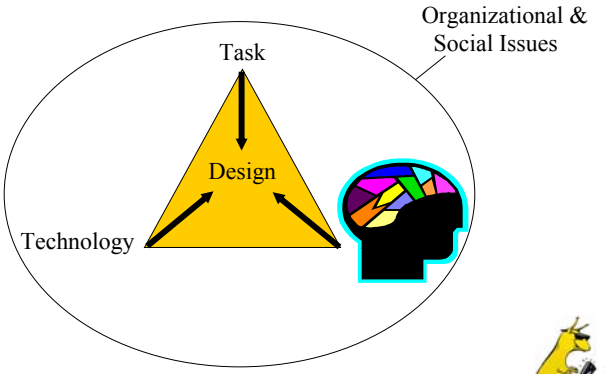
HCI Application: Ubiquitous Computing



History

Mark Weiser (1952-1999)

- Chief Technologist Xerox PARC
- Began Ubiquitous Computing Project in 1988
- Weiser, M. "The Computer for the Twenty-First Century", *Scientific American,* 1991, 94-100
- Mark Weiser's vision
  - Computers everywhere, disappearing/integrated in environment/objects around us
  - Computer no longer isolates us from tasks/environment, no longer focus of attention
  - Social impact: similar to writing: found everywhere from clothes labels to billboards
  - Similar to electricity which surges invisibly through the walls of every home, office, car

Principles of Ubiquitous Computing

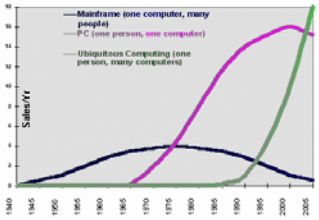


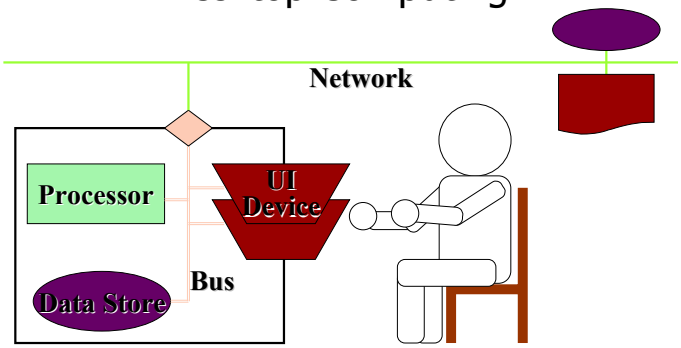
Figure 1. The major trends in computing

"… the third wave in computing, just now beginning.
First were mainframes, each shared by lots of people. Now we are in the PC era, person and machine staring uneasily at each other across the desktop.
Next comes ubiquitous computing, or the age of calm technology, when technology recedes into the background of our lives."

Paradigms

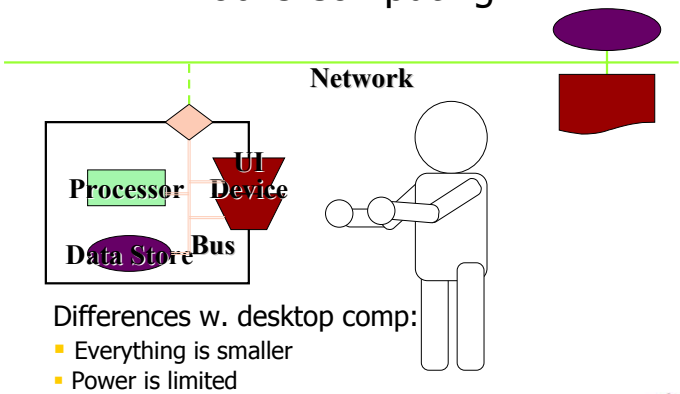
- Getting computing "off the desktop"
  - Connect with what else people do
  - "Pervading" the physical world
  - = "Pervasive", "Ambient", "Situated"
- Many ways to break the traditional PC model
  - Many communities working hard
  - Many different definitions
- Paradigms of Ubiquitous Computing:
  - Mobile / Wireless computing
  - Hands-free UI / Intelligent environment
  - Disaggregated computing / Migrating UI
  - Location-sensitive data & services
  - Invisible computing
  - Wearable computing

