MOBILE COMPUTING

CSE-4225

Fall-2019

The Future Of Mobile Computing

- 'The Future of Mobile Computing' is the conceptual exploration of potential applications of future flexible technology
- This means that in the future it is possible to have hardware that is interchangeable, that learns from use, which changes over time, that degrades gracefully and that works naturally

Future Topics

- **Improving capacity**
  - Dynamic spectrum access
  - Massive MIMO
  - Heterogeneous networks
- **Pervasive computing**
  - Internet of things
  - NFC / RFID
  - Smartphones and wearable computing
- **Other issues**
  - Energy efficiency
  - Security and privacy

Cognitive radios, dynamic spectrum access in TCP white spaces

- The general idea of a cognitive radio – identify what spectrum is free, and adapt its PHY parameters suitably.
- A concrete realization of this idea is the recent concept of "TV white space networking"
  - There are unused portions of the spectrum in the TV frequency bands
  - This is low frequency spectrum that has much better propagation characteristics
  - The idea is to opportunistically use the free spectrum, without hurting the "primary" TV user.
  - **Challenges** – spectrum sensing, coordinating among transmitters and receivers to agree on the available spectrum to use, coexistence of multiple such "secondary" networks operating in the spectrum.

Massive MIMO

- The idea of placing multiple antennas at transmitters and receivers to linearly scale capacity is gaining popularity.
- **Recap:** multiple antennas placed close to each other at transmitter and receiver can be used to send multiple streams of data in parallel (multiplexing mode), or improve the rate of single stream (diversity mode).
- What limits the number of antennas?
  - **Cost:** each antennas costs extra hardware to process the radio signals to/from it
  - **Form factor:** Ratio of RMS and average value. Spacing between antennas is half a wavelength. Makes is cumbersome, especially at lower frequencies (higher wavelengths)
- WiFi with 4 antennas is available now, 8 or more antennas likely in near future
- Since MIMO is mostly used for higher frequencies, propagation range is lower, so suitable for smaller (indoor) networks.

Heterogeneous networks

- The idea of stitching together multiple networks for connectivity, instead of just one network.
- Examples
  - LTE femto cells. Small “base stations” that serve a high-density environment like a building, stadium etc. The users are handed off to the “macro” cell when they go out.
  - WiFi offload of 3G/4G data traffic. Automatic authentication of WiFi, and seamless handoff to 3G when out of WiFi coverage.
- Different network designs for different use cases (e.g., massive MIMO for indoors vs. normal base stations for outdoors)
- Challenges
  - Configuring multiple networks so they don’t interfere
  - Seamless migration between networks

Internet-of-things and sensors

- Currently, most end hosts on the internet are people. They could be mostly machines in the near future.
- The vision of Internet-of-things: many objects have sensors that communicates over the internet (WiFi / cellular data) and can be monitored continuously. Examples:
  - Smart grid and smart meters
  - Home automation
  - Health monitoring
  - Environmental monitoring
- This is also called machine-to-machine (M2M) communication
- Challenges
  - Can current communication infrastructure scale when billions of machines talk over the internet?
  - What is the hardware and application platform to enable cheap deployment of these sensors?

NFC-based applications

- Near-field communication (e.g., based on RFID) can enable many applications in the future
  - Mobile payments
  - Inventory management
- Challenges
  - Scaling operation (e.g., reliably scan a cart of items once at checkout)
  - Lower costs (so that it is feasible to put an RFID tag everywhere)

Smartphones / Wearable computing

- More complex applications on smartphones beyond simple personal use
- Harness power of remote computing and code offload
- Smartphone / tablet as the general computing platforms for applications such as inventory monitoring, medical records etc.
- Better UI – gesture tracking, improved voice recognition, virtual reality
- Smaller form factor => wearable computing
- Lots of personal data streaming => can be harnessed for personalized experiences

Security and Privacy

- Localization techniques getting more accurate
  => users are always being tracked
- Applications trying to capture personal information for personalized ads and other things (sometimes in stealth)
- How to get personalized experiences without compromising privacy?
- Privacy-preserving computations and databases

Power and energy

- **The idea of energy harvesting:** harvest power from ambient signals such as cellular and TV signals.
- Other advances in energy such as wireless power.
- Better energy efficiency of networking protocols + advances in battery technology => longer periods of power for wireless devices
- Energy efficiency especially important for sensor networks

