

## Wearable Computing

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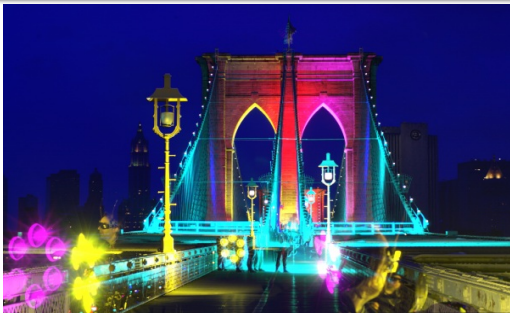
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## In the Beginning...



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## Steve Mann

- 1970s, pre-laptop, early computer era.
- Building computers he could wear.
- Inventor of wearable computing.



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### Steve Mann

- 1991: Started the "Wearable Computing Project" at MIT.
- 1995: World's first covert wearable computer – camera and display concealed in ordinary eyeglasses.
- 1997: PhD from MIT in the field he himself had invented.
- Today: Works at University of Toronto.



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### Steve Mann

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



(a) 1980 (b) Mid 1980s (c) Early 1990s (d) Mid 1990s (e) Late 1990s

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### What is Wearable Computing?

- Mann
  - constant and always ready,
  - unrestrictive, not monopolizing of user attention,
  - observable and controllable by the user,
  - attentive to the environment,
  - useful as a communication tool, and personal.
- "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

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### 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!
  - Better phrasing: User can identify computational and non-computational components of their clothing.
4. **Controllable** by the user. User can take control 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.*

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### What is Wearable Computing?

- Rhodes
  - provide portability during operation;
  - enable hands-free or hands-limited use;
  - can attract the user's attention, even when not in active use;
  - can run continuously;
  - and attempt to sense the user's current context.
- Kortuem et al.
  - *augmented reality*
  - "the user interface technique that allows focusing the user's attention and presenting information in an unobtrusive, context-dependent manner."

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### What is Wearable Computing?

- Manfred Clynes and Nathan Kline
  - *Cyborg* (cybernetic organism)
  - a human and machine combination where the interface becomes a natural extension of the user.
  - This interface would not require much conscious attention.
- J.C.R. Licklider
  - *Man-Computer Symbiosis*
  - human brains and computing machines will be coupled together very tightly and that the resulting partnership will think as no human brain has ever thought and process data in a way not approached by the information handling machines we know today.

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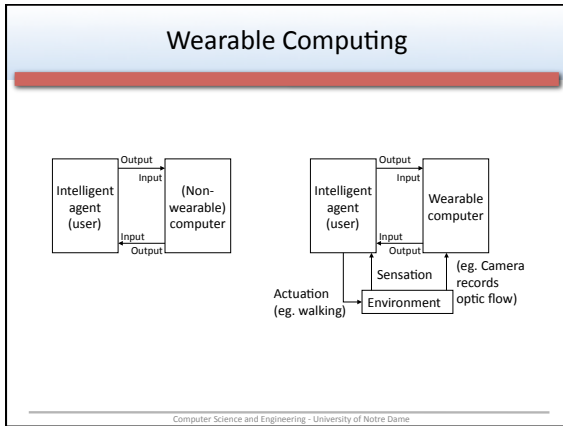
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- ### Ideal Attributes
- **Persist and provide constant access to information services.**
    - Everyday and continuous use.
    - Wearable can interact with the user at any given time.
    - The user can access the wearable quickly and with little effort.
  - **Sense and model context.**
    - The wearable must observe and model the user's environment, physical and mental state.
    - The user could provide explicit contextual cue to the wearable.
    - The user can identify misunderstanding and explicitly tutor the wearable.

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- ### Ideal Attributes
- **Adapt interaction modalities based on the user's context.**
    - The wearable should adapt its input and output modalities automatically to those that are most appropriate and socially graceful at the time.
  - **Augment and mediate interactions with the user's environment.**
    - The wearables should provide universal information support in both the physical and virtual realms.

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### Wearables

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- The physical *substrate* of wearables is often different from that of traditional computers.
- Substrate is often flexible, e.g., should be water-resistant, ...
- Example: Elektex (produced by Eleksen) 
- New materials allow new kinds of interactions.
- What human-computer interactions are possible using flexible materials?
- What interactions are possible using a material that can differentiate between torsion (i.e. twisting), stretching, and shearing?

