

MOBILE COMPUTING

CSE 40814/60814
Spring 2021



Steve Mann

- Considered to be inventor of wearable computing.
- "Wearable Computing Project" at MIT (1991).
- World's first covert wearable computer with camera and display concealed in ordinary eyeglasses (1995).
- PhD from MIT (1997).
- Works at University of Toronto.



Steve Mann

Steve Mann's "wearable computer" and "reality mediator" inventions of the 1970s have evolved into what looks like ordinary eyeglasses.



What is Wearable Computing?

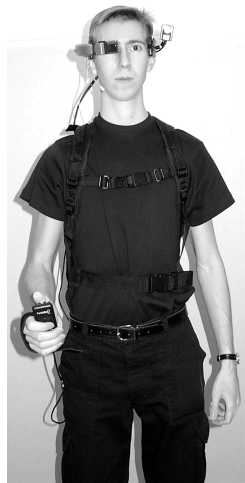
- “A wearable computer is a computer that is **subsumed into the personal space of the user**, controlled by the user, and has both operational and interactional constancy, i.e. is always on and always accessible. Most notably, it is a device that is always with the user, and into which the user can always enter commands and execute a set of such entered commands, and in which the user can do so while walking around or doing other activities”

What is Wearable Computing?

Seven attributes of wearable computing [Steve Mann, 1998]:

1. **Unmonopolizing** of the user's attention. User can attend to other events.
2. **Unrestrictive** to the user. Allows interaction while user carries out normal functions.
3. **Observable** by the user. As the system is being worn, there is no reason why the wearer cannot be aware of it continuously (but this contrasts with #1).
 - Different phrasing: User can identify computational and non-computational components of their clothing.
4. **Controllable** by the user; user can take control (on/off/configure) at any time.
5. **Attentive** to the environment; can enhance the user's environment and situational awareness.
6. **Communicative** to others; can be used as a communications medium.
7. **Shares the same physical and situational context as the user.**

Components of a Wearable Device



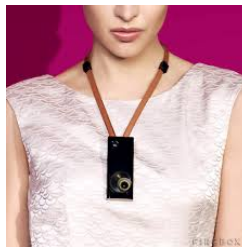
Head-Mounted Display (HMD)

- Small screen, typically covering one or both of your eyes.
- Works like an ordinary monitor, providing an image floating in the air in front of you.
- Transparent vs opaqu



Camera (& Sensors)

- Suitable placement
 - Head, follows user's gaze.
 - Shoulder, more stable.



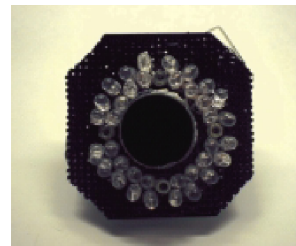
Input Device

- Keyboard
 - Canesta's IR keyboard
 - Arm-strapped keyboard
 - FrogPad
 - Twiddler chording keyboard
- Mouse
 - Twiddler



Input Device

- BrainGate
- Gestures
 - Gesture pendant (controlling smart homes)
- Voice recognition
 - Siri, Alexa, ...
- Multi-modal interfaces



Output Device

- Sight – Visual output
 - HMD, wristwatch...
- Hearing – Audio/sound/speech/music
 - Speakers, earplug/headset...
- Touch – Tactile feedback
- Taste and smell

The Computer Itself

- Anything small, low-power, but powerful enough
 - Embedded computers
 - Smartphones
 - Smartwatches



Network Connection

- Benefits of having a network
 - Access to the Internet
 - Communication
 - Localization
- Wireless network connection
 - WLAN
 - 3G, 4G, LTE
 - Bluetooth, ZigBee
 - InfraRed



