INTRO TO MOBILE SYSTEMS

CSE 599 N1: Modern Mobile Systems

modernmobile.cs.washington.edu

Content borrowed from Jon Froehlich, Alex Mariakakis, Don Patterson, Shwetak Patel, Gregory Abowd

Plan

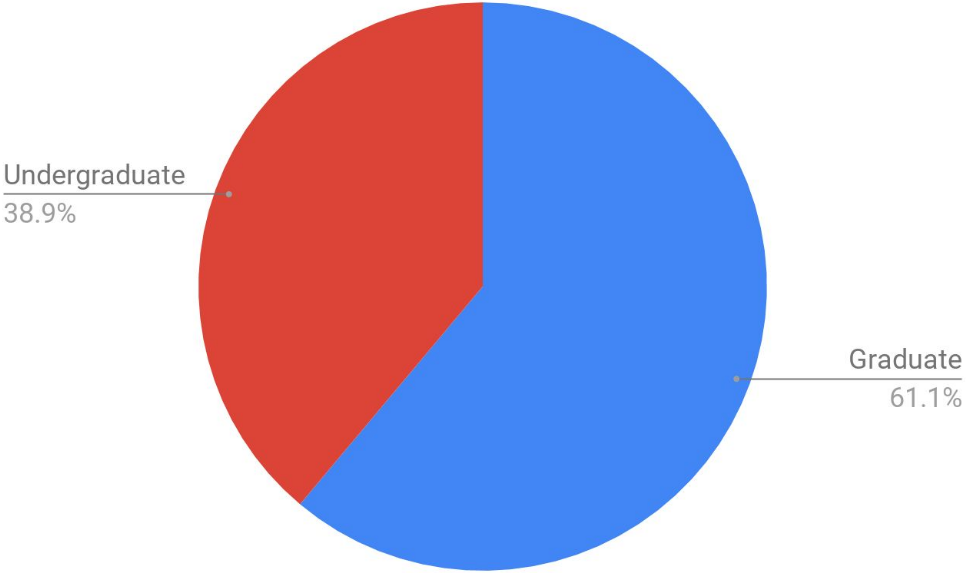
- Why this course
- Course aims and goals
- Administrivia
- What is ubicomp?
- Historical context of ubicomp

If you want to...

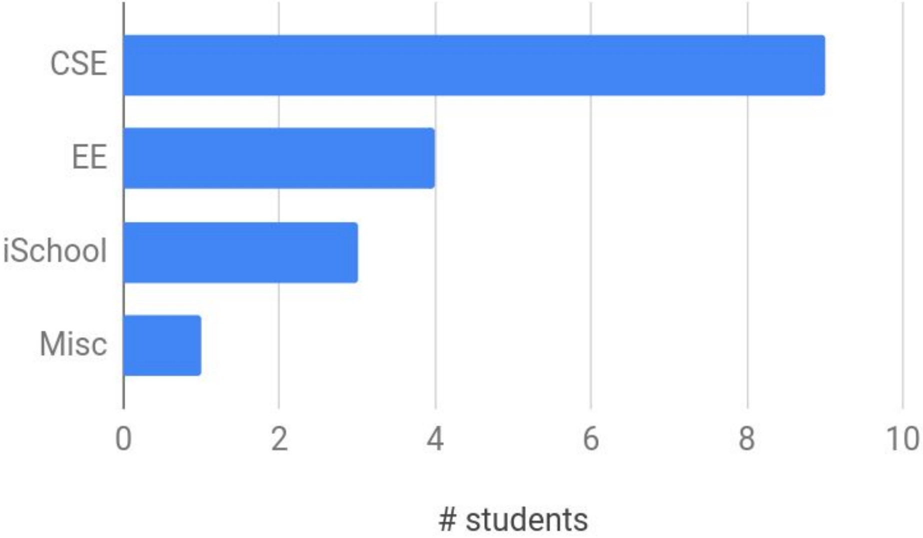
- Learn how to reuse traditional sensors in the smart devices in an unconventional manner to have impact on real world problems like diagnosing diseases and health disorders that affect millions of people
- Explore state of the art interfaces to interact with VR/AR systems and drones
- Leverage sensor fusion, signal processing and deep/machine learning for activity monitoring and motion tracking
- Exploit the waves of signals around us for communication, gesture recognition, sensing and more
- Apply technical skills and knowledge of the world to solve issues that touch lives (instead of getting people to click on more ads)

This class is for you

Enrollment (n=~18)



Even split between CSE/non-CSE



Goal of the course

- Have an understanding of state of the art research going on in mobile systems
- Broaden view of what applications are capable with computing devices
- Acquire knowledge about the different techniques required to solve problems in this area
- Appreciate the different challenges and constraints that go into developing a mobile system
- Be able to critically evaluate mobile systems papers and know the tradeoffs made as a result of different design decisions

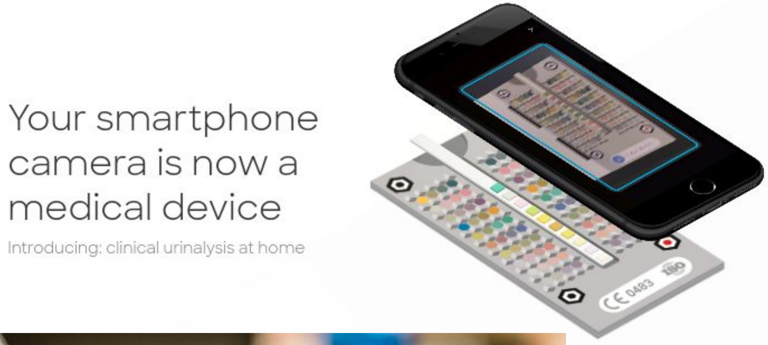
Mobile Health

Detecting medical conditions with just a smartphone

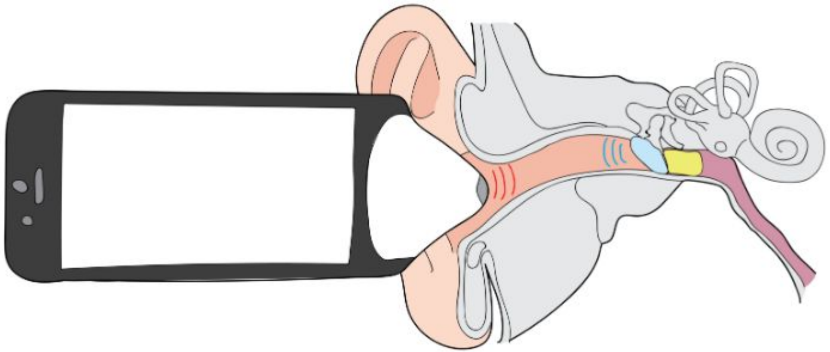
Instructors: Sleep apnea, opioid overdose, middle ear infection, agonal breathing, vascular anomalies, fetal heartbeat, sinus infection, speech dysfunction, microtia

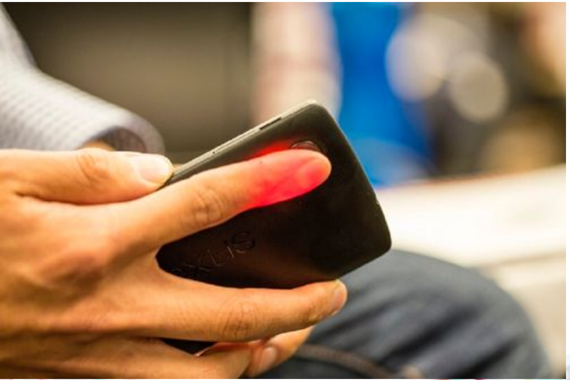
Ubicomp lab/elsewhere: Jaundice, hemoglobin monitoring, lung function, melanoma detection skin cancer, blood pressure monitoring, HIV/syphilis detection, semen analysis, urinary tract infection diagnosis