Wearable Computing

The Past – The Present

Steve Mann

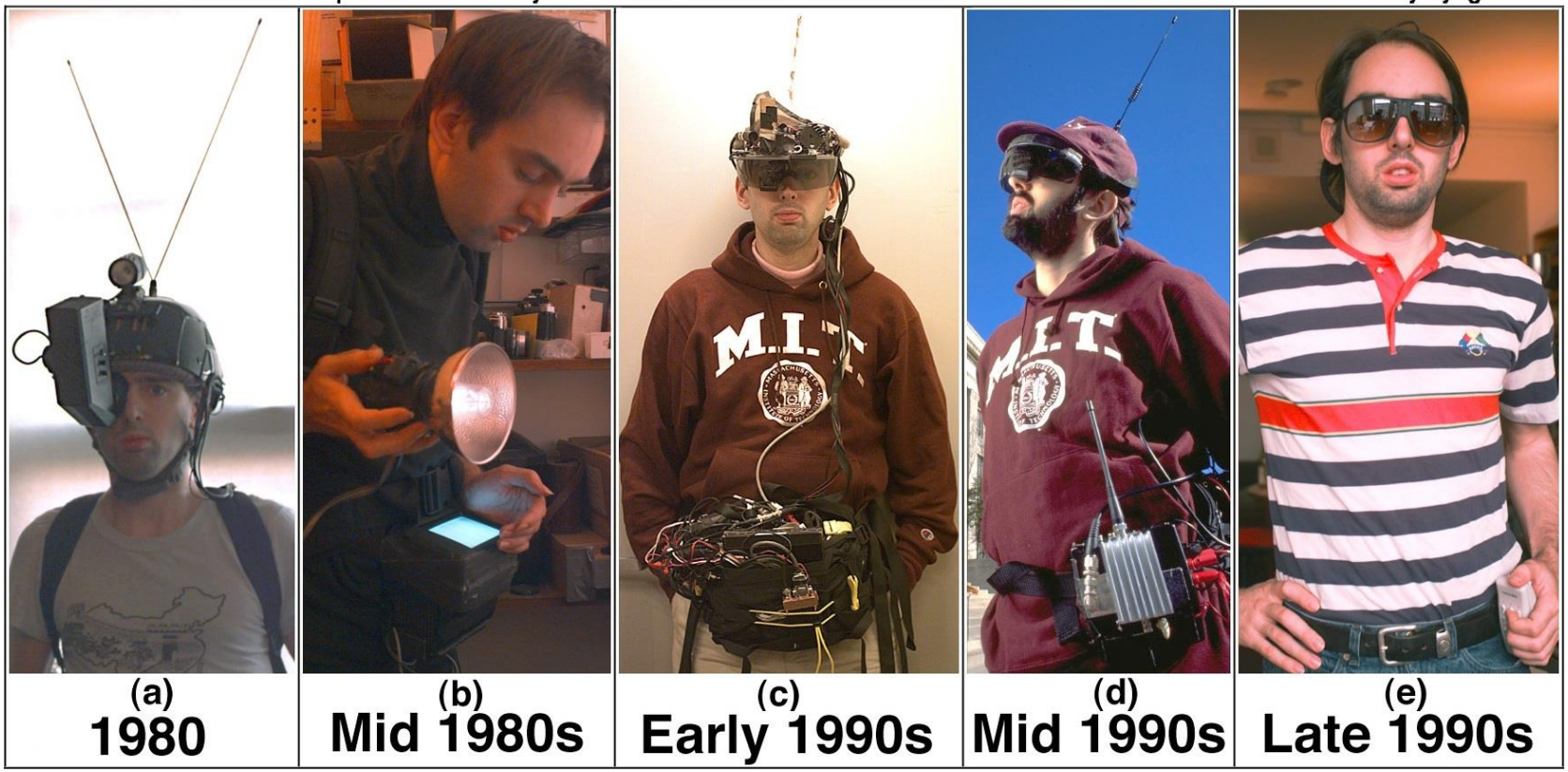
- 1970s, pre-laptop, early computer era
- Building computers he could wear
- Inventor of wearable computing

Steve Mann

- 1991: Started the ”Wearable Computing Project” at MIT
- 1995: World’s first covert wearable computer – camera and display concealed in ordinary eye glasses
- 1997: PhD from MIT in the field he himself had invented
- Today: 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?

- 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.

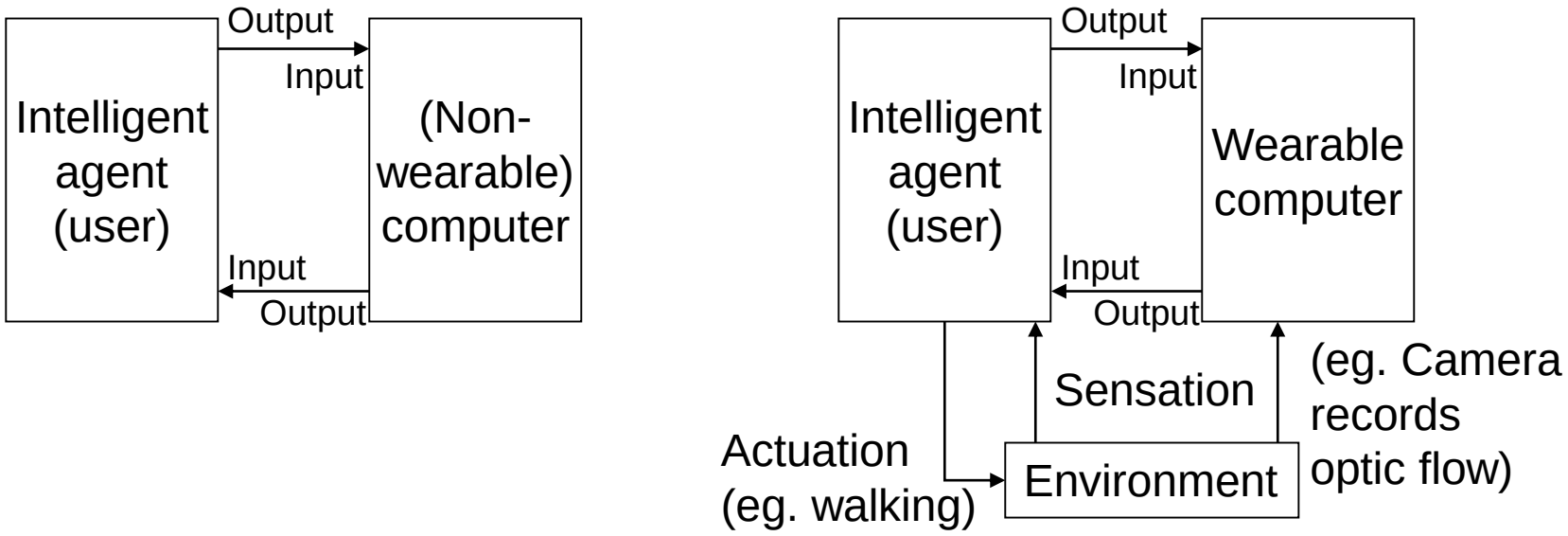
  - "A wearable computer is a computer that is ***subsumed into the personal space of the user***, controlled by the user, and has both operational and interactional constancy, i.e. is always on and always accessible. Most notably, it is a device that is always with the user, and into which the user can 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"