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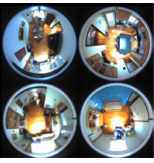
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### Wearables

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- What additional uses can technology have that continually records user-centered data?
- Example: The Human Speechome Project
- Babies naturally acquire language skills by interactions with the environment, but exactly what environmental cues trigger language development?
- MIT Project: Record the experiences of child through continuous video and audio capture from each room in the house.
- Goal: 400,000 hours of data over three years
- What did the baby see/do/hear just before uttering a certain word for the first time?
- What other questions could you answer with this technology?
- What other applications might it have?



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### Wearables

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- What additional uses can technology have that continually records user-centered data?
- Example: **MyLifeBits: A personal digital archive**
- Article: Gordon Bell and Jim Gemmell: "A Digital Life", Scientific American, March 2007
- "For the past six years, we have attempted to record all of Bell's communications with other people and machines, as well as the images he sees, the sounds he hears and the Web sites he visits--storing everything in a **personal digital archive** that is both searchable and secure."
- "Digital memories can do more than simply assist the recollection of past events, conversations and projects. Portable sensors can take readings of things that are not even perceived by humans, such as oxygen levels in the blood or the amount of carbon dioxide in the air. Computers can then **scan these data to identify patterns.**"
- How could you use both recorded conversations and physiological data to determine the (psychological/physiological) stress history of a patient?

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### Why Use Wearable Computers?

- Some people wear too many computers.
  - PDA, cellular phone, pager, laptop, electronic translator, calculator, MP3 player, digital camera.
- These devices all contain very similar components.
  - Microprocessor, memory, screen, keyboard, battery, and in some cases, a wireless modem.
  - The main distinctions between these devices are the interface and the application software.
- Wearable computers could exploit the commonality in components to eliminate cost, weight and redundancy.

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### Mediate Interactions

- Wearable computers will help provide a consistent interface to computationally augmented objects in the physical world.
  - Example: Gesture Pendant.
  - One gesture could provide an intuitive command for many devices.

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### Aid Communication

- The wearable can also assist in human-to-human communication.
- Wearable computers can also help manage interruption in the user's daily life.

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### Provide Context-Sensitive Reminders

- Instead of simply acting as a virtual secretary, the wearable could be proactive and intimate, listening to the wearer's conversations and providing reminders as appropriate.

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### Augment Reality

- Augmented reality overlays information-rich virtual realities onto the physical world.
- In a sense, augmented reality is a combination of the application domains described previously.

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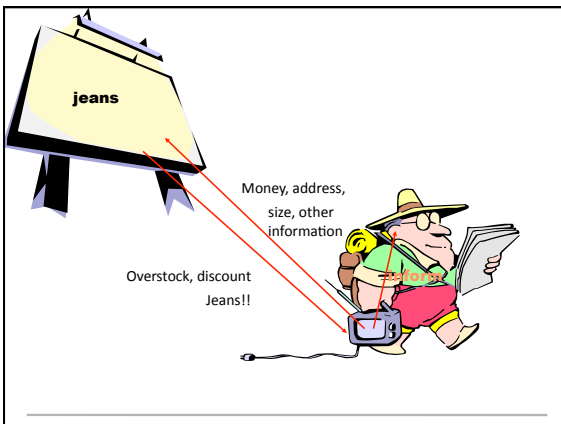
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### What is a Wearable Computer?

- Laptop?
  - ... in a backpack?
  - ... with a head-mounted display?
- PDA?
- Wrist watch running Linux and XFree86.
- Clock and video conferencing application.
- What a wearable computer is depends on your definition...
  - But it must be **wearable!**



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### Why use Wearables?

- They are **wearable!**
  - Always with you, not as easily forgotten.
- Instant access, information anywhere.
  - Laptop requires time to prepare for use.
  - PDA requires use of both your hands.
- Wearables can become a part of you.
  - Transparent use, not just "a thing".

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### Who Uses Wearables Today?

- 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



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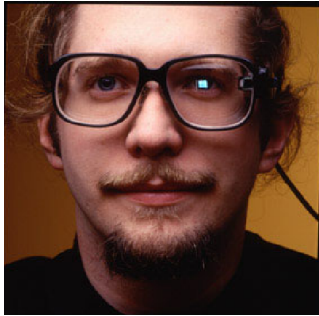


Figure 3: MicroOptical's display embedded in a pair of eyeglasses. The actual display is in the earpiece. An optical path deflects the image through the lens to a half-silvered mirror that reflects the image to the user's eye. Photo by Sam Ogden

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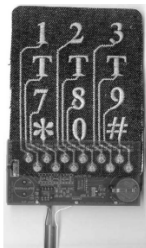