Desktop Computing



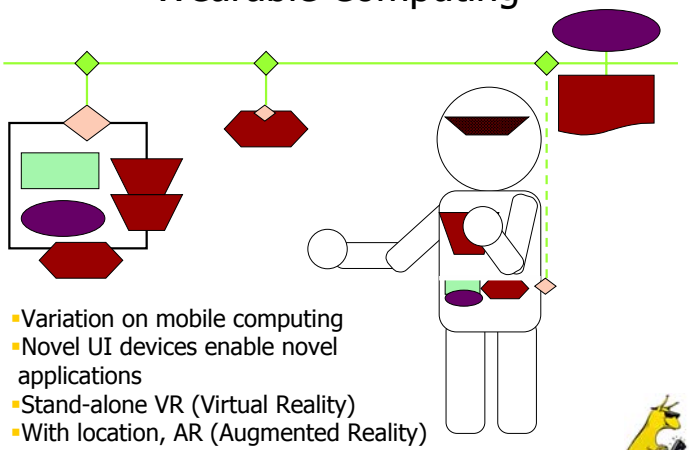
Bus provides speed, connection, ID, trust, synchrony
Processor assumes minimum suite of devices
Key feature: User has to sit in chair

Mobile Computing



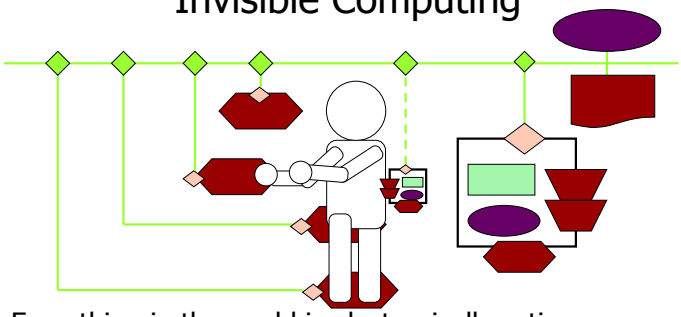
Differences w. desktop comp:
- Everything is smaller
- Power is limited
- Network connection is wireless
- Person is standing or moving!

Wearable Computing



- Variation on mobile computing
- Novel UI devices enable novel applications
- Stand-alone VR (Virtual Reality)
- With location, AR (Augmented Reality)

Invisible Computing



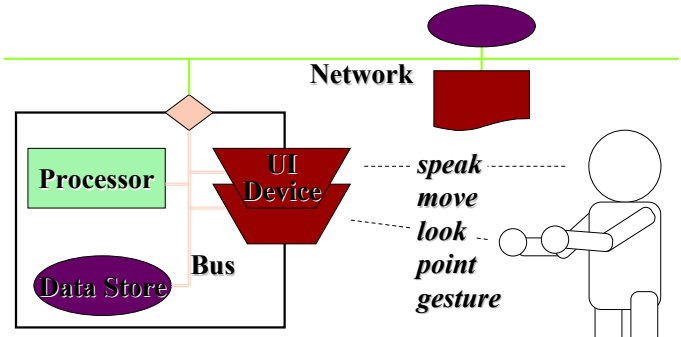
Everything in the world is electronically active
Your attention is on your task
- Of course, there are computers present
- "Calm" or "ambient" computing