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.*

Wearable Computing



Purpose: 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

Purpose: 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.

Purpose: Provide Context-Sensitive Reminders

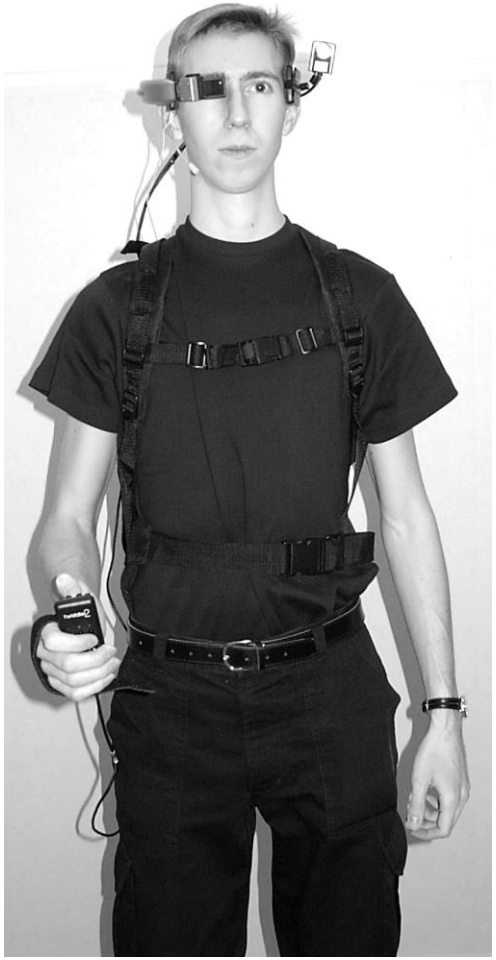
- Instead of simply acting as a virtual secretary, the wearable could be proactive and intimate, listening to the wearer's conversations and providing reminders as appropriate

Purpose: Augmented 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.

- https://www.youtube.com/watch?v=vDNzTasuYEw

Components of a Wearable Device



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
- Transparent vs opaque

Camera (& Sensors)

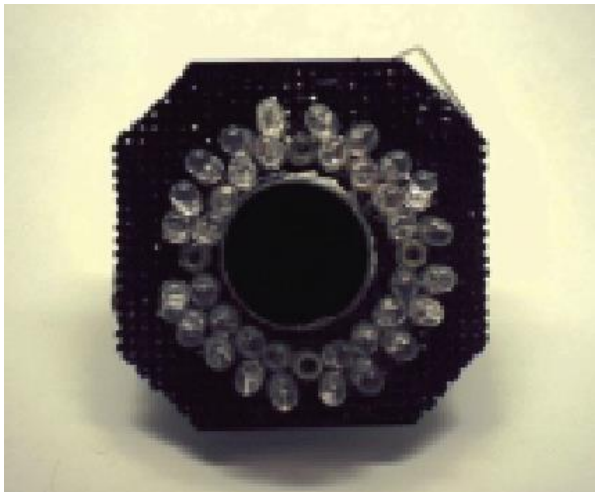
- Suitable placement
  - Head, follows user's gaze
  - Shoulder, more stable

Input Device

- Keyboard
  - Canesta's IR keyboard
  - Arm-strapped keyboard
  - FrogPad
  - Twiddler chording keyboard
- Mouse
  - Twiddler, again.
- BrainGate

Input Device

- Gestures
  - Gesture Pendant (controlling smart homes)
- Voice recognition
  - Siri



- Multi-modal interfaces
- Something new?

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, but powerful enough
  - Smartphones
  - Smartwatches
  - Embedded computers

Network Connection

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

Other 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

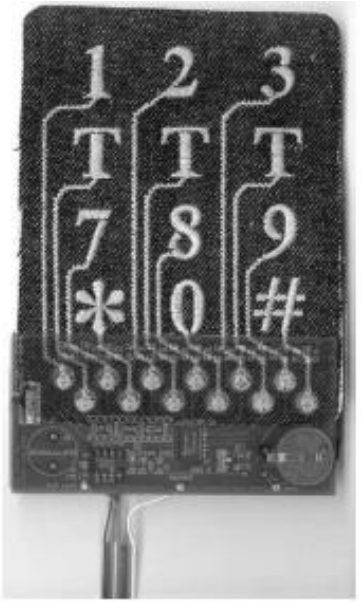


Figure 4: Functional chording keyboard embroidered into a jacket. *Photo courtesy of Rehmi Post and Maggie Orth*

