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Mobile and Ubiquitous Computing

Fundamental Concepts

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Session Overview

- The mobile computing paradigm
- The ubiquitous computing paradigm
- Elements of mobile and ubiquitous computing
- Enabling technologies
- Computer science challenges
- Applications and their role

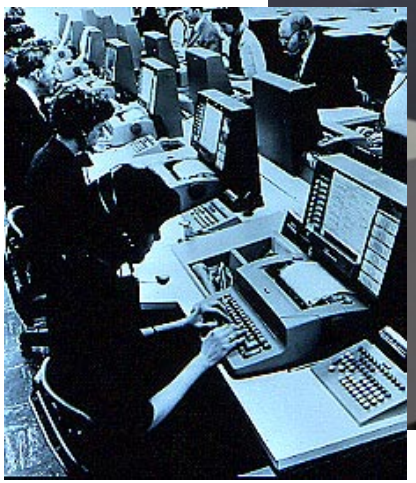
1940s

NACA High Speed Flight Computer Room

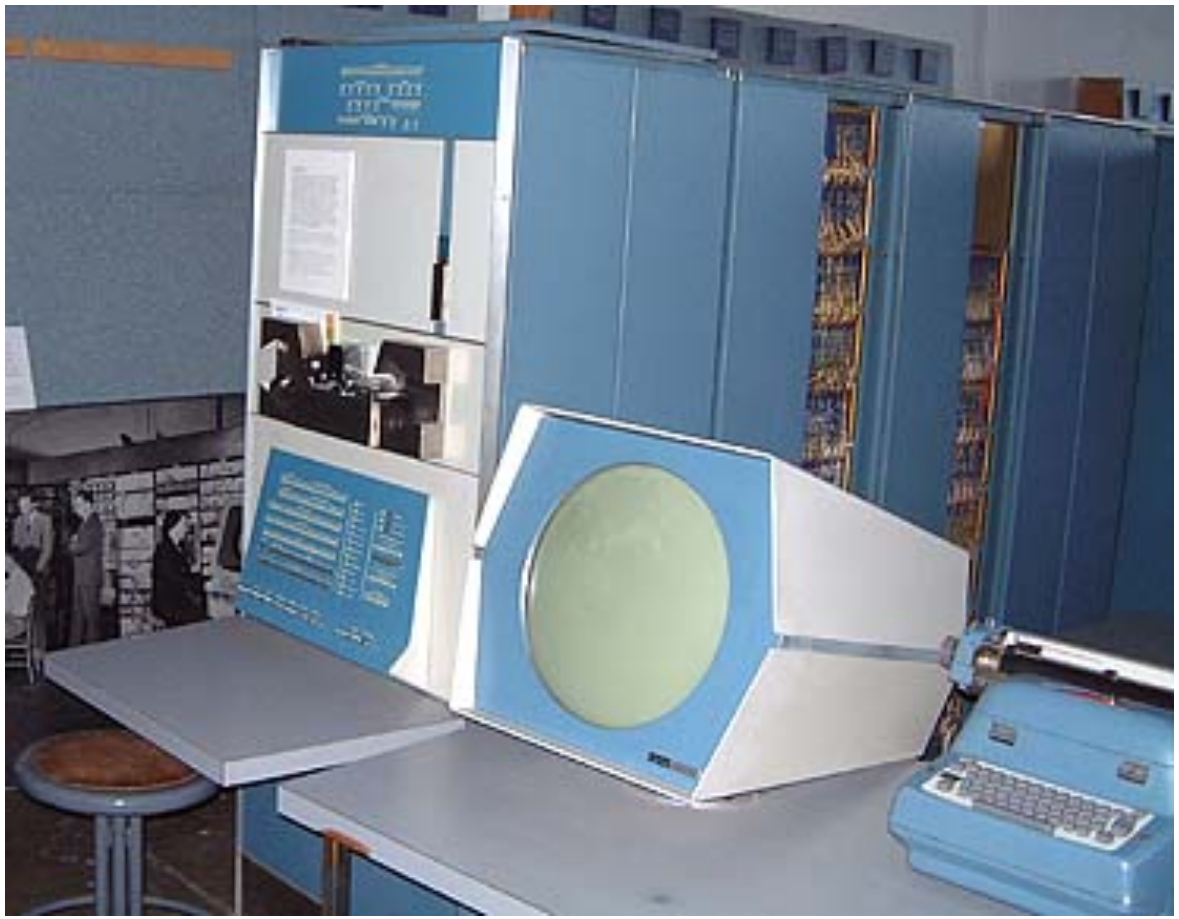
1950s

LEO Computer 30,000 watts, 5,000 square feet

1960s



1970s



PDP-1, 114kb, 200kHz

1980s

Apple II 4K-48K,
1MHz

1990s

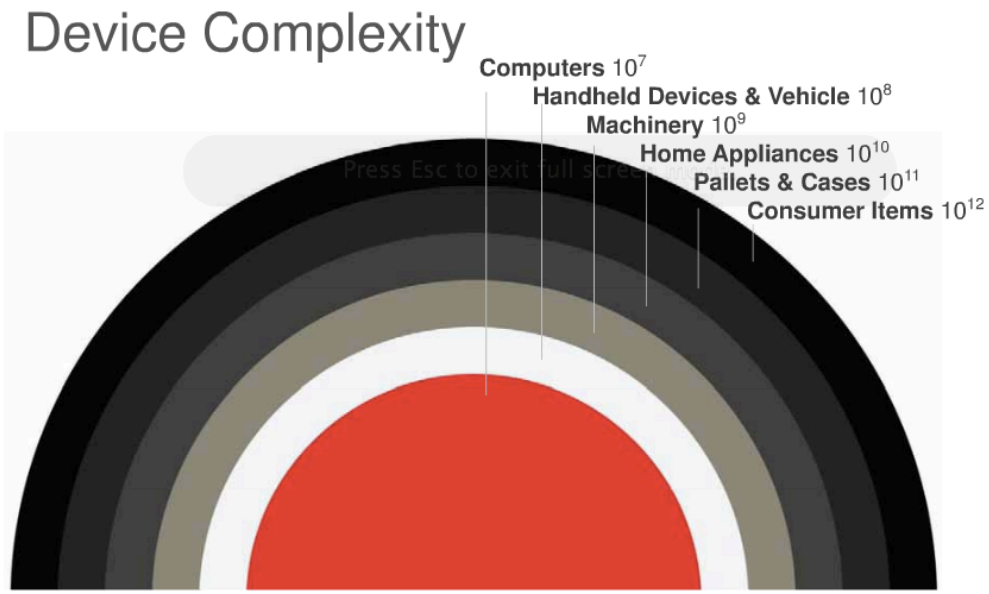
2000

2005

Why mobile and ubiquitous today

- Computers camouflaged as non-computers, i.e. invisible computers
- Mobile and ubiquitous computers are orders of magnitude more than desktops and servers:
  - 8 billion embedded processors
  - 150 million desktops/servers
- Developments are coming from different disciplines:
  - built environment, embedded systems, telephony, automotive, supply chain, security, appliances etc

Device numbers vs. complexity



Example

- BMW 745i
- 2,000,000 LOC
- Windows CE
- 53 8-bit processors
- 11 32-bit processors
- 7 16-bit processors
- Multiple networks

What networks does this car have?

What other networks can you think of?

Mobile Computing

- The application of small, portable, and wireless computing and communication devices
- Being able to use a computing device even when being on the move (and thus changing location)
- Portability is one aspect of mobile computing
  - portable vs. mobile
- Mobile telephony in particular allows you to make and receive voice calls on the move

Mobile Computing Ingredients

- Device
  - laptop, PDA, mobile phone, tablet, smart phone
- Network
  - cellular telephony, data over cellular, wi-fi, Bluetooth, Zigbee, infra-red, 3G, 4G
- System support
  - routing, billing, voice mail, data routing

- In-depth discussion of the issues raised by mobile systems architectures later today

What does ubiquitous mean?

