1. Introduction

Need for Wearable Electronics

- Invasive and Uncomfortable Sensors
  - Restricted applications where the sensing function is crucial to the subject's health
    - Medical
    - Military

- Truly Wearable Sensors
  - A close interdisciplinary cooperation is necessary
    - Electronics, textiles, clothing science
  - Trade-off for sensing accuracy must be overcome
    - For full-range applications

- Clothing as a New Platform
  - Fully integrated electronic functionality
  - Modular approach
Introduction

What Makes Something Wearable

- **Comfort**
  - Size, weight, and shape
    - Small and lightweight packages with curved shapes work best in the body context
    - This is why many wearables-oriented circuit boards are designed with rounded edges and corners
  - Placement
    - Keep heavier items close to the core
    - Run connections along seams and edges
    - Pockets offer excellent support and protection for electronic components
    - Lining also provide lots of opportunities

- **Durability**
  - Strain relief
    - Continually tugged connection is likely to eventually break
  - Insulation
    - Use layout, stitching, coating, layering, and lining

Yarn Layout

Zigzag Stitch

Fabric Paint
What Makes Something Wearable

- **Durability**
  - Designing a circuit that contains removable modules can increase the durability
  - The ability to remove sensitive components makes it easier for washing
  - Good connectors are required

- **Protection**
  - A layer of foam, batting, or felt could protect exposed elements
  - Waterproof case or coating can protect circuit
  - A lining can protect an exposed circuit from bare skin

**Usability**

- Wearables should be comfortable to use
  - Does it function well as the wearable it is intended to be?
  - Do the electronics function as expected?
  - Does it make for a 'good' or 'satisfying' or 'successful' experience for the wearer?

**Aesthetics**

- Importance
  - Wearables are objects that occupy your most intimate spaces
  - How they look influences how you use them

- Question
  - Whether to hide or reveal wearable devices
    - Hiding increase the opportunity for seamless integration of technology
    - Revealing has stylistic and functional advantages
Chronology of Wearable Electronics

Mid 1990s
- Practical Possibility Emerged
  - Carrying an always-on computer combined with a HMD and control interface

July 1996
- "Wearables in 2005" Workshop in July 1996
  - Sponsored by DARPA (Defense Advanced Research Projects Agency)
  - Attended by industrial, university, and military visionaries
  - Abstract definition of wearable computing
    » Data gathering and dissemination devices which enable the user to operate more efficiently
    » Devices which are carried or worn by the user during normal execution of his/her tasks

1997
- Further Definition of Wearable Computing (Steve Mann)
  - A wearable computer is worn in such a way as in can be regarded as being part of the user
  - It is controllable, not necessarily involving conscious thought or effort
  - It is always active and operates in real time though it may have a sleep mode

Steve Mann (1962~, Prof. at U. of Toronto)
- "Steve Mann is the perfect example of someone who persisted in his vision and ended up founding a new discipline" - Nicholas Negroponte (MIT Media Lab)
Textiles for Information Processing

- Requirements for a Well-designed Information Processing System
  - Easy access to information anytime, at any place, by anyone
  - Customizable and be in tune with the human

- Clothing as an Information Processing System
  - Clothing is always there and in complete harmony with the individual

Textiles as an Ideal Platform for Information Processing System

- Ultimate flexibility in system design
  - Broad range of fibers, yarns, fabrics, and manufacturing techniques
- Large surface area for hosting the large number of sensors and actuators
  - Can be deployed over large terrains
- Fault tolerance
  - Built in redundancies
Introduction

Application Groups of Wearable Electronics

- User Convenience
  - Built-in electronics may control and support more advanced textile functionalities
    - Temperature control
    - Moisture control

- User Interfacing
  - Enables the interfacing between the user and electronic belongings or external networks
    - Microphone
    - Speaker
    - Textile keyboards
    - Flexible display

Product Identification

- Textile based RFID (Radio Frequency IDentification) tags
  - Use textile based antenna
  - Complex tags contain simple micro-controllers and non-volatile memories

- Enable intelligent logistics
  - Stock Control
  - Quality control
  - Anti-theft protection

- Enable intelligent washing machine
  - Washing machine can recognize type and number of clothes
  - Optimum treatment method can be determined automatically
Examples of Wearable Electronics

- **Application**
  - Prevention Tool
    - Monitor a person's environment
    - Warn or project when possible threats are detected
  - Rehabilitation
    - Drug supply
    - Muscle activation

- **Key Technology**
  - Packaging of electronic elements
  - Interconnection technology for deep textile integration

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Examples of Wearable Electronics

- **ADL (Activities of Daily Living) Monitoring**
  - In-shoe pressure and acceleration sensor system (Sazonov et al. 2009)
  - Step counting device for Parkinson's diseases patients (Giansanti et al. 2008)
  - Wearable sensor to monitor the recovery after abdominal surgery (Aziz et al. 2007)

- **LiveNet (MIT Media Lab)**
  - Detecting Parkinsonian symptom and epileptic seizure
    - Measures 3-D acceleration, electrocardiogram(ECG), electromyograph(EMG), skin conductance

- **LifeGuard (NASA)**
  - Monitor health status of individuals in extreme environments
Introduction

Examples of Wearable Electronics

- AMON (European Commission)
  - Wrist-worn device for monitoring high-risk patients with cardiorespiratory problems
    - Monitoring blood pressure, skin temperature, blood oxygen saturation, ECG

- MyHalo (Halo Monitoring)
  - Chest strap for monitoring falls, heart rate, skin temperature, sleep/wake patterns and so on
  - Reliable detection of fall is important but difficult
    - Bourke et al. 2008, Bianchi et al. 2010, Land and Messelodi 2009, ...