Challenges

- Connecting all pieces
 - Wires (embedded into clothing?), wireless (security?), body as conduit
- Power supply
 - Batteries (rechargeable; solar power)
 - Human powered devices
 - Body heat, 0.6 – 4.8W (wetsuit clothes)
 - Breath, 0.4 – 2.5W (pressure mask)
 - Blood pressure, 0.2W
 - Limb motion, 0.3 – 1.5W
 - Finger motion, 0.019W (keyboard typing)
 - **Walking, 5 – 8W** (shoe generator)
- Heat dissipation

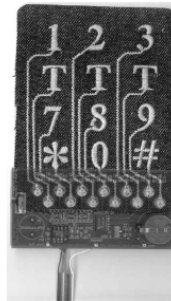


Figure 4: Functional chording keyboard embroidered into a jacket. Photo courtesy of Rehmi Post and Maggie Orth

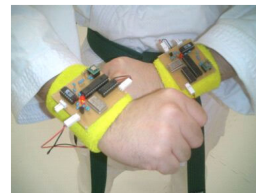
Examples

- Technicians
 - Blueprints, etc.
- Field workers
 - Access to information given by remote experts.
- Military personnel
 - Soldiers, monitoring health, equipment, etc.
 - Maps and terrain.
 - Infrastructure (sewers, roads) in urban areas.
- Researchers



Examples

- **Wearables for sports training**
- Karate trainees are instrumented with acceleration sensors.
- Sensor data is translated directly into sound output.
- Trainees can now 'hear', as well as see instructor's movements.
- Trainees can also hear themselves: attempt to match own sound to sound of instructor.
- Martial arts training is about reproducing patterns over time, not just matching static poses; therefore, sound is a useful sensory stimuli to introduce to training.
- Result: Trainees with system tended to learn faster than trainees without system.



Examples

- **Wearables for the military: Future Force Warrior (FFW)**
- Onboard physiological/medical sensor suite to accelerate casualty care
- Netted communications to maximize robustness and integration of small teams
- Embedded training (similar to martial arts example?)
- Enhanced situational awareness (heads-up display?)
- Synchronized firing of weapons from team
- Bone conduction technology: “talking and speaking without sound or hearing”



Examples: Smartwatches & Trackers



Examples: Fitness & Health

- <http://www.sensoriainc.com/>



Examples: Fitness & Health

- Hexoskin Clothing
- <http://www.gizmag.com/hexoskin-sensor-t-shirt-body-metrics/29098/>



Applications

- **Mediated Reality**
 - Experiencing the world through the computer
 - Allows computer to process the sensory cues before reaching the user
 - E.g., block commercial billboards
- **Augmented Reality**
 - Overlaying virtual information on the real world
 - E.g., allow architects to build virtual houses
 - E.g., Pokemon Go
- Both realities can enhance your senses

Applications – Augmented Memory

- Trivial example, finding your way
 - "Where did I park my car?"
- Camera on your body records the way
- Replay helps you find your way back
 - Only key events need to be recorded
 - Example: Intersections at a car park



Applications – Augmented Memory

- Elderly or people with poor memory
 - Remember name and face of people
 - Image processing can recognize a face and map it to the person's name and affiliation
 - How should it be presented?



Applications – Annotated Reality



Applications - Advertising



Applications - Entertainment



Applications - Entertainment



PrioVR gaming

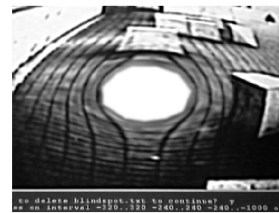
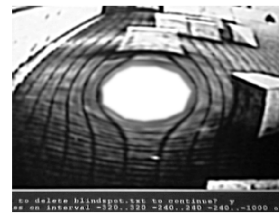
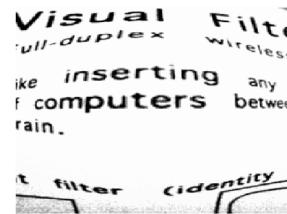
Applications – Aiding the Visually Disabled

- Some forms of low vision can not be alleviated by use of ordinary glasses
 - User wears non-transparent glasses with integrated displays, experiences the world through a camera
 - Computer processed video stream
 - Enhance contrast
 - Adjust colors
 - Night vision
 - Enlarged view



Applications – Aiding the Visually Disabled

- Fisheye lense for reading text.
- Remapping around blind spots.