Related: Personal memory devices; Physical icons

Calm Technology

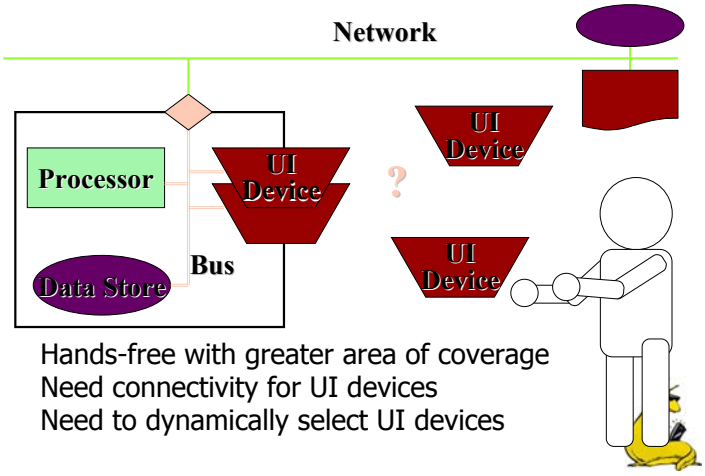
- Proposed by Mark Weiser & Seely Brown in 1995
- "Calm": technology that informs but doesn't demand our focus or attention
- Contrast with the way technology is designed now: in your face, highly interactive,using multiple modalities, etc
- Moves easily between center of attention & periphery
- Other word for Ambient Interfaces (Ishii)
- Example:
  - dangling string representing network traffic (Jeremijenko)
  - Inner office windows
- Reading: http://sandbox.xerox.com/hypertext/weiser/calmtech/calmtech.htm

Hands-Free Computing



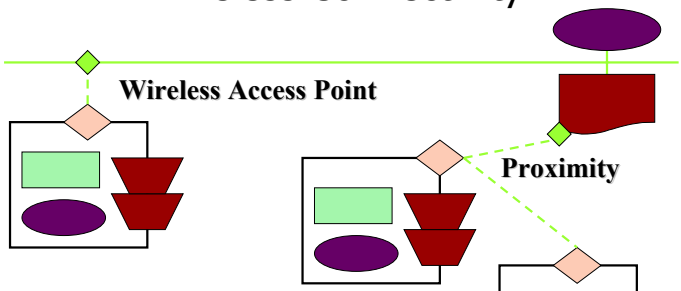
Change UI devices to work at a distance
No need to carry anything
Mobility very limited

Intelligent Environment



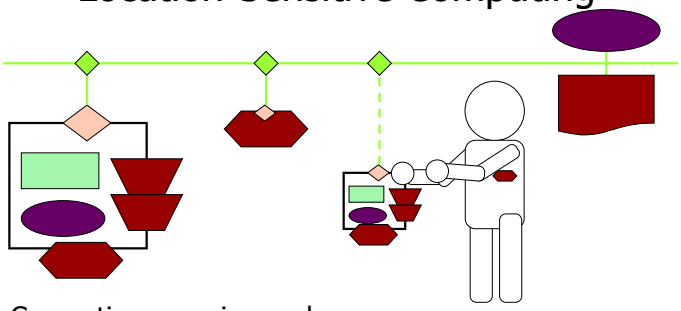
Hands-free with greater area of coverage
Need connectivity for UI devices
Need to dynamically select UI devices

Wireless Connectivity



Proximity connectivity (e.g. Bluetooth):
- Per-device (no wires needed)
- Ad hoc networking (peer-to-peer)
- Locality of connection ≠ locality of access
- If device is static, you know where you are

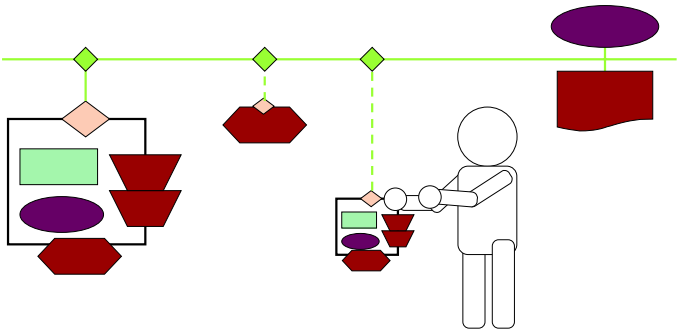
Location-Sensitive Computing



Computing experience changes as you move
- Migrating ("Follow-Me") UI
- Location-Specific Data