Figure 4: Functional chording keyboard embroidered into a jacket. Photo courtesy of Rehmi Post and Maggie Orth

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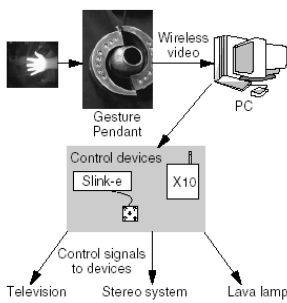


Figure 5: Using a near-infrared computer vision and lighting system, the Gesture Pendant lets users control appliances through gestures. The Slink-e converts control instructions from a computer's serial port and the X10 is a home automation control standard that communicates with signals over electrical lines.

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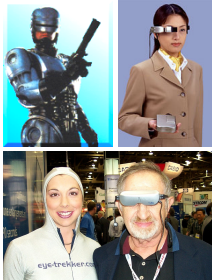
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### Who Will Use Wearables in the Future?

- Medical workers?
- Firefighters?
- Police department?
- Warehouse clerks?
- Regular people?



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### What Do You Need for a Wearable?

- Depends, but these parts are common
  1. Head-mounted display.
  2. Camera recording view.
  3. Audio, e.g. speaker and mic.
  4. Input device, e.g. keyboard.
  5. The computer itself.
  6. Network connection.



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### Head-Mounted Display (HMD)

- Small screen, typically covering one of your eyes.
- Works like an ordinary monitor, providing an image floating in the air in front of you.
- LCD or TFT technology.
  - Used to be a real CRT in the old days.



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### Head-Mounted Display (HMD)

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- Transparent displays
  - Allows augmented reality, where virtual information overlaps the real world.
- Opaque displays
  - Less sensitive to the background noise.
- State of the art.
  - Smallest.
  - Advanced.

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### Camera

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- Any small camera.
  - Ordinary web camera.
  - Custom made camera.
- Suitable placement
  - Head, follows user's gaze.
  - Shoulder, more stable.

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### Input Device

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- Keyboard
  - Canesta's IR keyboard.
  - Arm-strapped keyboard.
  - FrogPad.
  - Twiddler chording keyboard.
- Mouse
  - Twiddler, again.
- Maybe we need to use something else?
- BrainGate

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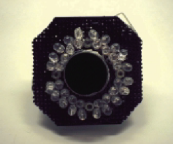
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### Input Device

- Gestures
  - The Gesture Pendant ->
    - For controlling smart homes
    - Fingers for dialing numbers
- Voice recognition
  - Suitable at times, but not as a generic solution for everything.
- Multi-modal interfaces
  - Combining several types of input, e.g. voice and gestures.
- What else?



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### Output device

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

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### The Computer Itself

- Anything small but powerful enough!
  - Laptop or TabletPC
  - PC104 (a small PC)
  - Xybernaut
  - PDA, iPAQ, Toshiba
  - Or something else...



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### Network Connection

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- Benefits of having a network
  - Access to the Internet.
  - Communication.
- Wireless network connection
  - WaveLAN, IEEE802.11b
  - GPRS or UMTS (3G)
  - Bluetooth
  - Infra-red



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### Putting it all together...

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- Now you have all gadgets you need.
  - But how do you connect them?
- Wires
  - Having too many wires can become rather cumbersome.
  - Solution: Integrate into the normal clothing.
- Wireless
  - Comfortable, but easier to eavesdrop on.
- Body network
  - Send signals by using your human body as a conduit.

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### Powering the wearable

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- Power is a significant problem!
  - You don't want to drag a power cable behind you...
  - All devices consume power.
    - Tradeoff between functionality and power.
  - Batteries never last long enough.
    - e.g. a laptop can run ~3-6 hours.
- Important problem, how to solve it?

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### Human Powered Devices

- Typical power consumptions
  - Desktop computer, 100W
  - Laptop computer, 10W
  - Embedded CPU, 1W
- Human body uses ~120W.
  - We need, let's say, 5W for a wearable.
  - What if we could tap into this power..



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### Human Powered Devices

- Examples of human power availability
  - 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)
- Walking is the best method so far.

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### Heat Dissipation

- Heat dissipation is one of the foremost limiting factors in the design of high-end laptops, and providing heat dissipation is a source of considerable expense.
  - Make processors tolerate higher temperatures.
  - Make lower-power processors and components

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### Heat Dissipation

- Feasible for wearable computers
  - Airflow
  - Close proximity to the human body to aid in cooling.
- Thermal reservoirs
  - Charging--chill batteries
  - Operation--transfer heat into batteries
- Phase-change materials provide an attractive method to compensate for lack of cooling.
- Careful use of resources might help avoid many heat generation crises.