Applications – Additional Vision Tricks

- "Edgertonian" eyes
 - Freeze-frame effect, fast shutter
 - Reading text on a tire of a speeding car
 - Clearly seeing the rotor blades of a helicopter
 - Counting the number of bolts holding an airplane rotor together in mid-air
 - Plus lots of other interesting effects
 - <https://www.youtube.com/watch?v=yr3ngmRuGUc>

Applications – Additional Vision Tricks

- Giant's eyes
 - Enhances depth perception of distant objects



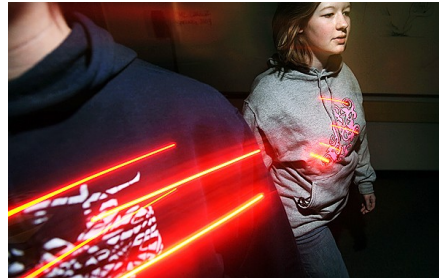
Applications – First Response



Applications – Social Software

Usually designed for urban settings; interface to groups or individuals.

- Safety net
 - Heart rate, perspiration, breath rate
 - Alert friends in case of abnormal values
- Friend finder



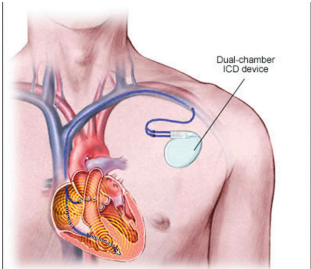
Applications – Google Glass

- Google Glass Enterprise (Version 2)
- Snapdragon 710, LTE modem, Bluetooth 5.0, 802.11ac Wi-Fi, 3GB of RAM, Android Oreo OS, a 32MP camera (4K video at 30fps or 1080p at 120fps)
- Boeing, Brain Power (<http://www.brain-power.com/>), EyeSucceed (<https://www.eyesucceed.com/>), Aira (<https://aira.io/>)

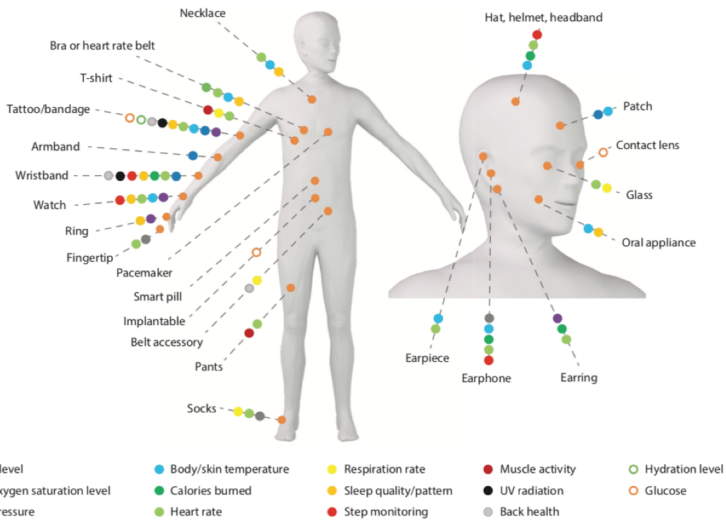


Applications – Healthcare

- Motion evaluation
- Cardiac implantable devices
- Ambiance parameters



Sensor Placement Options

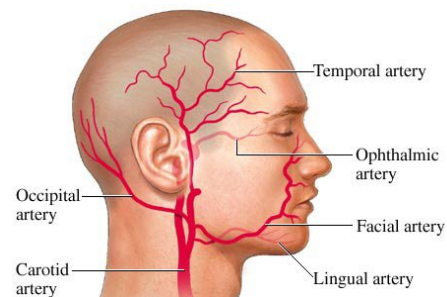


Sensor Examples



SensoTRACK Ear Sensor

- Heart rate, oxygen saturation, respiration rate, steps, calories burned, activity level, geolocation, body posture, ...
- Does not impede motion
- Can minimize device's exposure to ambient parameters
- Easy access to temporal artery
- Can be used for audio replay