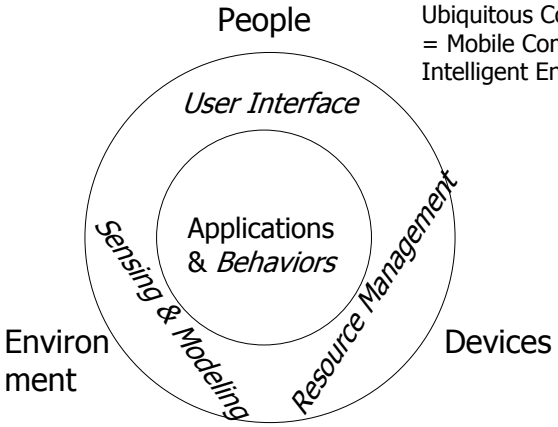
Need device to know where you are
- Cell phone, GPS, active badge, camera, …

Non-Traditional Devices



Why be limited to traditional computing devices?
More pervasive, more subtle, more informative
Enable novel applications – "immobile robot"

Ubiquitous Computing



An interconnected system

Specialized Ubicomp Devices

- LoveGety – Japan, 1998 (matchmaker)
- Pirates! – Viktoria Institute (treasure hunt, combat)
- Human Pacman – University of Singapore
- The ARQuake Project, at the University of Southern Australia
- EasyLiving - Microsoft

What makes technology disappear?

- Psychological effect of learning (transparency)
  - When people learn something sufficiently well, they cease to be aware of it, they can focus beyond the technology on new (true) goals
  - Called "compiling" by H. Simon, or "periphery" by J. Seely Brown
- Distribution of technology (distributed computing)
- Physical invisibility (devices embedded everywhere)
- Location: must know where users are in order to provide appropriate services
  - Outdoor: GPS, wireless/cellular networks
  - Indoor: active badges, electronic tags, vision, motion detectors, keyboard activity
- Scale
- Context awareness/automated functions

Context-Aware Computing

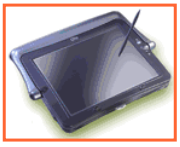
- Context: any information that can be used to characterize the situation of an entity (who, where, when, what)
- Computing services sense aspects of environment (location, objects, identity, emotion,…) and tailor provided services
- Using context to:
  - present relevant information: e.g., 'smart' museum guide
  - perform an action automatically, e.g., print to nearest printer
  - show an action that use can choose, e.g., want to phone the number in this email?

How? Automated Capture

- Automated capturing everyday experiences
  - Machines are better at some of these things than we are
- Multiple streams of information need to be captured
- Logging of events for later use
- Summarizing and making available to the user in multiple formats
- Capturing of process?
- But
  - At what level to integrate information streams?
  - Shall user be able to modify the captured streams?
  - Which information is important?

Scale

- Desktop screens vary by a factor of 2.5 in size and a factor of 4 in pixels
- Ubicomp screens vary by factors of 100 in size and a factor of 625 in pixels
  - Cell phone to interactive wall (3796 x 1436 pixels) → even nano-scale device?