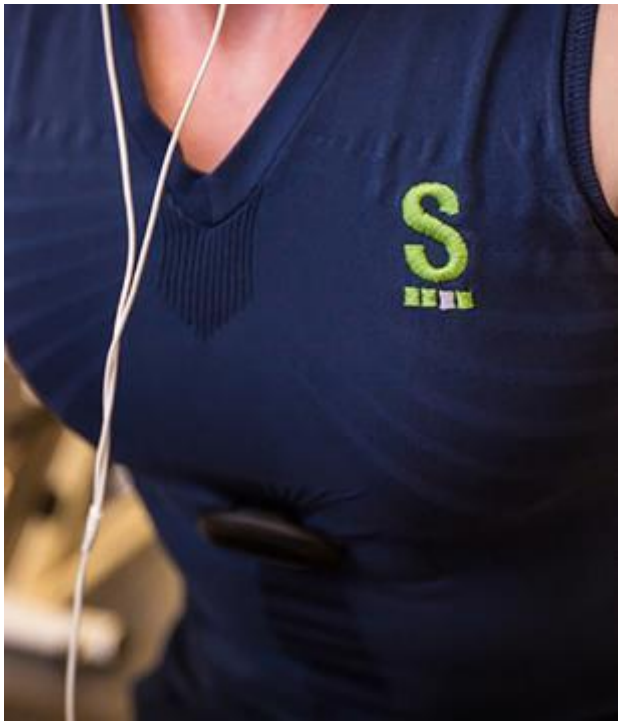
Examples

- 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: Smartphone Extensions & Fitness Trackers

Examples: Fitness & Health

- http://www.sensoriainc.com/



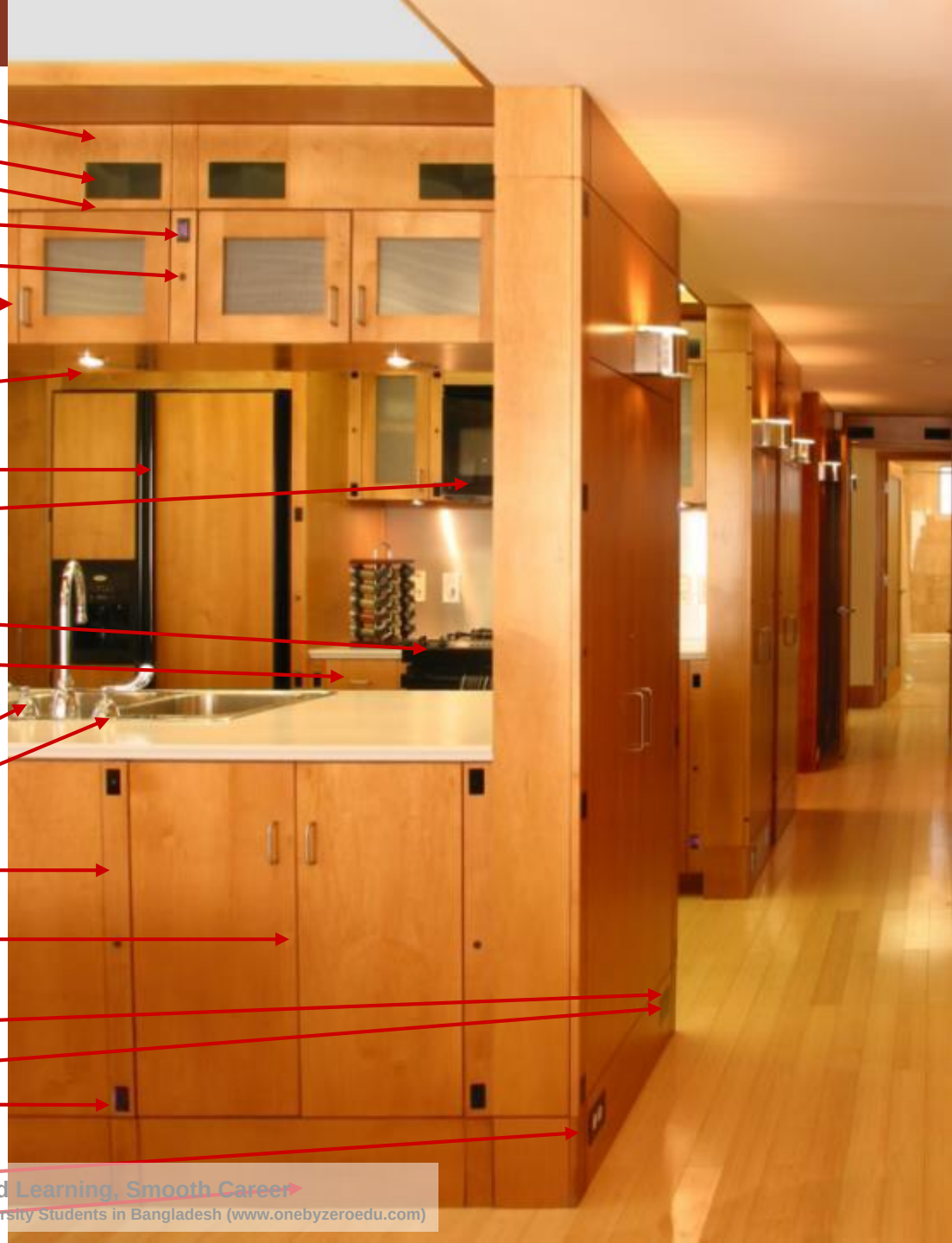
Smart Homes

Smart Homes

- Georgia Institute of Technology: Aware House
- MIT: House of the Future
- University of Washington: Assistive Cognition
- Honeywell: Independent Lifestyle Assisting (ILSA)
- University of Rochester: Center for Future Health