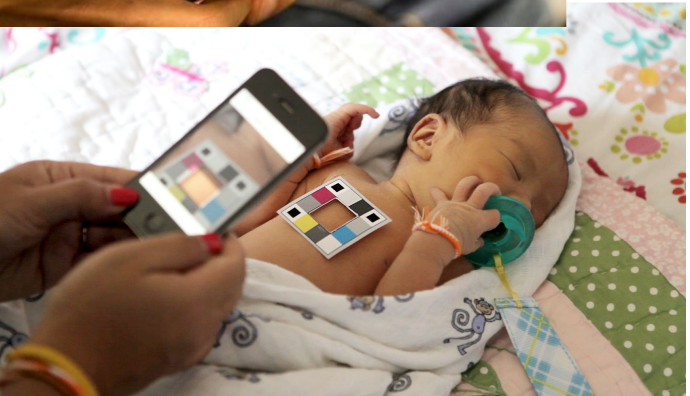
Highly accessible and cheap alternative to medical devices that are expensive/difficult to acquire/requires expertise/inaccurate

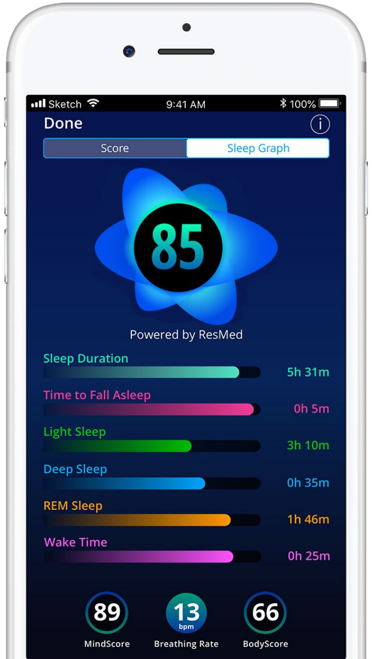


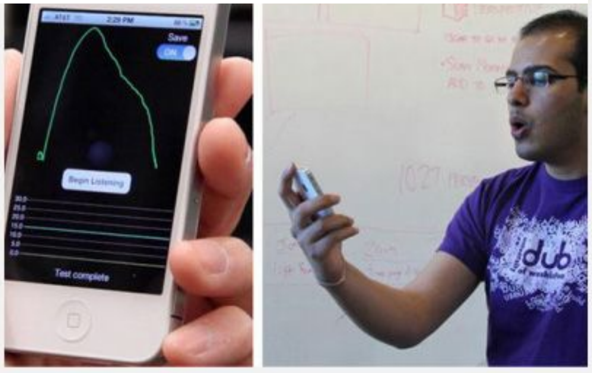
Mobile health











Sensors

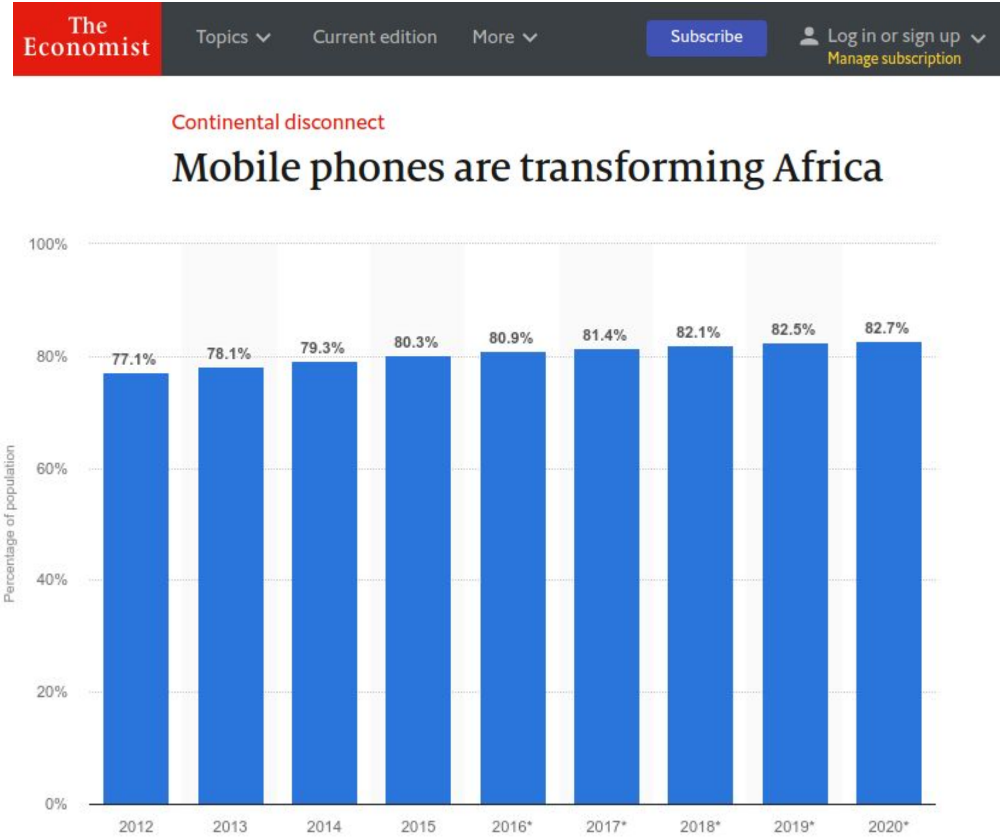
Accelerometer
Gyroscope
Speaker/microphone
Camera
Magnetometer
GPS
Proximity
Thermometer
Barometer
Light sensor
Hygrometer

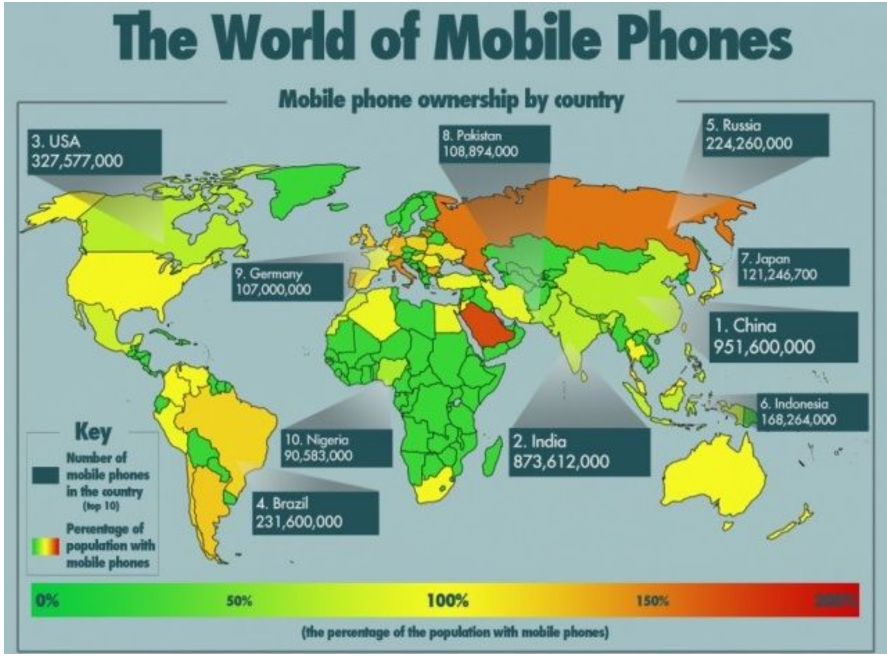
Functions as an ECG monitor that can monitor heart rate detect cardiac arrests.
Detects falls

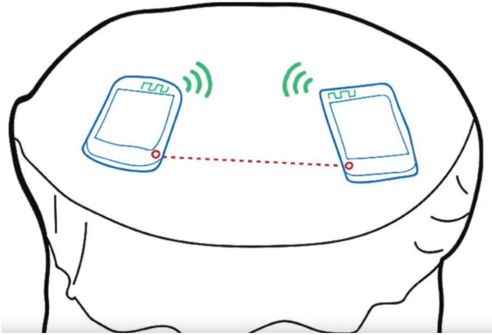
In one year alone, <u>**475,000 Americans die from a cardiac arrest**</u>. Globally, cardiac arrest claims more lives than colorectal cancer, breast cancer, prostate cancer, influenza, pneumonia, auto accidents, HIV, firearms, and house fires combined.

About 90 percent of people who experience an out-of-hospital cardiac arrest die.