- Dictionary definition:
  - being or seeming to be everywhere at the same time;
  - omnipresent;
  - found in large quantities everywhere;
  - "all over the place."
- Term introduced by Mark Weiser (but others have also described the vision, notably Ken Sakamura)

Smart Planet

ubiquitous computing deeply embedded computing

ambient intelligence B4G mobile Internet of Things

Industrial Internet The sensor-aware planetary computer

pervasive computing

cyber-physical systems wireless sensor networks ubiquitous sensor networks calm computing intelligent environments smart cities sentient computing

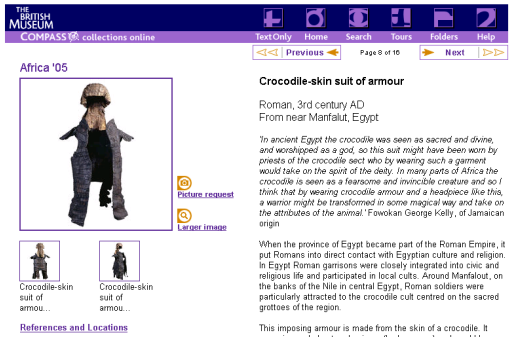
The physical/digital discontinuity

Physical

Physical (real) resources:

- People
- Objects
- Places

Digital



Digital resources:

- Object info and location
- Maps
- Person info
- Activities

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Ubiquitous Computing

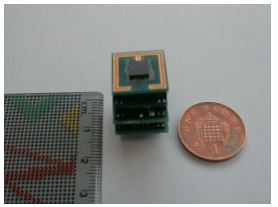
- Ubiquitous computing:
  - activates the world,
  - is invisible, everywhere computing that does not live on a personal device of any sort, but is in the woodwork everywhere,
  - makes a computer so imbedded, so fitting, so natural, that we use it without even thinking about it.
- Also called: pervasive, deeply embedded, 4G mobile or sentient computing, and ambient intelligence.

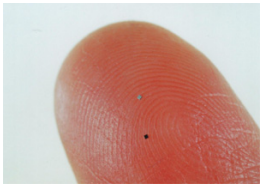
Four Waves - Four Paradigms

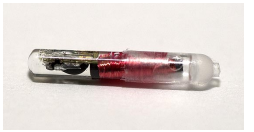
- Mainframe computing (60's-70's)
  - massive computers to execute big data processing applications
  - very few computers in the world
- Desktop computing (80's-90's)
  - one computer at every desk to help in business-related activities
  - computers connected in intranets to a massive global network (internet), all wired
- Mobile computing (90's-00's)
  - a few devices for every person, small enough to carry around
  - devices connected to cellular networks or WLANs
- Ubiquitous computing (now)
  - tens/hundreds of computing devices in every room/person, becoming "invisible" and part of the environment
  - WANs, LANs, PANs – networking in small spaces

Enabling Technologies, Part 1

- Wireless (data) communication
  - higher bandwidth
  - lower power
  - commodity (readily available and secure)
- Small form factor devices
  - shrinking electronics
  - better displays
  - new input methods
- Personalisation
  - Machine learning
  - Inference

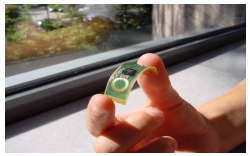






Enabling Technologies, Part 2

- Automatic identification
  - RFID, numbering schemes, network information services
- Sensing and actuation
  - mechanical, chemical, electric, bio
- Context awareness
  - physical: properties of objects
  - Information: data, profile, provider
  - social: identity, situation, role
- Ambient displays
  - public screens, interaction
- Tangible interfaces



Extremely Varied

- Embedding for smart control
  - Embedded systems for cars, airplanes, etc.
- Creating new computing devices
  - Hi-tech, silicon-based gadgetry, e.g. PDAs, cell phones, mp3 players, active displays
- Connecting the existing physical world to a computational infrastructure
  - Ordinary objects and tasks re-evaluated and extended with computational/communication capabilities

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Applications First

- How can we enhance [everyday] activities by connecting them to a computational infrastructure?
- What computational infrastructure do we need?