Sensing

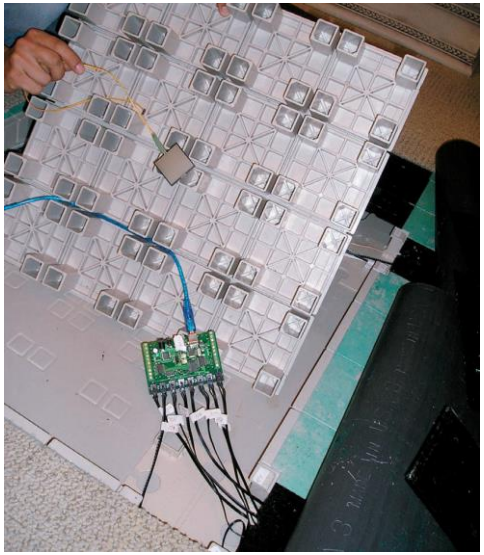
- Data acquisition from elderly without the awareness of the person.
- The detectors will be placed in the house in many different places, and the person will continue her (his) regular life without wearing anything special on her (him) self (except of a wrist watch).



MIT – n_House

Sensor: Smart Floors

- Fall detections
  - Falls are the second leading cause of unintentional-injury death for people of all ages and the leading cause of death for elders 79 years and older.
  - Studies have shown that the medical outcome of a fall is largely dependent upon the response and rescue time.
- Smart Floor
  - Measure the pressure signals on the floor's cell via piezoelectric sensor.
- Mobility Assessment
  - Changes in some aspects of mobility correlate with changes in cognitive function and can perhaps predict future cognitive decline.



Sensor: Smart Toilet

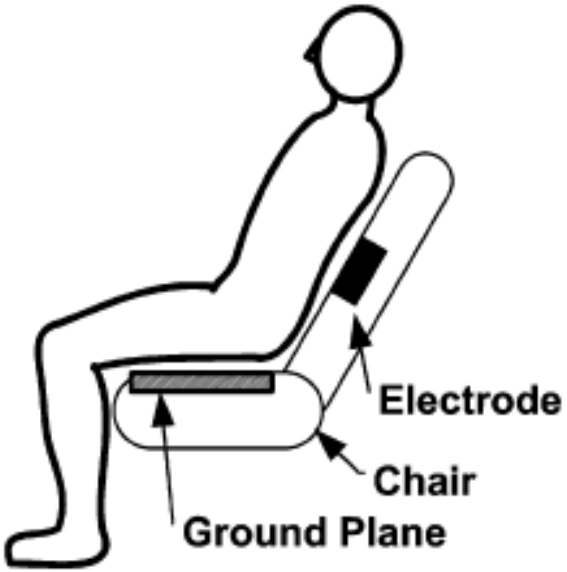
- Analyze of urinary salts and sends the results to a computer through LAN.
- How many times during the night did a person go to the bathroom?
- Analyze blood sugar levels, body weight, and fat percentage; can even have a blood pressure cuff.

Sensor: Full Body Sensor

- Compute weight, body fat, BMI, visceral fat, skeletal muscle, resting metabolism, and physical age.

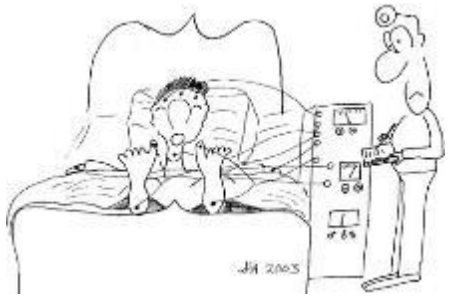
Sensor: ECG Chair

- ECG waveforms can be obtained using electrodes fixed on a chair or in the bed, and measurements obtained without direct contact with the skin.
- The signal will be sent to the home central computer via Bluetooth signals.



Sensor: Sleeping Disorders

- Recording of an EEG, EMG, measurements of brain waves, and muscles activities. Electrodes can assess the sleep quality, but their attachment to the patient's body affects sleep.
- Sleep disorders measurements can be obtained via analysis of physiological characteristics such as body temperature, movement in bed, breathing rate, heart rate, and snoring analysis.