Mobile phone penetration

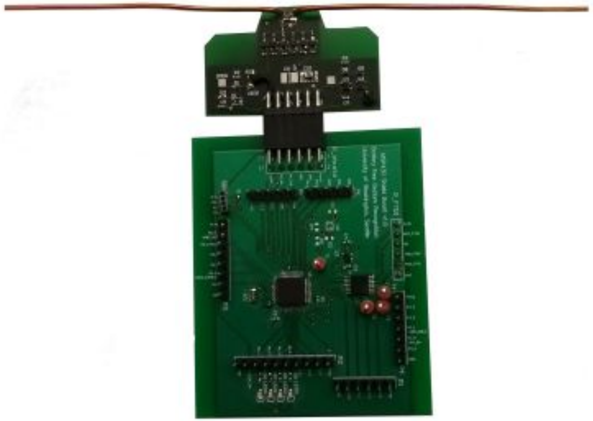


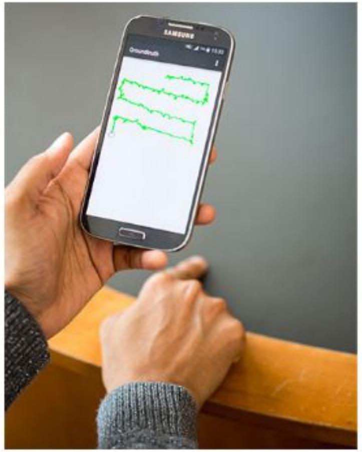


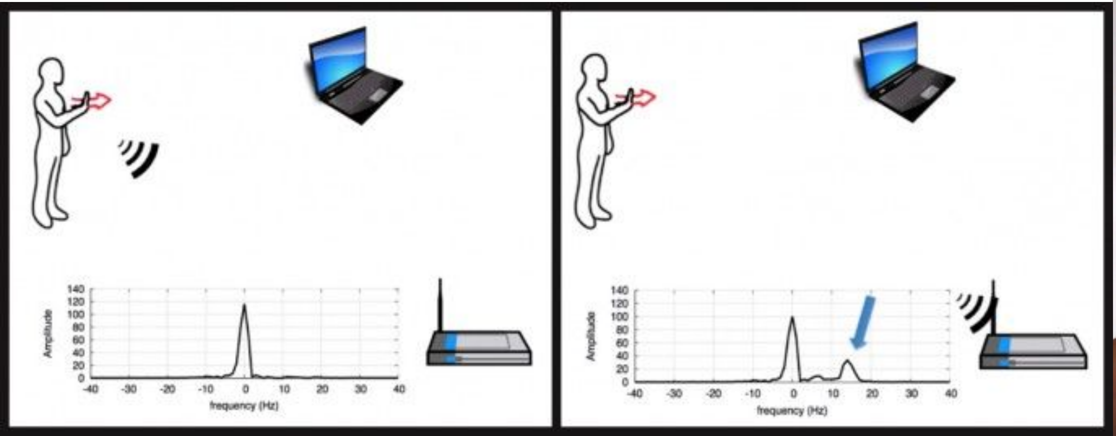


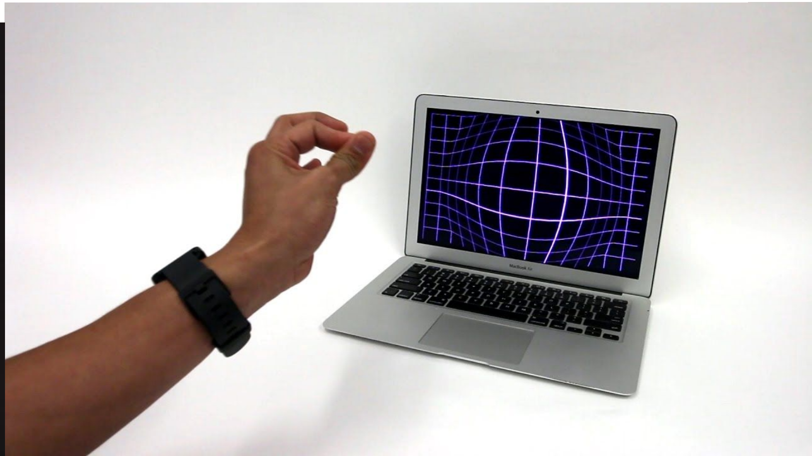
Smart
homes

Interaction

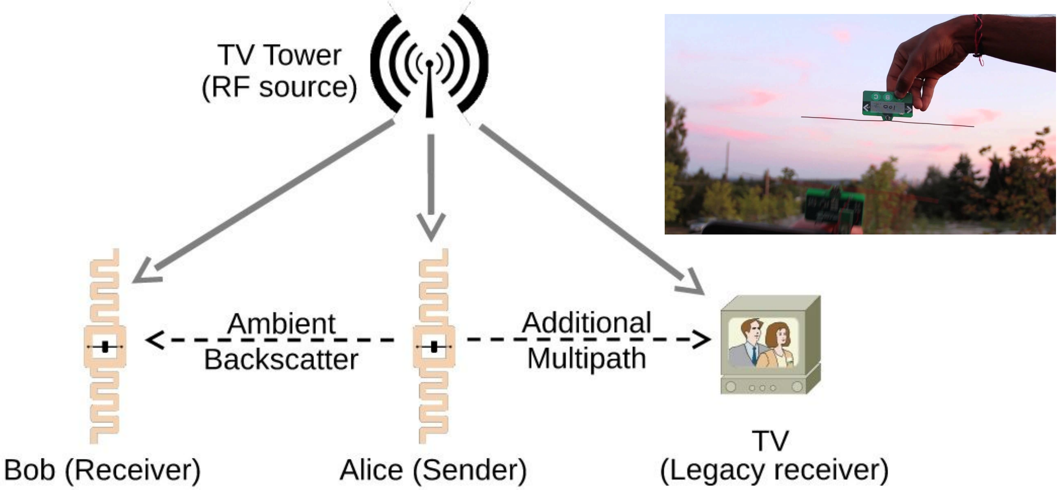


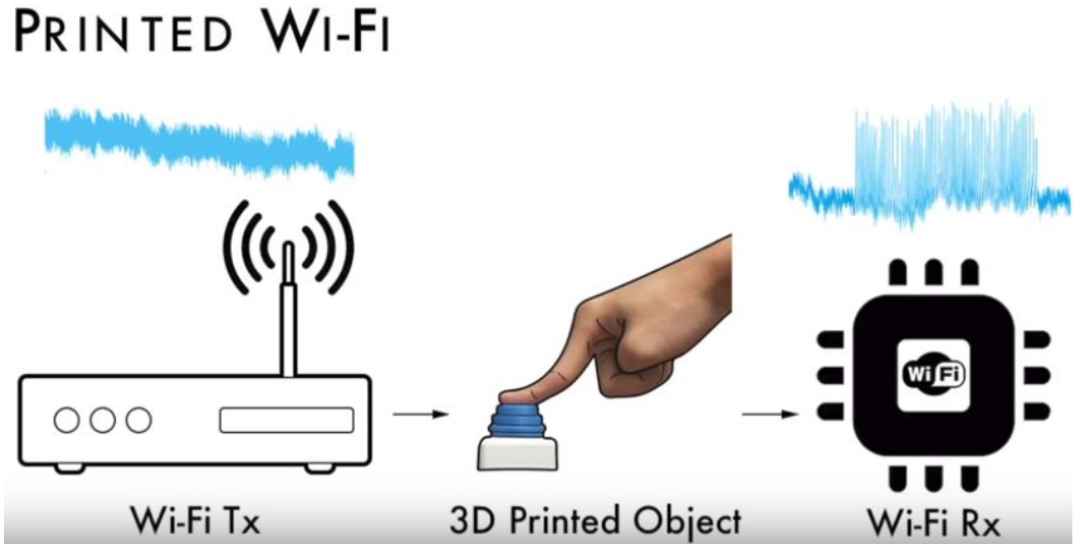


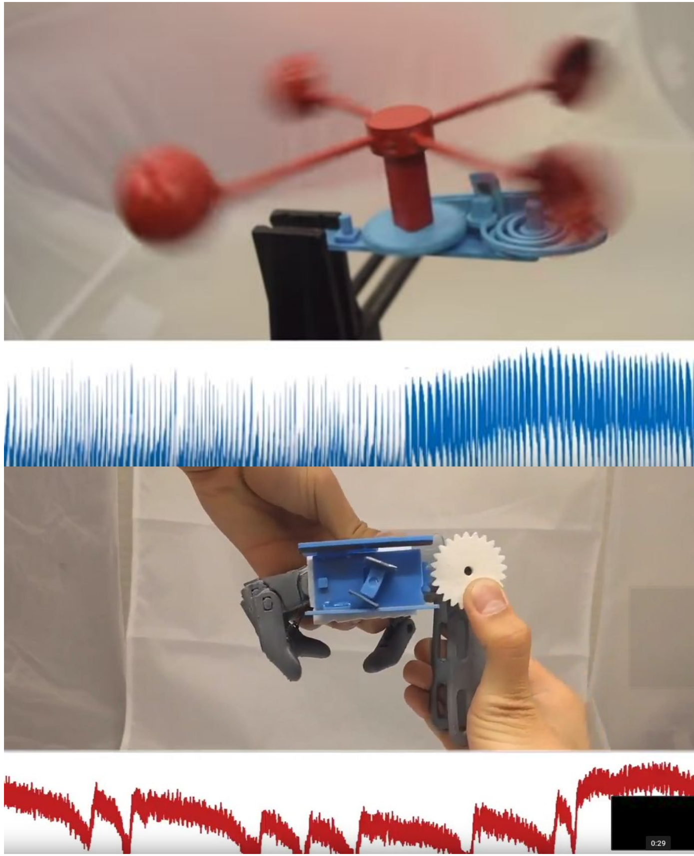




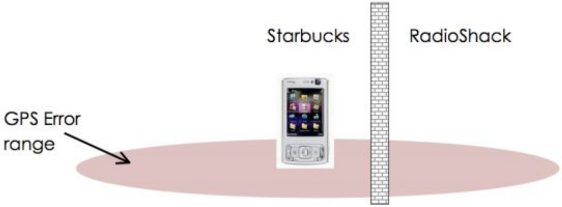
Backscatter

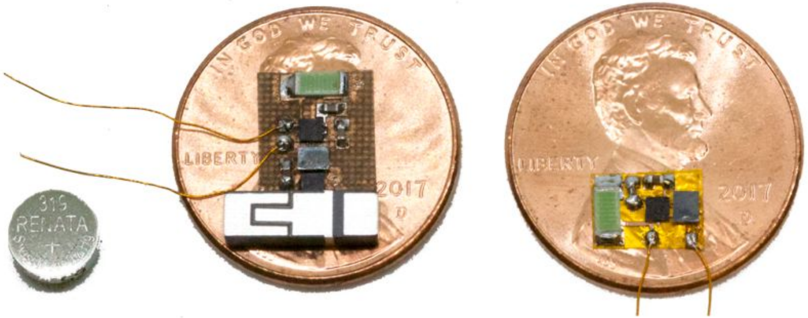


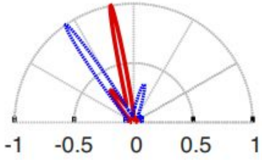


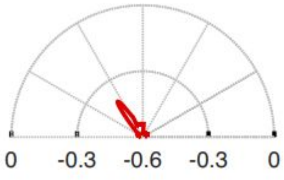


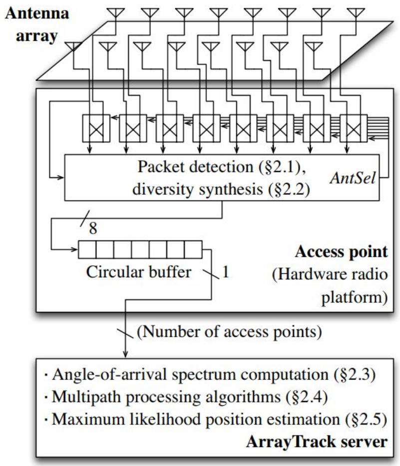
Indoor localization

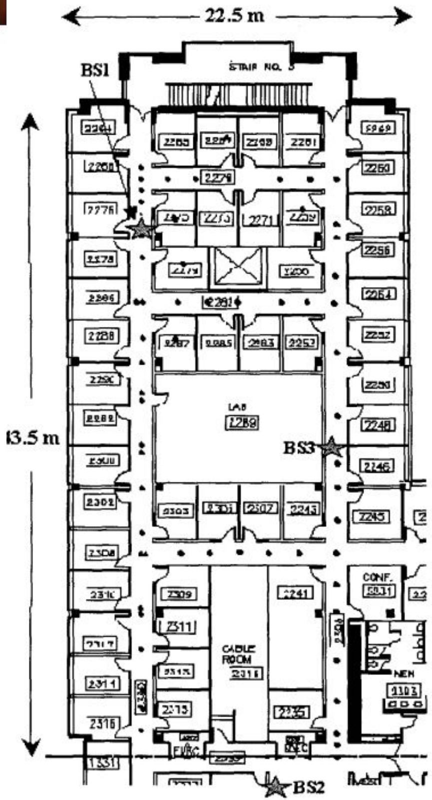












Syllabus

- Ubicomp/mobile systems
- Interaction (wireless, through-body, acoustic etc.)
- Localization
- Mobile health
- Physical computing
- Low-power systems
- Smart homes
- Fabrication
- Drones
- Deep learning
- Security and privacy
- Etc...

CSE 599 N1: Modern Mobile Systems

CSE 599 N1, Autumn 2018 Modern Mobile Systems

Lecture: Wednesday, Friday 2:00-3:20 Room: Loew Hall 105

Instructors: Rajalakshmi Nandakumar and Justin Chan

Contact: cse599n1-instructor@cs.washington.edu
(aliases to {rajaln, jucha}@cs.washington.edu)

Office Hours by appointment

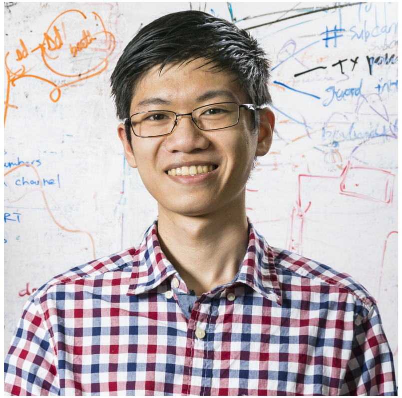
Canvas

Staff

Rajalakshmi Nandakumar

Final year PhD
Active sonar/acoustic technologies
ApneaApp, FingerIO, CovertBand, Opioid overdose detection

Justin Chan



3rd year PhD
EarApp, cardiac arrest detection, pediatric health
3D printing and fabrication
Smart homes and interfaces

Hours

Course hours

Wednesday, Friday, 2 - 3:20 pm

Office hours:

By appointment

Both instructors away during week of Oct 29th

Guest lectures will occur during that week

Prerequisites

Knowledge of basic programming