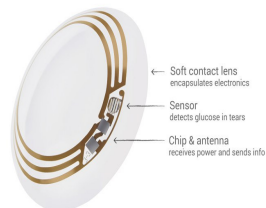
SensoRING

- Blood pressure, PPG, heart rate, ECG, respiration rate, oxygen saturation, activity level, perfusion index.



Google Contact Lens

- Novartis + Google project.
- Lens contains a tiny and ultra slim **microchip** that is embedded in one of its thin concave sides.
- Uses tiny **antenna** to send data about the glucose measurements from the user's tears to smartphone.
- Considered adding LED lighting to warn users when their glucose levels dropped (abandoned due to **arsenic** composition of the LED).
- November 2018: discontinued due to lack of correlation between tear glucose and blood glucose.



Essentials of Tear Fluid

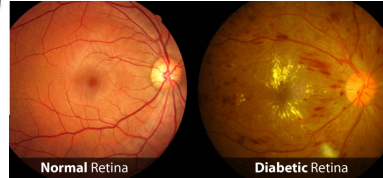
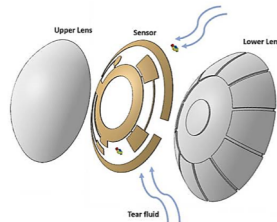
- Among body fluids, tear fluid is a complex multilayered concoction of proteins, lipids, enzymes, and salts. As a result, a variety of biomarkers are present in the fluid and can be potentially used for disease screening.
- In general, the tear film consists of three major layers that functions as a lubricant and cleansing agent for the eye.
- Tear fluid is proven to be a less complex body fluid as compared with serum or plasma because of the blood-tear barrier.

Why Contact Lenses?

- Contact lenses are the most popular wearable devices designed for vision correction, aesthetic, and therapeutic purposes all around the world.
- An estimated population of more than 45 million people in the United States rely on contact lenses daily.
- Blinking and tear secretion also allow for natural, fresh sample replenishment for reliable analyte collection.
- Significant progress in the fabrication process and materials used has increased contact lens accessibility and appeal to consumers, making the cost for daily disposable lenses to be roughly US \$1.
- Contact lenses are portable in size and considered minimally invasive medical devices with the capability of integrating a variety of sensing techniques through surface or structural modifications.

Use Cases

- Dry Eye Syndrom
- Diabetes
- Cancers
- Cystic Fibrosis



- **Complications:**
 - Flow-dependent concentration effects, low sample volumes, and low concentrations of analytes within the fluid all require highly sensitive analysis techniques.
 - Use of medication or supplements by patients (healthy or otherwise), can impact the compositions of tear fluid as well.

BioPatch

- Heart rate, breathing rate, ECG, and posture.



Basis PEAK/Fitbit Versa

- Fitness and sleep tracker

HEALTH & FITNESS

Basis recalls every Peak fitness tracker ever sold after some users sustain burns



QardioCore

- Wireless medical grade (continuous) ECG monitor.
- No shaving, skin abrasion, patches, or adhesives.
- Water-resistant.
- Can communicate with physician.
- For people with increased health risk caused by family predisposition, history of heart attacks or strokes, high blood pressure, high cholesterol, diabetes, and excess weight.



Vital Jacket

- ECG monitor; wirelessly connected.



Moov

- Personal fitness trainer.
- Analyzes form, counts repetitions, measures landing impact, ...
- Sweatband version (heart rate).