Scale

- Some interaction techniques for desktop will not work
  - Real estate problem on small devices
  - Can't reach menubar on wall-size devices → gesture/voice modality?
- How do you ensure presentation consistency across different devices?
- How do you ensure privacy and security?
- Significant implications for design tools
  - Moving target problem
  - Tools for coordinating multiple, distributed, communicating devices

Scenario: Turning on the lights

- How?
  - Flip a switch
  - Dialog box with buttons
  - Touch a map with lamp indicators
  - "Turn on the room lights"
  - Make a funny gesture
  - It's dark outside
  - You enter the room, you sit down by that desk lamp
- How to activate?
  - Built in by hardware manufacturer
  - You program the behavior
  - Learn by repetition
- Technological implications
  - Tracking: location/pose/activity
  - Sensors: gesture/voice/light recognition

Identification vs. Privacy

- People enter the space as "unknowns"
- How to establish person's identity?
  - Password by keyboard or voice
  - Active badge or cardkey
  - Scan eye / fingerprint / face
- Privacy issues
  - Passive identification = unobtrusive use of cameras / voice
  - When your whole life is on the network, where does the information go?
  - If no "active badge" assumed, people can't physically turn off identification
  - People need to trust the system
  - Need clear policies, deeply rooted in system
  - Keep sensitive data in secure places

Privacy Issues

- One consequence of Ubicomp
  - Way more data about us can be gathered (and used).
  - Potentially a great thing for collaborative algorithms
- But, it's potentially a great problem because...
  - Protection of the user data generated and maintained by the environment
  - Privacy of individuals who use the environment
  - Ability of legitimate users to make use of data recorded in the environment
  - Dealing with high-speed streams of data

Everyday Risks → Extreme Risks

Friends, Family	Employers	Government	Stalkers, Muggers
Over-protection Social obligations Embarrassment	Over-monitoring Discrimination Reputation	Civil liberties	Well-being Personal safety

Challenges and existing solutions

- Challenges
  - Unfamiliar environments
  - Dynamic, ad hoc and shared (difficult to determine access rights)
  - No central control
  - High data rate (must be processed in real-time)
  - Collaborative applications
- Existing solutions (inadequate for ubicomp)
  - Based on authentication/authorization model
  - Require a piece of running code to actively check permissions
  - Why won't it work for ubicomp? Dynamic, distributed, environment; protecting agent can be bypassed. Others?

Potential solutions (?)

- Empower people so they can choose to share:
  - the right information
  - with the right people or services
  - at the right time
- Clear value proposition
- Simple and appropriate control and feedback
- Plausible deniability
- Limited retention of data
- Decentralized control
- Special exceptions for emergencies
- Make the data secure by themselves
- In line with philosophy in cryptography:
  - Assume the adversary has access to the communication
  - Obscurity is not security

Other Problem – Localized Scalability

- As smart spaces grow in sophistication, the intensity of interactions between a user's personal computing space and his/her surroundings increases.
- This has severe bandwidth, energy, and distraction implications for a ubicomp user.
- The presence of multiple users will further complicate this problem.
- Good system design has to achieve scalability by severely reducing interactions between distant entities.

Other Problem – Masking uneven conditioning

- Huge differences in the "smartness" of different environments — what is available in a well-equipped conference room, office, or classroom may be more sophisticated than in other locations.
- This large dynamic range of "smartness" can be jarring to a user, detracting from the goal of making pervasive computing technology invisible.
- One way to reduce the amount of variation seen by a user is to have his/her personal computing space compensate for "dumb" environments. How?

Future Trends

- "Gap" between user and desktop widening
  - Both in time and space
- Widespread ubicomp device proliferation
  - Mobile phones achieve huge penetration worldwide → need systems that are intuitive for many types of users
  - Wall-sized ads, large display are parts of urban life
  - They are used in a variety of context: environmental, social, ethical, contextual factors become increasingly important
- Convergence of computing capabilities onto the phone/PDA
  - Take photos, play music, record notes, etc.
- Our society is aging
  - Accessibility of small devices will be an issue

Research Responses

- Ubi-input
  - "Learn once, write anywhere"
- Understand, sense, and adapt to "situational impairments"
- Sensors everywhere: Many things will need some rudimentary input
  - Don't want to learn a new technique for every new device
- Simple, extensible techniques applicable to a variety of devices
- Deliver education and medical information on portable devices
  - Particularly in developing nations → ex. South Africa