Assignments will be loosely specified, you have the freedom to select which mobile platform you wish to develop on e.g. iOS, Android, Windows, BlackBerry…

So long as the code works, the implementation details do not matter

Assignment grading (demo or die)

- Assignments will be graded based on in-person demos
- Code must be submitted by the start of the demo session
- Late code submissions will not be able to earn any points for the demo portion of the grade, but can still earn full points for the code portion

Assignments (TBD)

- Step counting (pedometer)
- Acoustic gesture recognition or acoustic communication
- Heart rate monitor with microcontroller

Around two weeks to complete each assignment

Schedule a demo session with instructors

All code should work in realtime on the mobile device

Reading summaries

- Post response to readings on Canvas before class
- Ideas for what to write in response
  - Compare papers assigned for that day
  - Compare with papers assigned previously in course
  - Compare with papers of your own choosing
  - Pros and cons of approach in the paper
  - How can the paper be improved?

Late policy

Don’t be late

Within reason we will accept assignments without penalty

Without reason assignments will be penalized

Participation

- Active participation and discussion is valued
- Everyone should be comfortable commenting and providing insights from their own perspectives

Conferences for course project

- MobiCom/MobiSys - mobile systems, fabrication
- CHI/UIST - human computer interaction
- Nature, Science, Ubicomp - mobile health
- Sigcomm, NSDI - wireless, backscatter, networking

Aim high for course project -- ideal project should be publishable at these conferences!

Mobile projects can have fast development cycles.