- Applications are a good way to explore a new paradigm before we have a complete specification of the problems/open questions

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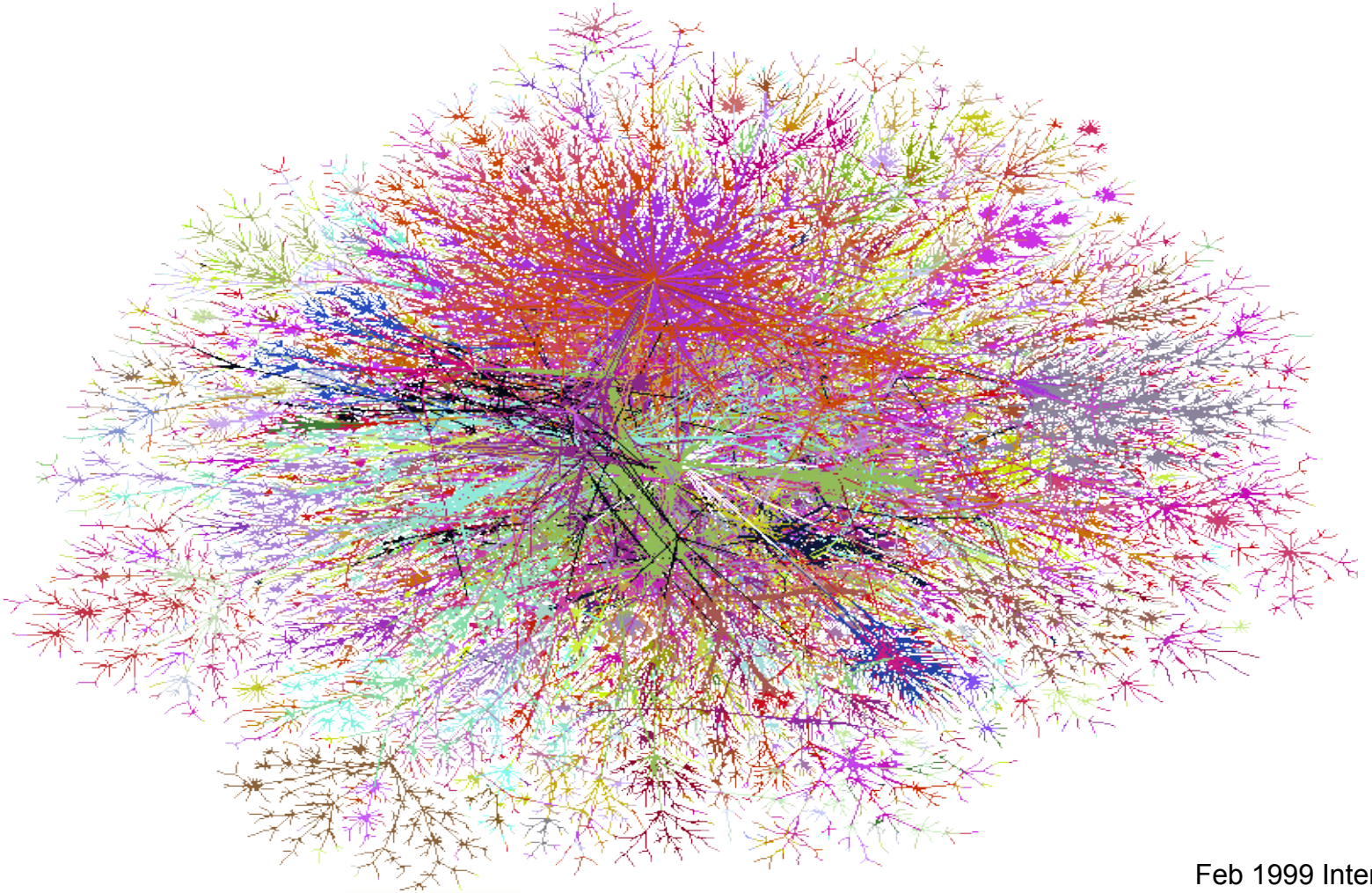
Computer Science and Engineering Issues