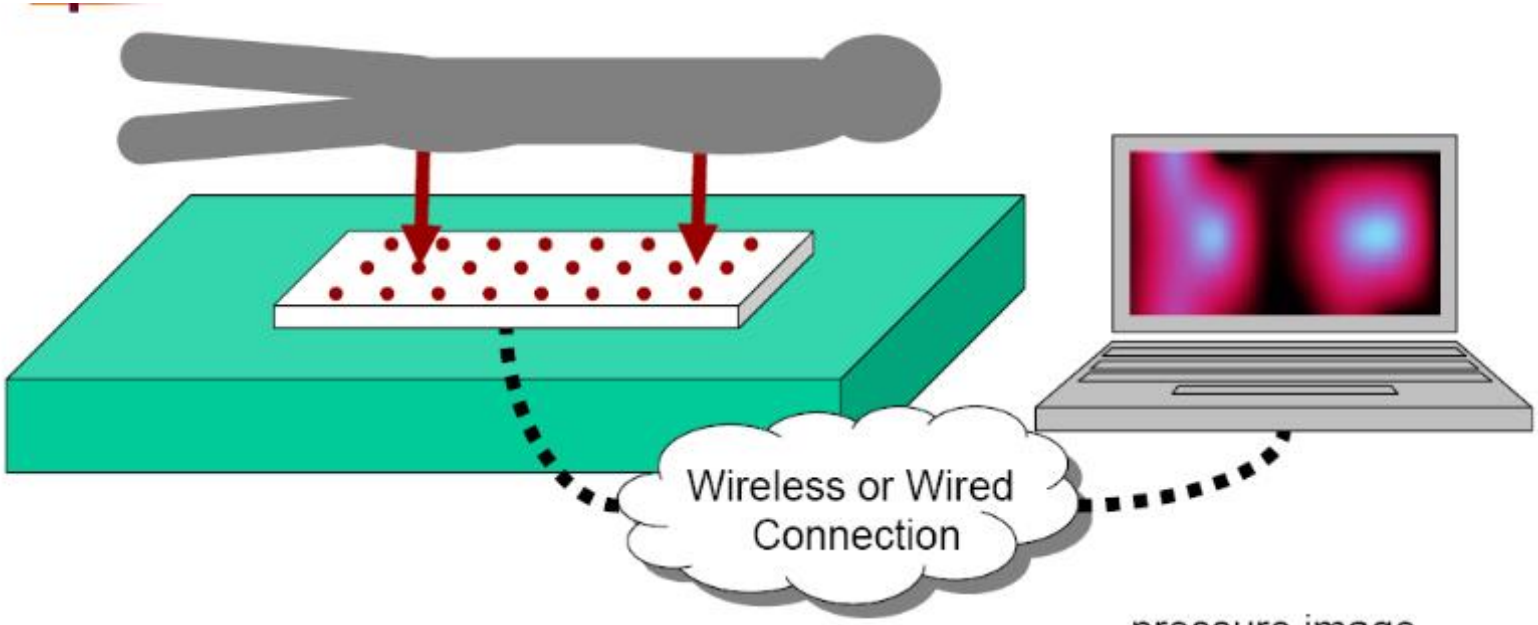


Sensor: Sleeping Disorders

- **Piezoelectric transducer** provides information about heart rate and breathing rate.
- **Temperature sensors** attached to the mattress measure the temperature changes of the person.
- **Pressure sensors** detect movements of the person while sleeping and when out of bed.
- **Sound recorder** for the detection of snoring.
- **Detection** of bacterial infection developed in bed sores.

All the sensors above allow the subject to sleep comfortably without having to wear electrodes or be hooked up to a machine.