Feasible to prototype an idea publishable at these top conferences

Grade breakdown

60% project

30% homeworks

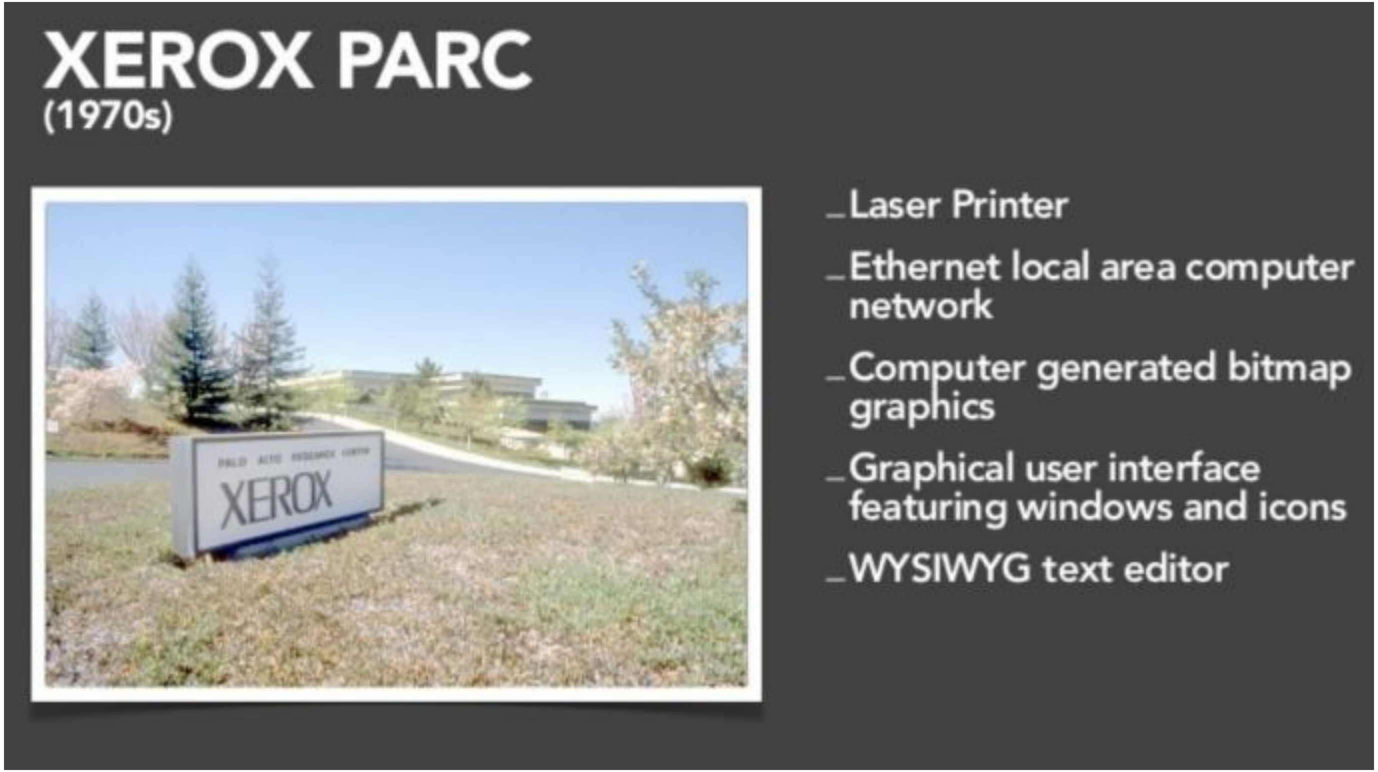
10% paper reviews, participation

Introduction to Ubiquitous Computing Background and Context

Definitions of UbiComp

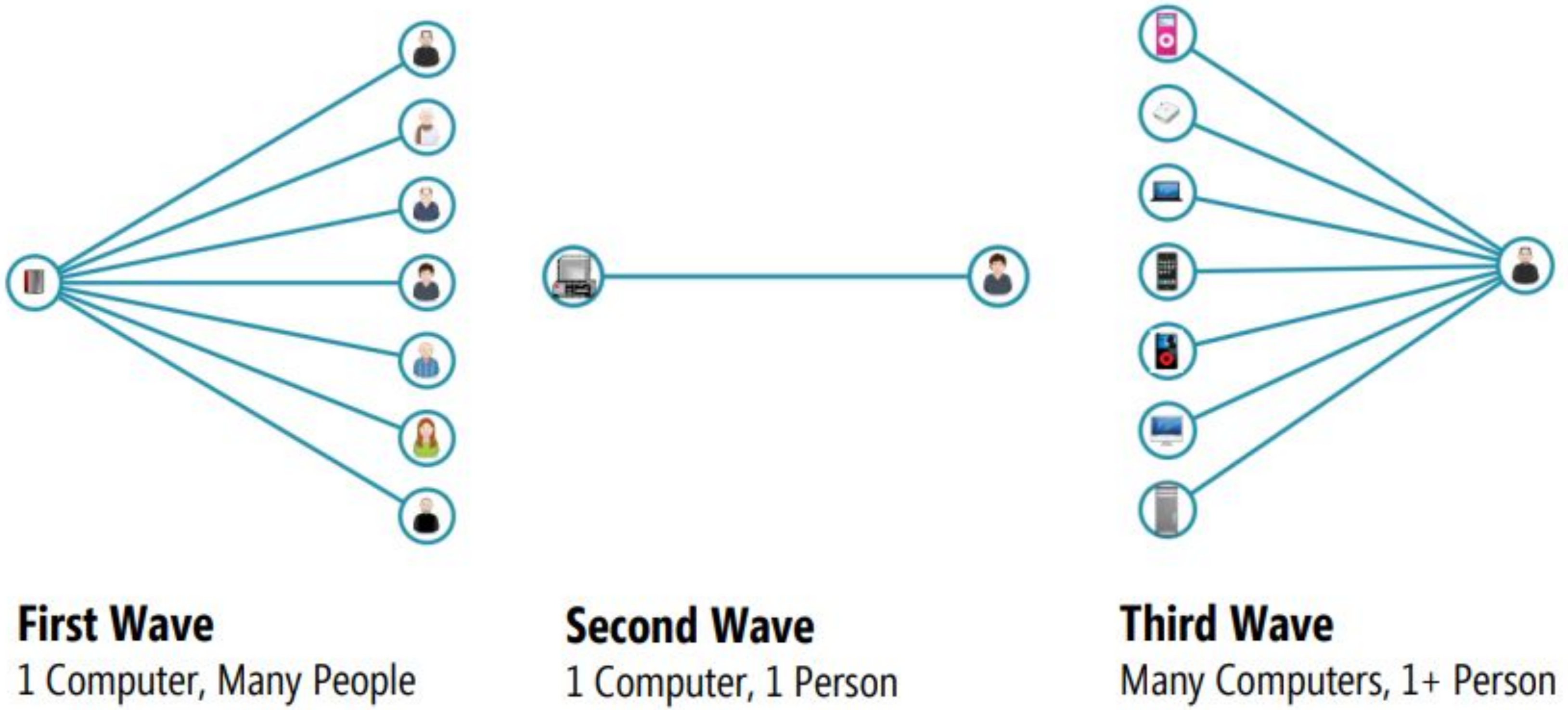
- Computing that moves beyond the desktop
- Computing that is embedded everywhere in the environment
- A technology where the task is the focus, not the technology itself

Origins of UbiComp



Invented many ideas that were foundational to the original Apple Macintosh system

3 eras of computing



First wave

- Main Frame Computing
- 1960-1970
- Massive computers to do simple data processing
- Few computers in the world
- Killer apps: scientific calculations

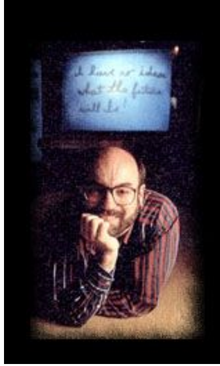
Second wave (PC era)

- Desktop Computing
- 1980-1990
- Business applications drive usage
- One computer per desk
- Computers connected in intranets to a massive global network
- All wired
- Killer apps: spreadsheets, text editing