Examples of Wearable Electronics

- Proe-TEX (European Commission)
  - Smart garment for emergency-disaster personnel
    - Health status parameters of the user
    - Environmental variables
      - External temperature
      - Presence of toxic gases
      - Heat flux passing through
Designing a Wearable

**Choosing a Form**

- **Variety of Forms**
  - Jumpsuits
  - Wristbands
  - Gloves
  - Hats
  - Scarves
  - Socks
  - Jewelry
  - Underwear

**Choosing Materials**

- **Use both Hard and Soft Materials**
  - Hard circuits are excellent for creating small, complex, and robust circuits
  - Soft materials are advantageous for simple, pliable, flexible, and comfortable circuits

- **Choosing Components**
  - Printed circuit board design is useful for building wearable electronics but very difficult
  - Being thoughtful about the component choice can get you a long way
Designing a Wearable

Creating a Layout

- Think about a Three-dimensional Way
  - Physical design using a mannequin and garment will be helpful

Iterative Design

- You’re Never Going to Get It Totally Right the First Time
  - Create a first prototype
  - Wear it or have someone else wear it
    - Some of your design choices will likely work quite well
    - There will be things you didn’t expect
    - Learn from seeing the way something performs with actual use
  - Make some revisions and create a second prototype
  - Committing yourself to multiple iteration
Designing a Wearable

- **Maintaining Access**
  - Don’t Forget to Leave a Backdoor
    - Be sure not to enclose your circuit completely when incorporating your circuit

- **Experiment: Eight-Hour Wearable**

Functions of Smart Garment

- **Strain Measurement**
  - **Flexible Sensors**
    - Current research trends are to develop flexible sensors out of textile materials
    - Novel flexible strain sensors have been developed for use in smart clothing or textiles
    - The type, position and number of sensors depend on the end-use of the smart clothing
Functions of Smart Garment

- **Pressure Measurement**
  - Capacitive Sensors
    - Measurement of pressure during day-to-day, physical or sports activities
    - Providing an input interface for the wearer in the form of keyboard or touch pad
    - Provides detailed information on the pressure positions and forces

- **Biometric Measurement**
  - Textile Electrodes
    - Measurement of body temperature, heart rate, respiration rate, skin conductivity, etc.
    - Long-term continuous monitoring of patient's conditions
    - Help the medical team in the military field or in a rescue situation
Functions of Smart Garment

Signal Output

- Actuators
  - Uses audible sound to warn the wearer
  - Sensing knee sleeve which monitors the angle of knee
  - Flexible display to provide information to the wearer
  - Chromatic or electro-luminescent materials that react with electric current
  - Shape memory materials
  - Changes shape upon receiving a stimulus such as heat or electrical field

Data Management and Communication

- Short Range Communication
  - Effective transfer of data or power between different modules in the system
  - Conductive fibers, yarn, and textile circuitry
  - Bluetooth network

- Long Range Communication
  - 3G, 4G wireless communication
  - Power supply became a major problem
Applications

- Health Care
  - Biomedical Monitoring
- Sports
  - Smart Sports Wear
- Entertainment
  - Wearable Musical Instrument
- Fashion
  - Fashionable Smart Garment
- Safety
  - Environmental Control
- Experimental
  - Various Purposes

Materials

- Conductive Material
  - Conductive Fiber
  - Conductive Yarn
  - Conductive Fabric
  - Carbon Nanotube
- Textile based Sensors
  - Capacitive Sensor
  - Temperature/Pressure Sensor
- Energy Harvesting Material
  - Textile based Battery
  - Textile based Solar Cell
Rapid Prototyping

- Conventional Prototyping
  - NC Machining

- Rapid Prototyping
  - Modeling
  - 3D Printing

- RP in Fashion

Basic Electronics

- Circuits
  - Components
  - Design
    - Breadboard
    - Protoboard

- Switches
  - Textile Switches
Sensors and Actuators

- **Sensors**
  - Basics
  - Selection Guide
  - How to Use

- **Actuators**
  - Basics
  - Selection Guide
  - How to Use

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Microcontrollers

- **Hardware**
  - Arduino
  - E-Textile Toolkits

- **Software**
  - IDE
  - C Language

- **Advanced Topics**
  - I/O Connections
  - Wireless Communication
Practical Examples

Simple Examples