Heart Activity Trackers



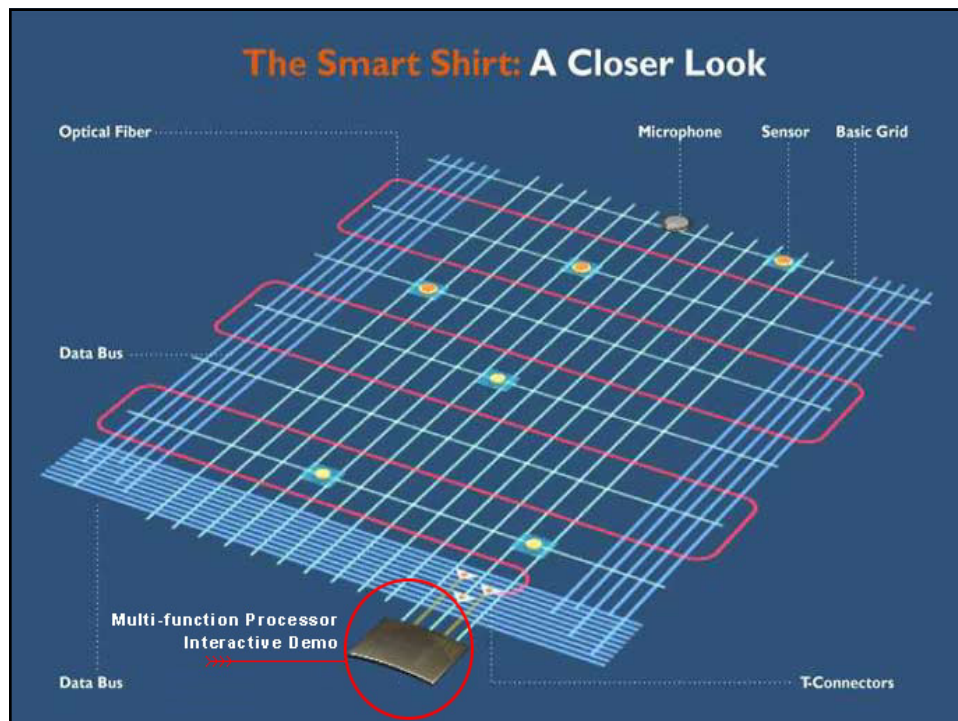
Georgia Tech Smart Shirt

- Combat casualty care.
- Optical fibers detect bullet wounds.
- Sensors monitor vitals.
- Sensors can be plugged into fabric (which serves as “motherboard”).



Textile Electrodes

- Textile electrodes/sensors are used for collecting data from the body.
- Consists of traditional textile fibers (natural or synthetic) and electrically conductive elements (metal, conductive polymer, carbon, graphene)



Application Areas of Conductive Textiles

- Body/vitals monitoring
- Signal and power transfer
- Heating (arctic shirts)
- Antennas
- Sensors and actuators
- EMI-shielding
- Prevent electro static dissipation (ESD)

Advantages

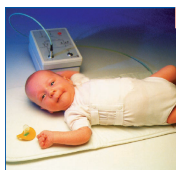
- Enable perfect electrode/sensor placement and shape.
- Flexibility of electrodes guarantees proper skin contact.
- Cables and wires can be invisibly integrated into textile.
- System invisibility (and low weight, washability, etc.) makes it acceptable for the user.
- Comfortability and softness of electrodes enable long time measurement.