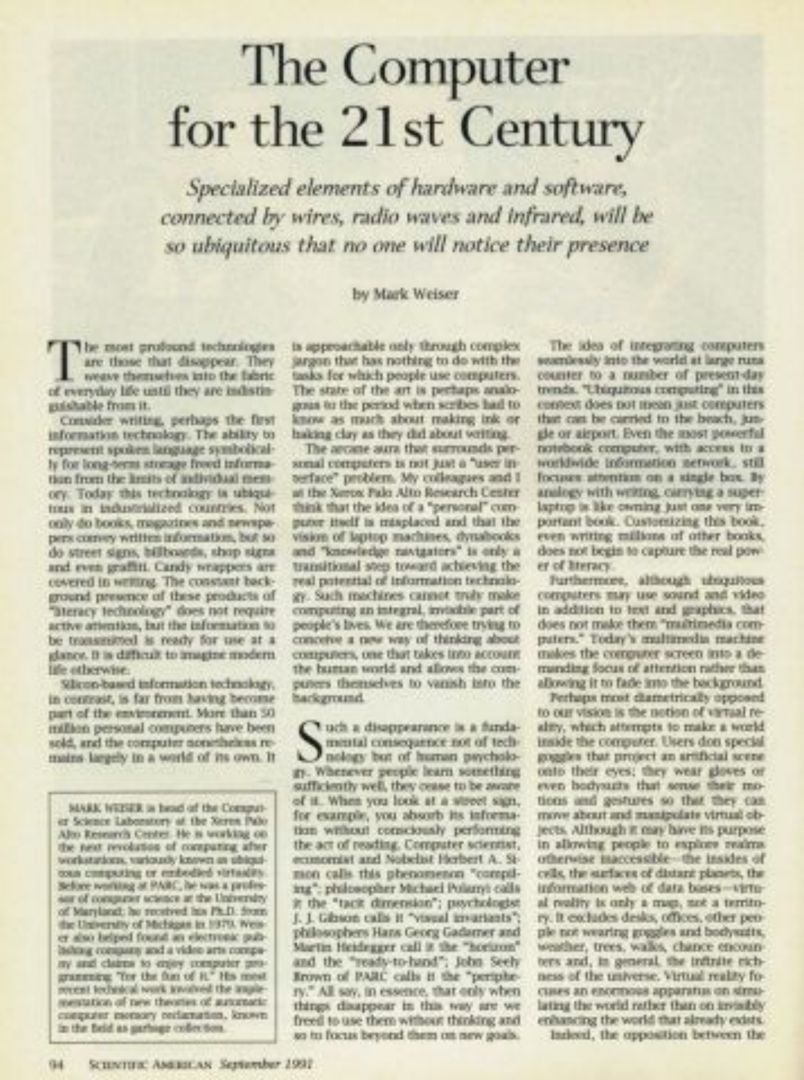
Third wave

- Ubiquitous computing
- 2000-present
- Information creation, access, communication drive usage
- Multiple computers per environment/person
- WANs, LANs, PANs, ad-hoc networking, wireless
- Traditional notion of a ‘computer’ disappearing
- Killer apps: social networks, ridesharing apps

Mark Weiser (1952 - 1999)



- CTO of Xerox PARC
- Introduced notion of “calm technology”
  - interaction between the technology and its user is designed to occur in the user's periphery rather than constantly at the center of attention.
  - E.g. video conferences, smart homes
  - E.g. water kettle, you fill it up and walk away, and don’t need to focus on it
- Computing should be as “refreshing as a walk in the woods
- Late 1980s, Mark Weiser became new manager of PARC’s Computer Science Lab Mark felt it was time for a new and radically different paradigm of computing and proposed a new research agenda termed “ubiquitous computing.”



The Computer for the 21st Century

Specialized elements of hardware and software, connected by wires, radio waves and infrared, will be so ubiquitous that no one will notice their presence

by Mark Weiser

The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it.

Consider writing, perhaps the first information technology. The ability to represent spoken language symbolically for long-term storage freed information from the limits of individual memory. Today this technology is ubiquitous in industrialized countries. Not only do books, magazines and newspapers convey written information, but so do street signs, billboards, shop signs and even graffiti. Candy wrappers are covered in writing. The constant background presence of these products of "literacy technology" does not require active attention, but the information to be transmitted is ready for use at a glance. It is difficult to imagine modern life otherwise.

Silicon-based information technology, in contrast, is far from having become part of the environment. More than 50 million personal computers have been sold, and the computer nonetheless remains largely in a world of its own. It is approachable only through complex jargon that has nothing to do with the tasks for which people use computers. The state of the art is perhaps analogous to the period when scribes had to know as much about making ink or baking clay as they did about writing.

The arcane aura that surrounds personal computers is not just a "user interface" problem. My colleagues and I at the Xerox Palo Alto Research Center think that the idea of a "personal" computer itself is misplaced and that the vision of laptop machines, dynabooks and "knowledge navigators" is only a transitional step toward achieving the real potential of information technology. Such machines cannot truly make computing an integral, invisible part of people's lives. We are therefore trying to conceive a new way of thinking about computers, one that takes into account the human world and allows the computers themselves to vanish into the background.

Such a disappearance is a fundamental consequence not of technology but of human psychology. Whenever people learn something sufficiently well, they cease to be aware of it. When you look at a street sign, for example, you absorb its information without consciously performing the act of reading. Computer scientist, economist and Nobelist Herbert A. Simon calls this phenomenon "compiling"; philosopher Michael Polanyi calls it the "tacit dimension"; psychologist J. J. Gibson calls it "visual invariants"; philosophers Hans Georg Gadamer and Martin Heidegger call it the "horizon" and the "ready-to-hand"; John Seely Brown of PARC calls it the "periphery." All say, in essence, that only when things disappear in this way are we freed to use them without thinking and so to focus beyond them on new goals.

The idea of integrating computers seamlessly into the world at large runs counter to a number of present-day trends. "Ubiquitous computing" in this context does not mean just computers that can be carried to the beach, jungle or airport. Even the most powerful notebook computer, with access to a worldwide information network, still focuses attention on a single box. By analogy with writing, carrying a super-laptop is like owning just one very important book. Customizing this book, even writing millions of other books, does not begin to capture the real power of literacy.

Furthermore, although ubiquitous computers may use sound and video in addition to text and graphics, that does not make them "multimedia computers." Today's multimedia machine makes the computer screen into a demanding focus of attention rather than allowing it to fade into the background.

Perhaps most diametrically opposed to our vision is the notion of virtual reality, which attempts to make a world inside the computer. Users don special goggles that project an artificial scene onto their eyes; they wear gloves or even bodysuits that sense their motions and gestures so that they can move about and manipulate virtual objects. Although it may have its purpose in allowing people to explore realms otherwise inaccessible—the insides of cells, the surfaces of distant planets, the information web of data bases—virtual reality is only a map, not a territory. It excludes desks, offices, other people not wearing goggles and bodysuits, weather, trees, walks, chance encounters and, in general, the infinite richness of the universe. Virtual reality focuses an enormous apparatus on simulating the world rather than on invisibly enhancing the world that already exists.

Indeed, the opposition between the

MARK WEISER is head of the Computer Science Laboratory at the Xerox Palo Alto Research Center. He is working on the next revolution of computing after workstations, variously known as ubiquitous computing or embodied virtuality. Before working at PARC, he was a professor of computer science at the University of Maryland; he received his Ph.D. from the University of Michigan in 1979. Weiser also helped found an electronic publishing company and a video arts company and claims to enjoy computer programming "for the fun of it." His most recent technical work involved the implementation of new theories of automatic computer memory reclamation, known in the field as garbage collection.

94 SCIENTIFIC AMERICAN *September 1991*

"The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it"

(1991)

Disappearing technologies

Virtual reality focuses an enormous apparatus on simulating the world rather than on invisibly enhancing the world that already exists.

The vanishing of electric motors: Cheap, small, efficient electric motors made it possible first to give each machine or tool its own source of motive force, then to put many motors into a single machine.