Sleep Studies

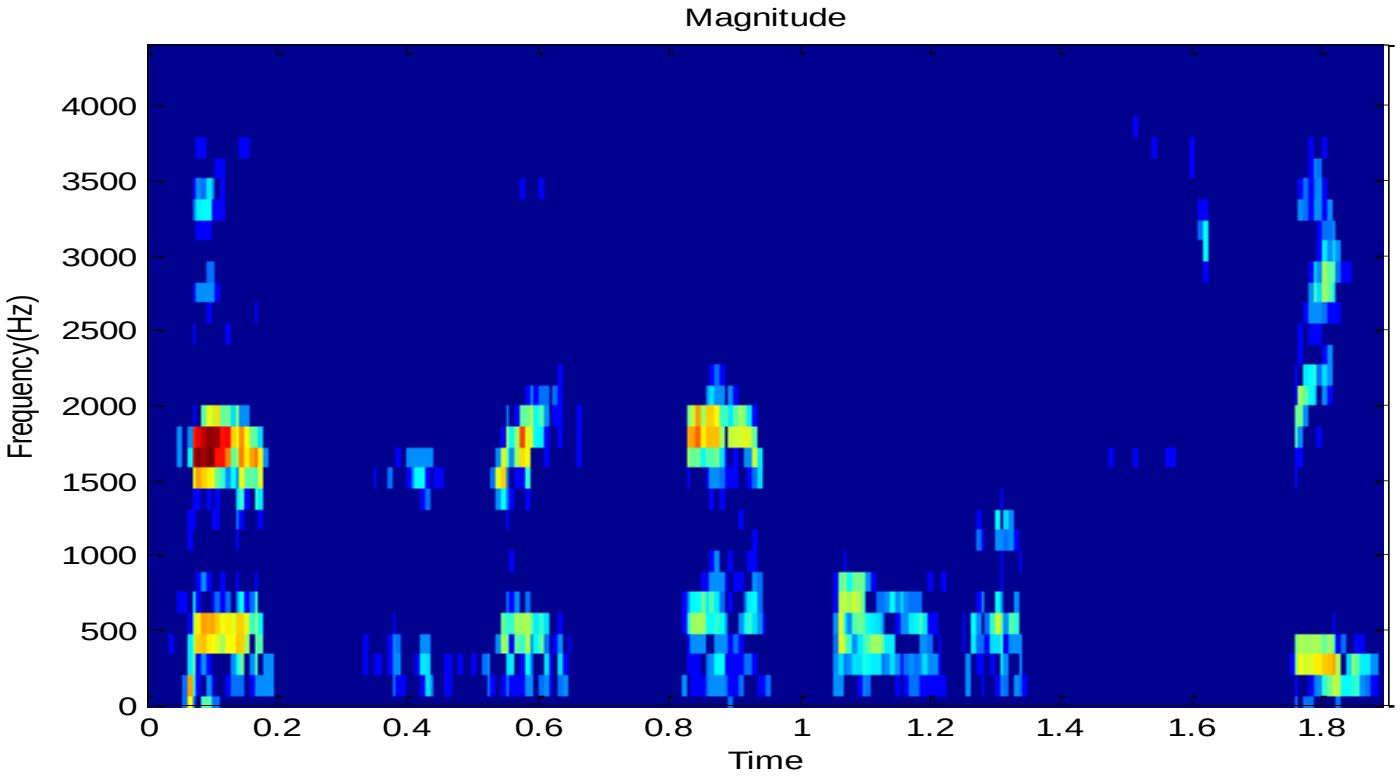


pressure image
of a person lying on back

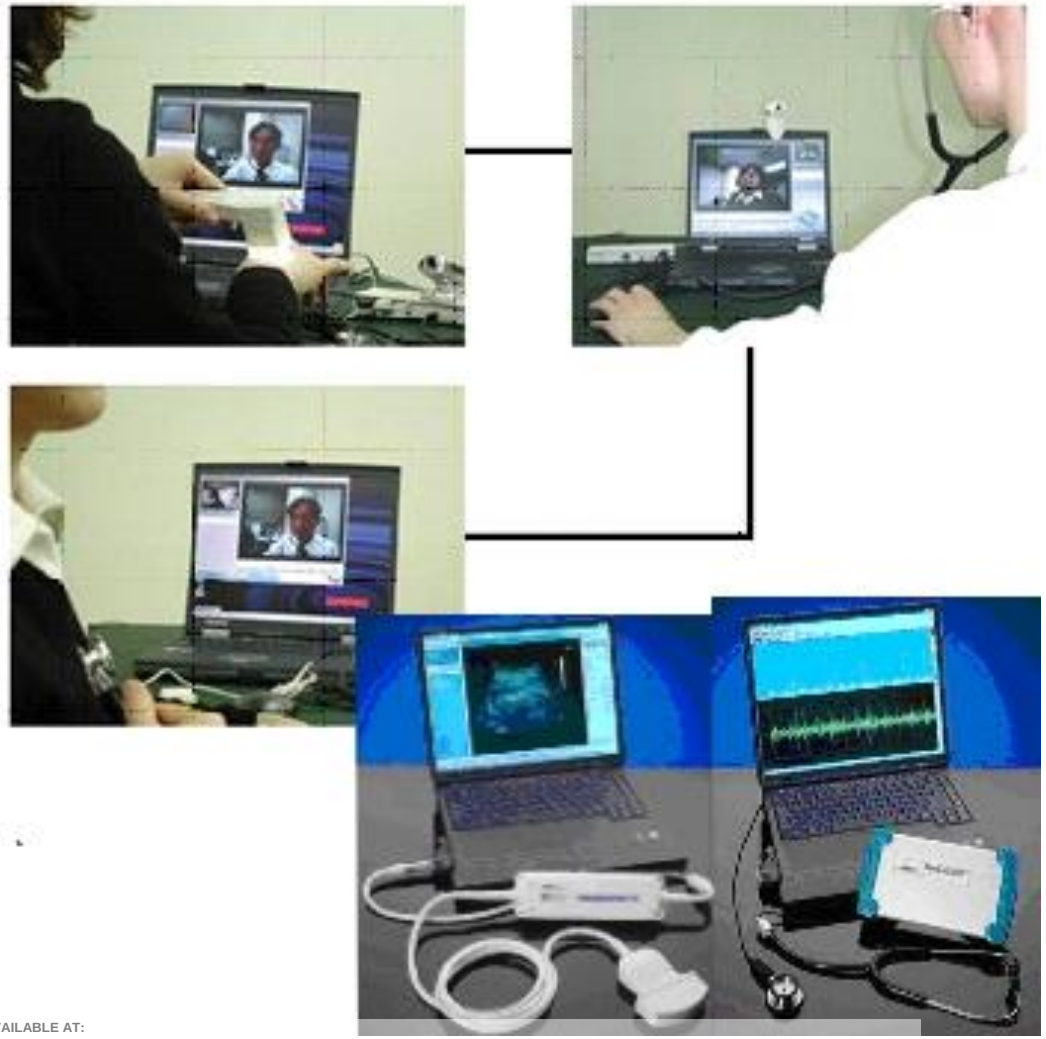
pressure image
of a person lying on side

Sensor: Voice Analysis

- Spectrogram: measure pitch versus time.



Teleconsultation



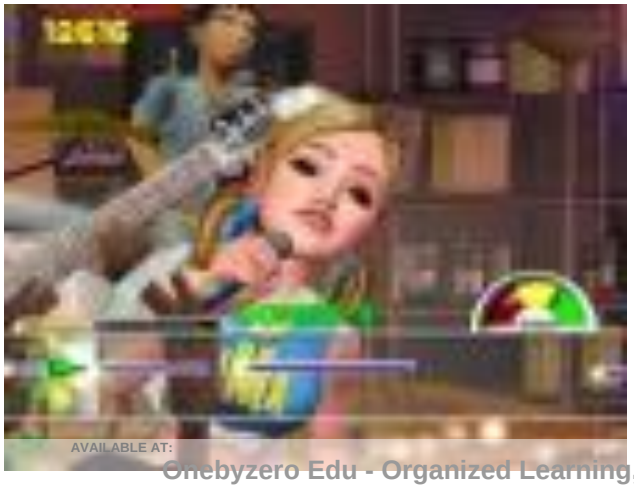
Telemonitoring

What Are Smart Homes Good For?

