the final laminates are comparatively rigid and not suitable for large-area clothing integration. Current thin-film solar cells consist of a layer stack that is continuous in two dimensions and very thin in the third. Because of their planar substrates, these cells bend but do not crinkle. Solar cells have been formed on copper wires for fabrics made of photovoltaic fibres. Without a continuous planar substrate, however, the fibres arbitrarily move against each other, which gives rise to many problems like moving interconnects, shadowing, and cancellation of the electric output of single fibres. Finding a compromise between the minimum total thickness and, hence, maximum conformal flexibility of integrated photovoltaic modules on the one hand, and washability, mechanical resilience, and durability on the other, is an important task that has not yet been solved for most of the flexible cell technologies described here. A lot of hope is focused on organic and dye-sensitized solar cells that could, in principle, be printed on polymer foils. In a major breakthrough in organic solar cell technology, Brabec et al (2004) demonstrated bulk hetero junction cells with a conversion efficiency of 5%. The main challenge for all these organic and dye-sensitized cell concepts, however, is in their encapsulation and long-term stability.
2.14 SUMMARY

Health monitoring is among the most attractive application fields for wearable electronics and has been studied by many research groups. A variety of wearable devices for monitoring physiological parameters are commercially available today with many others in research and development stage. However the majorities of such devices are aimed at the recreational market and are not suitable for medical monitoring of high risk patients. Today’s consumer is demanding interactivity, connectivity, ease of use, and a “natural” interface for information processing. The enabling technologies of electronics, sensors, computing, and communications are becoming pervasive. Since textiles is pervasive from clothes for newborns to senior citizens, from fabrics in automobile seats to tents in battlefields and presents a “universal” interface, it has the potential to meet this emerging need of today’s dynamic individual. Moreover, an individual is likely to be forgetful and leave a PDA behind, but is unlikely to walk out of the home without clothes. Therefore, there is a critical need to integrate the enabling technologies into textiles so that the traditionally passive, yet pervasive, textiles can be transformed into an interactive, intelligent information infrastructure for the demanding end user to facilitate pervasive information processing. Such a system can facilitate personalized mobile information processing and give new meaning to the term “human–machine symbiosis” in the context of pervasive/invisible computing.