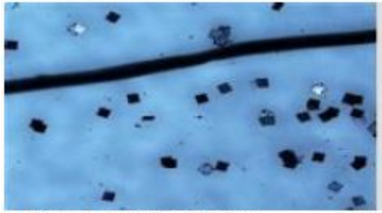
Abstraction of technologies

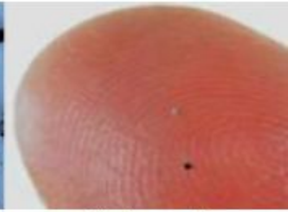
Scale: Inch, foot, yard contributions

- Research agenda focused on addressing the problems of everyday life (away from the desk).
- Developed a computational agenda around computing by the inch, foot and yard
- Each sized device is built for different tasks

Tabs (inch) | Pads (foot) | Boards (yard)

Tabs (smart dust)


Smart dust particles


smartdust on a finger

Post-it note sized, like Active Badge

Titles on book spines, labels on controls, thermostats and clocks, small pieces of paper

Clip-on computers that can identify themselves and track people or objects

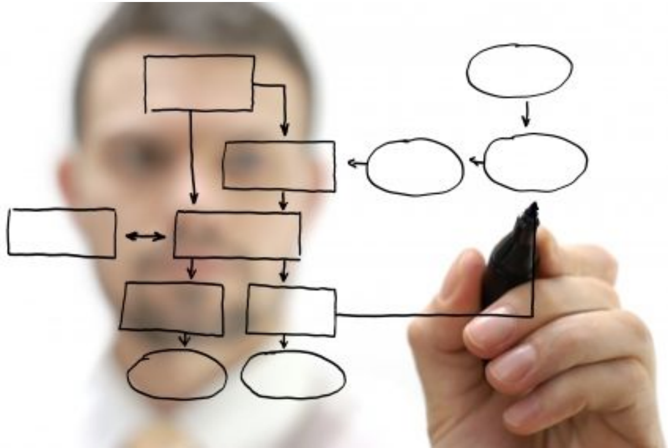
Vision: 100s of computers per room

These computers will become invisible like wires in the walls to accomplish everyday tasks

Animate objects previously inert. Beep to locate objects. Make active maps for any book

Design requirements

- Cheap low-power computers, convenient displays
- Network - support hundreds of machines in every room that can work indoors and outdoors
- Tiny range wireless, long range wireless, high speed wired
- Software systems, future OSes based around tiny kernels of functionality that adapt to changing needs of environment



Pads

Size: sheet of paper/current laptop

Pads are *not* like laptops, they are ‘scrap computers’ that can be grabbed and used anywhere like scrap paper. They have no individualized identity or importance.

Pads can be used as reminders and spread out over the desk, not limited to desktop screen

Boards

Video screens, bulletin boards, whiteboards, flip charts

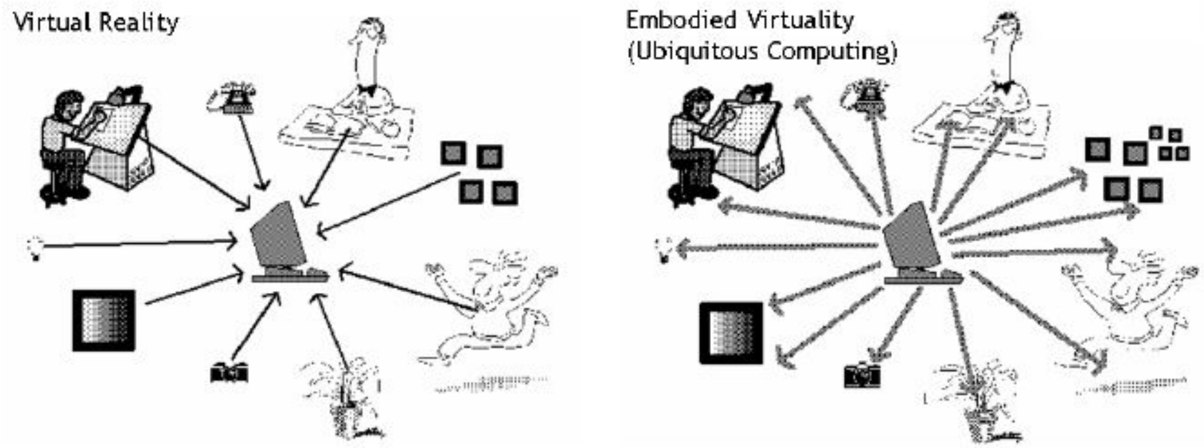
Computer interaction that casually enhances every room

Trends

Present: people holed in offices before glowing screens and smartphones, gets in the way of human interaction

VR: outside world ceases to exist

Vision: computers reside in human world and pose no barrier to personal interactions



What next UbiComp? (2012)

Thesis: ubicomp is here and no longer requires special attention -- ideas and challenges are widespread throughout computing

Everything that is published in Ubicomp could find a publication home elsewhere and vice versa

Fourth generation of computing (?): many to many

Crowd sourced/deep learning results benefitting the masses

Get answers to complex questions in real time, get medical advice instantly, personal assistants etc.

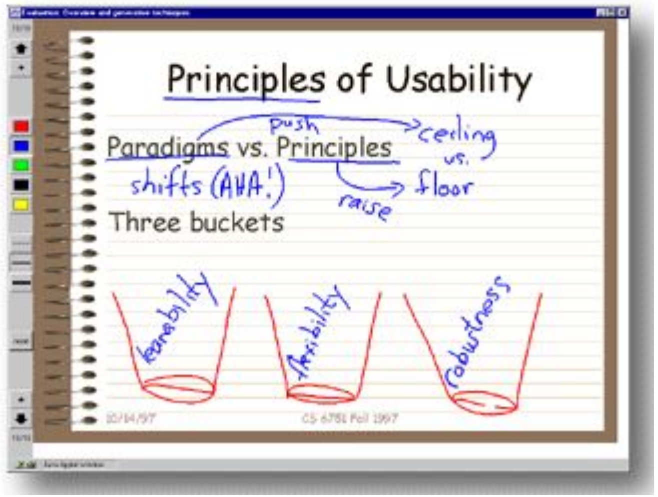
Early UbiComp research themes

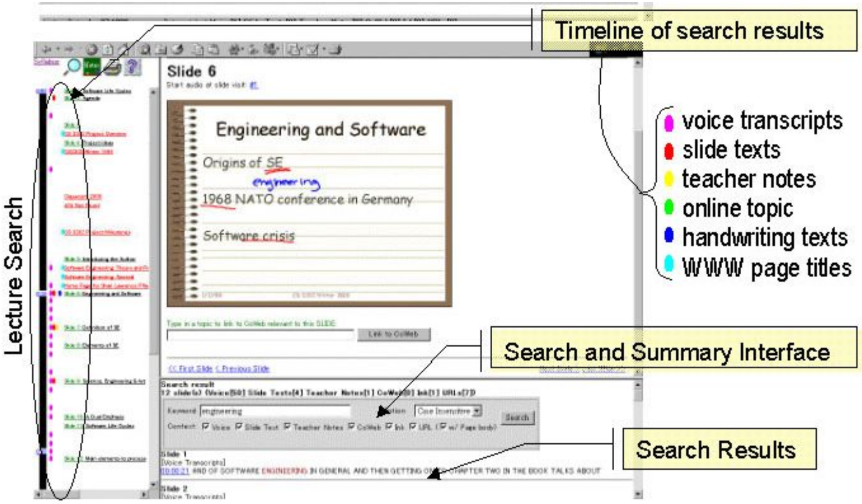
Charting Past, Present and Future Research in Ubiquitous Computing (2000)

1. Automated capture and access
2. Natural and implicit feedback
3. Context-awareness

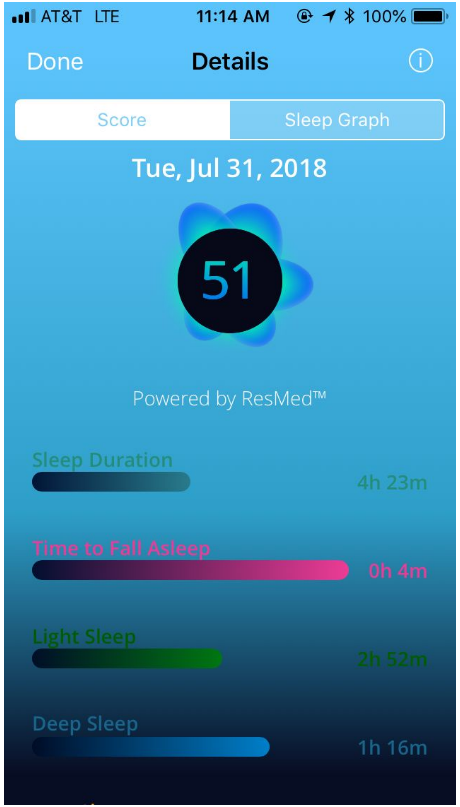
Automated capture

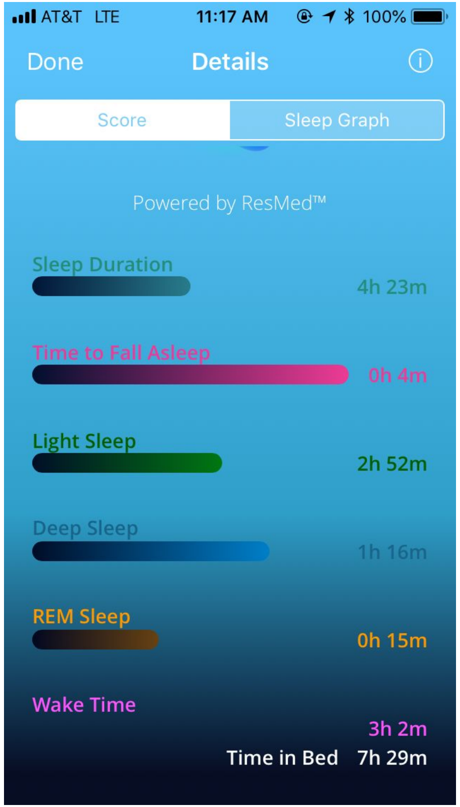
- Manual record-taking is hard
- Machines can record some things better than humans
- Multiple streams of information sometimes need to be synchronized