- Value proposition: **safety for you and your family**
- Safety from intruders already well-established
- Sensor-based systems enable new areas:
  - “Is the gas leaking?”
  - “What’s in the water?”
  - “Is the oven off?”

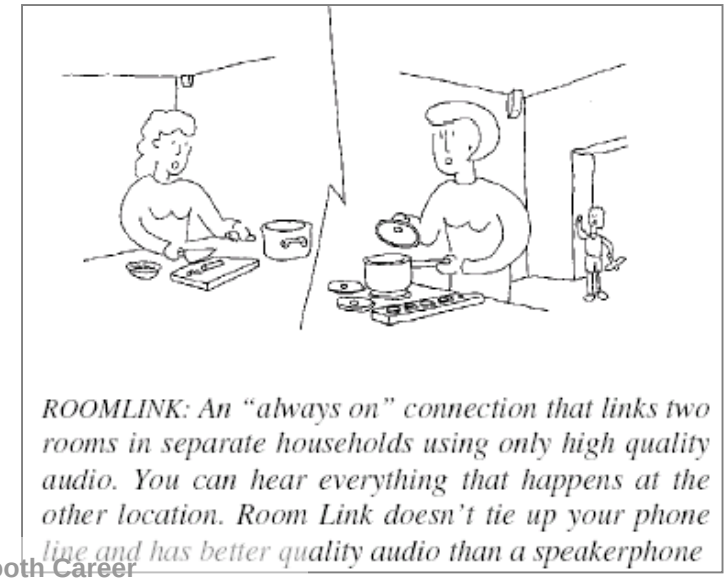
What Are Smart Homes Good For?

- Value proposition: **great fun**
- Again, well-established market
  - Smart toys, home theaters, video games
- New twists:
  - How about make it easier to find neighbors and compete?
  - Games where you learn something “useful”?



What Are Smart Homes Good For?

- Value proposition: **stay in touch, know your neighbors**
- Carpooling
- Always on connection with close friends
- Wi-Fi NeighborNode
- “How much is our community recycling?”



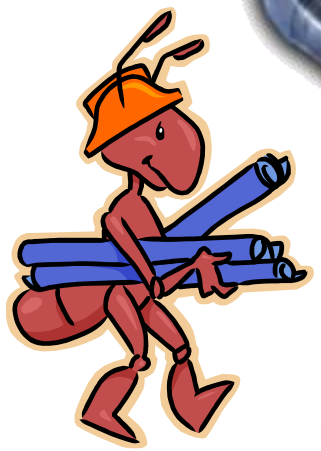
ROOMLINK: An “always on” connection that links two rooms in separate households using only high quality audio. You can hear everything that happens at the other location. Room Link doesn’t tie up your phone line and has better quality audio than a speakerphone

What Are Smart Homes Good For?

- Value proposition: **stay in better health**
- Suite of mobile and fixed wireless devices
- “Great weather outside, how about walking today?”
- Intel Research Seattle – Group coordination
- Smart toilets

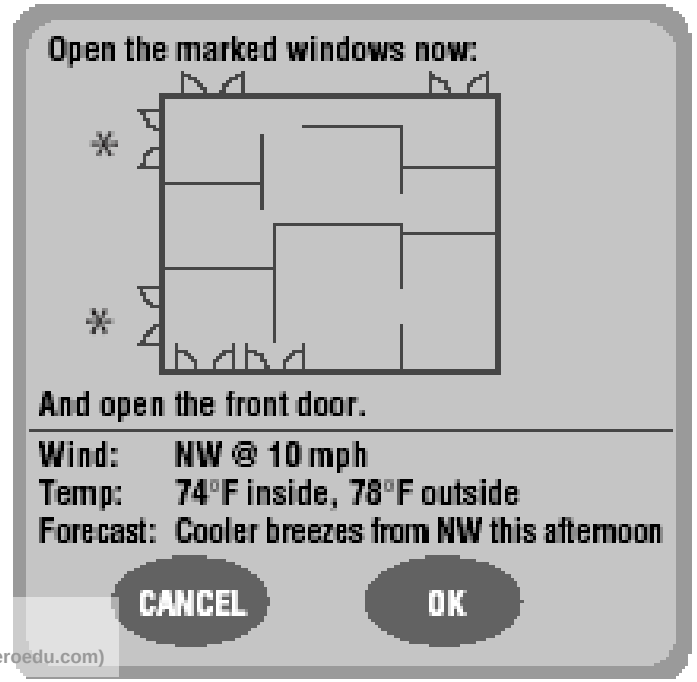
What Are Smart Homes Good For?

- Value proposition: **We'll warn you before it's too late**
- "Are ants/termites/roaches invading?"
- "Are my sewer pipes okay?"
- "Your plants need water…"



What Are Smart Homes Good For?

- Value proposition: **save energy and money**
- Add “smarts” that also encourage sustainable behavior
  - “Are my windows leaking warm air in winter?”
  - “Did you know you can save water if…”
  - “Opening up the windows could increase sunlight.”



Have some fun with Microsoft HoloLens!

https://www.youtube.com/watch?v=QRQv74J7oSk

THANK YOU ☺ ☺ ☺

“Ends are not bad things, they just mean that something else is about to begin. And there are many things that don’t really end, anyway, they just begin again in a new way. Ends are not bad things aren’t really an ending; some things are never-ending.”

-C. JobBell C.