Biosignals

- Heart rate, heart rate variability, heart activity (ECG)
- Stress level and sleep quality (ECG)
- Brain function and vitality level (EEG)
- Muscle rate and balance (EMG)
- Body motions and postures (EMG)
- Body composition; fat content and fluid balance (EBI)
- Lung function (EIT)
- Respiration rate and frequency
- Skin conductivity
- Skin temperature

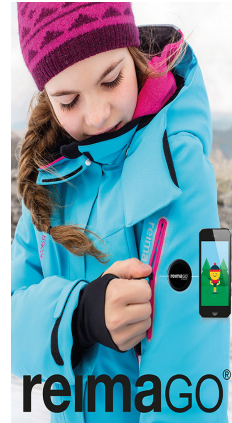
Example: Sudden Infant Death Syndrome

- SIDS is sudden, unexpected death of baby; caused by breathing failure.
- Pyjamas with built-in sensors, signal processing, and data collection unit.
- Track baby's heart rate and breathing patterns with multiple sensors.
- When a problem is detected pyjama sounds an alarm.



Example: Child Tracker

- Durable, washable ReimaGO® activity sensor by Suunto can be attached to Reima outerwear using a special pocket with laminated Movesense press studs.
- The sensor wakes up when the wearer starts to move.
- Parents see kids' activity scores in a mobile app.
- The app also has a fun kids' interface through which rewards can be gained.



Example: Firefighter Jacket

- Thermal sensors embedded into fabric.
- Visually indicate critical heat levels to the firefighter in action and his colleagues before it's too late.
- The thermal sensors monitor the outer temperature near the firefighter and on the inside of the coat close to the body.
- The sensors are attached to two LED displays, one on the sleeve and one on the back.



Implantable Medical Devices

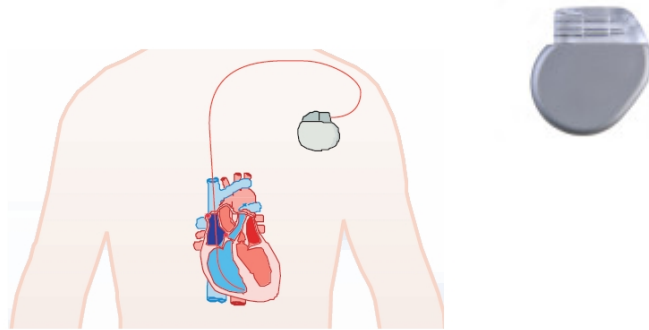
- Two main functions:
 - Applying a therapy, usually by delivering electrical signals to some organs or tissues.
 - Monitoring relevant parameters or signals in order to avoid risks to the patient or to optimize his treatment.
- They usually are capable of measuring and analyzing electrical and mechanical physiological signals and transmit this information or use it as input data for the therapy.

Market Situation

- 5 big companies:
 - Share more than 98% of the market (mainly pacemakers and ICDs).
 - Buy patents and technology from small companies in the field or eventually buy smaller companies.
- Start-up companies:
 - Investigate feasibility of treating a disease using an implantable device implementing a therapy conceived by themselves.
 - Few per year, mainly from US, Israel, and Canada.
 - Without capacity to develop and manufacture the devices.

Cardiac Pacemaker (ICD)

- Since 1960!



Cochlear Implants



Functional Electrical Stimulation

FES

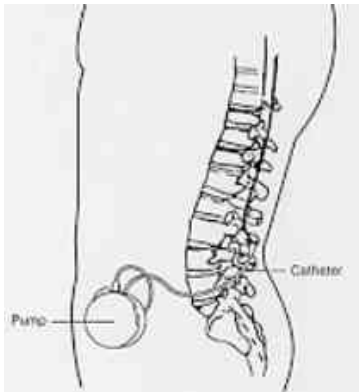
Functional electrical stimulation is a treatment that applies small electrical charges to the leg to improve mobility in people who have difficulties with walking arising from damage in their brain or spinal cord.



Read more at mstrust.org.uk/fes



Implantable Infusion Pump



Wearable Computing & the Market

- Growth in wearable Computing
 - 35% growth by 2019
- Smartwatch will be leading product
 - Will rise by 41%
- Apple Watch market share
 - Account for 40% market share in 2015
- Fitness bands, smart eyewear, etc.
 - 36% percent market share this year