Automated capture examples

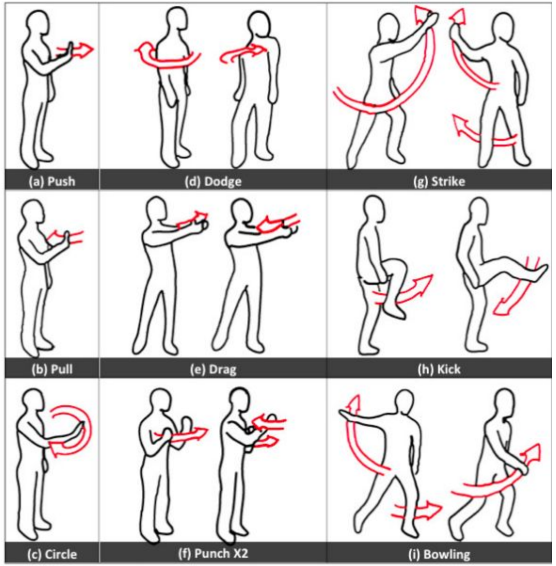




Natural and implicit interfaces

- Traditional computing involves interacting with a computer using command terminals, mice, and keyboards
- More intuitive and natural interfaces allow devices to be used more easily

Figure 1: SoundWave allows non-contact, real time in-air gesture sensing on existing commodity computing devices.



Natural and implicit interfaces examples

“we expect that 75 percent of households with VPAs (virtual personal assistants) will have one, 20 percent will have two, and five percent will have three or more devices by 2020.”
-- Gartner

Microsoft PixelSense

Minority Report (2002)

Context-aware computing

When devices are used in different scenarios, they might need to do different things

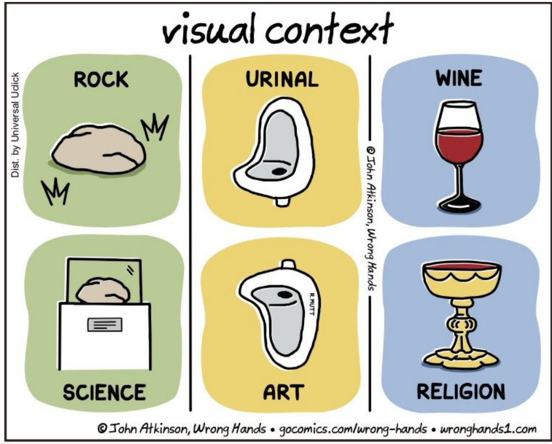
Computing services should sense the environment (e.g. location, emotion) and automatically change their behavior

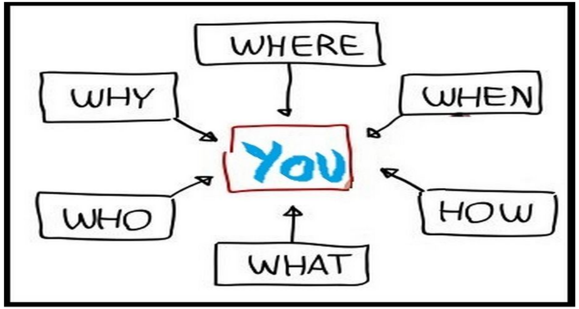
Critical contextual elements

- Location and scale
- Biometrics
- Time
- Conversational context
- Environment context (e.g. temperature)
- Identity (i.e. who is using it)
- Proximity to other devices
- Human behavioral patterns
- Interests and beliefs
- Emotional context

Minimal set of contextual elements

- What are we doing?
- Where are we doing it?
- Who are we and who are we doing it with?
- When are we doing it? Have we done it before?





Example contexts

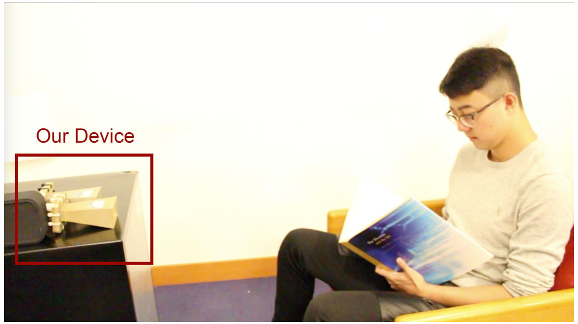
Location

Movement

Activity

Social interaction

Emotion



Location

Computers must know where they are

When a computer has this knowledge it can adapt its behavior is significant ways

“Simple” context can be hard

- Re: location. What does the system need to infer?
- Lat/long?
- A physical address (185 E Stevens Way NE)
- The room I’m in?
- A semantic place (e.g., my home, my work, a friend’s house)
- What’s near me?
- Which way I’m facing?
- ...

Location inference: Active Badge

The Active Badge emits a unique IR code every 15 secs, which are picked up by a sensor network placed throughout a building, which communicates with a centralized server and provides a social location API. IR was chosen because ultrasonic too expensive.

Technologies

Infrared

Ultrasonic

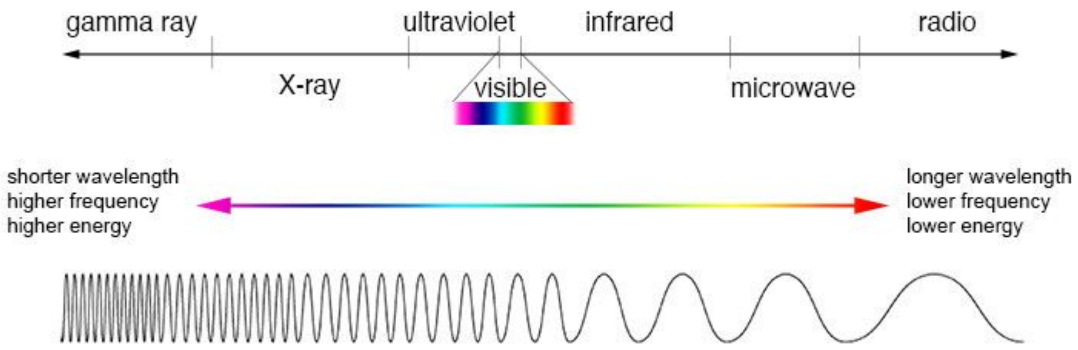
Radio frequency/Wi-Fi

FM radio

Bluetooth

GSM

Etc.



Today

- The **Active Badge** Location System Want et al., ACM Trans. **InfoSys'92**
- The **Cricket** Location-Support System Priyantha et al., **MobiCom'00**
- **RADAR**: An In-Building RF-Based User Location and Tracking System Bahl & Padmanabhan, **INFOCOM'00**
- Location Systems for Ubiquitous Computing Hightower & Boriello, **IEEE Computer'01**
- **RightSPOT**: A Novel Sense of Location for a Smart Personal Object Krumm et al., **UbiComp'03**
- LOCADIO: Inferring Motion and Location from WiFi Signal Strengths Krumm & Horvitz, **Mobiquitous'04**
- **Place Lab**: Device Positioning Using Radio Beacons in the Wild LaMarca et al., **Pervasive Comp'05**
- Accurate GSM Indoor Localization Otsason et al., **UbiComp'05**

Everyday computing constraints

- Rarely have beginning or end
  - There is typically no point of closure, information from the past is often recycled
- Interruption is expected
  - Assume that activities will not be continuous, may have to operate in background
- Multiple activities operate concurrently
  - Assume the need for context shifts
- Time is an important discriminator
  - Incorporating notions of time (minutes, hours, days) since last interaction
- Associative models of information are needed
  - Context-rich model. User should be allowed to gather information from multiple paths