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### Commercial Wearables

- Why build it yourself?
- Motorola and Frog Design's "Offspring" concept.
  - No longer makes "mobile phones"
- Steve Mann and Siemens are also working on a product line.
- The market is still not very big.
  - Resembles the early days of personal computing.
  - Much do-it-yourself and hacking.



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### What can you do with a wearable computer?

- Everything a regular computer can do.
- However, the context differs.
  - You wear it and can move around.
  - The wearable computer is exposed to different environments and contexts.
  - Limitations in terms of hardware.
  - This makes a big difference...

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**Applications**

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- **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. the AR Quake or AR Pacman game.
- Both realities can enhance your senses.

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**Augmented Reality Pac Man**

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- [Mixed Reality Lab](#)

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**Applications – Augmented Memory**

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- 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.

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### 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?



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### Applications – Aiding the Visually Disabled

- Some forms of low vision can not be alleviated by use of ordinary glasses.
- Solution?

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### Applications – Aiding the Visually Disabled

- 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.



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### Applications – Aiding the Visually Disabled

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



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### Applications – Additional Vision Tricks (1/2)

- "Edgertonian" eyes
  - Freeze-frame effect, fast shutter.
  - This enables
    - 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.

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### Applications – Additional Vision Tricks

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



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**Applications – A-Life, Avalanche Rescue**

- Help rescue avalanche victims.
- Survival chance
  - 92% after 15 minutes.
  - 30% after 35 minutes.
- Time is not the only factor
  - Orientation, head up or down.
  - Air pockets, air channels.
- How can wearables help rescuers?

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**Applications – A-Life, Avalanche Rescue**

- Each victim wears a small sensor.
  - Tilt sensor
  - Heart rate
  - Blood/oxygen saturation
- iPAQ gets readings.
  - Sorts and prioritizes.
- Rescuers get advice on where to start digging.
  - Increased survival.



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**Applications – Social software**

Usually designed for urban settings. Interface to groups or individuals.

- Safety net
- Friend finder
- Familiar Strangers

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### Applications – Safety Net, Creating Villages in the City

- Social network of wearable users.
- Biosensors monitor user's body.
  - Heart rate, perspiration, breath rate.
  - Alert friends in case of abnormal values.
- Example
  - Start sending video in scary situations.
- Such "safety vests" exist already.

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### Applications – Friend Finder

- Connects people with common interests.
- Works for you automatically while you walk around and meet people.
- Imagine you want to buy a sofa...
  - Look at sellers on a bulletin board?
    - Can you really trust those people?
  - From a friend of yours?
    - Trustworthy, but may not have a sofa.
  - From a friend of a friend of a friend?
    - Well, that's an awful lot of persons to ask... So how do you solve that?

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### Applications – Network of Buyers and Sellers

- Use wearable computers!
- Buyer announces, electronically
  - "I want to buy a sofa."
- Someone else announces
  - "I have a sofa to sell."
- When meeting with a friend, you exchange your shopping lists.

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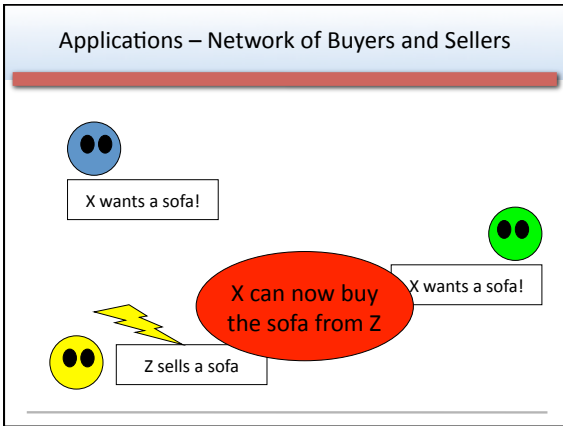
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- ### Conclusions and Summary
- Wearable computing
    - Invented by Steve Mann in the 1970s.
  - Technology
    - HMD, I/O devices, networks, power, etc.
  - Applications
    - Augmented memory.
    - Mediated reality.
    - Enhanced senses.
    - Avalanche rescue.
    - Market network.
    - Health-care.
  - Research issues
    - Interaction, merging with pervasive computing.
    - Much more remains...

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