- Interaction design
- Security + Privacy + Trust
- Communications and networks
- Operating systems
- Hardware design
- Software design

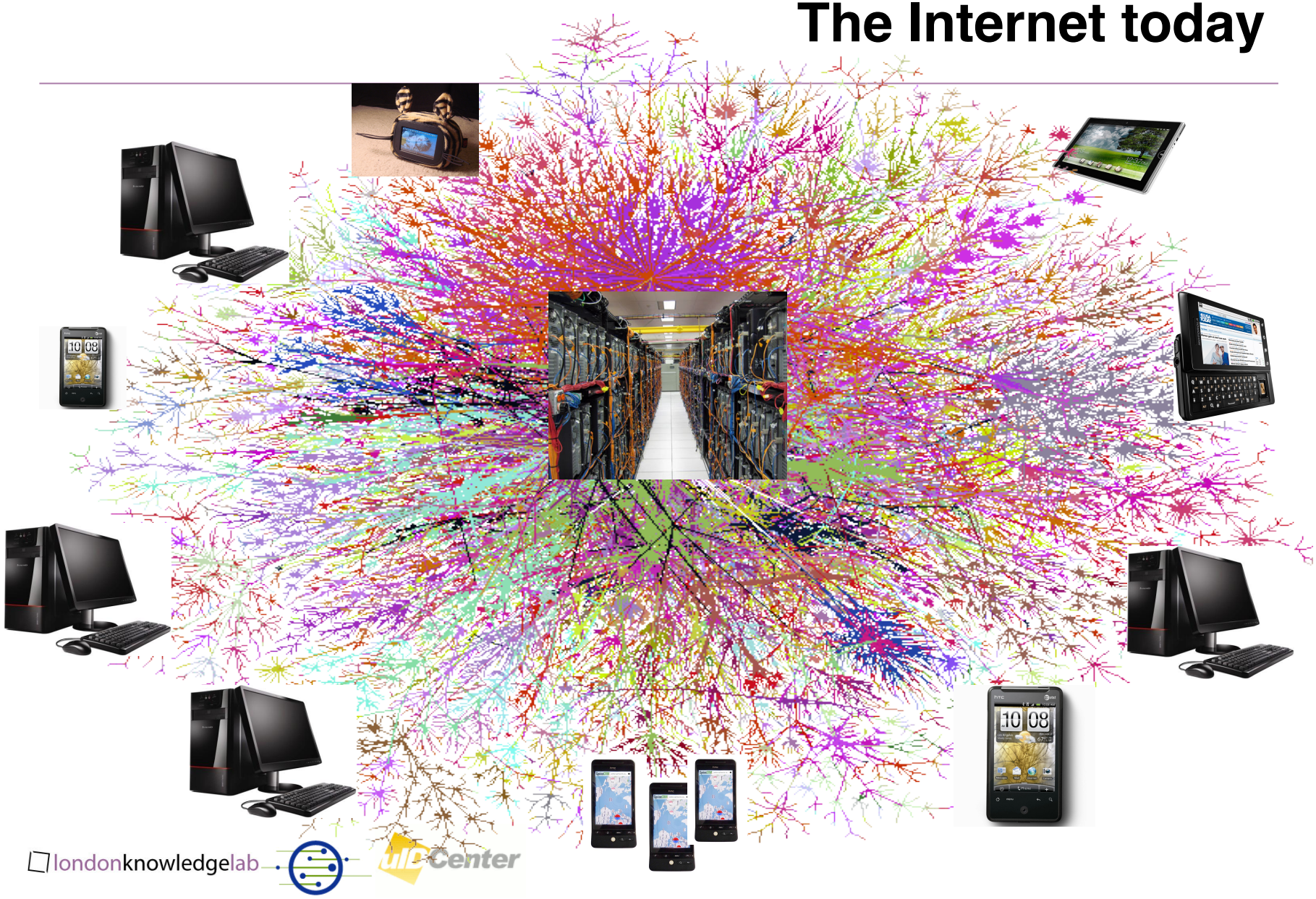
- The whole field! (and more: social science essential)

The Internet (circa 1999)



Feb 1999 Internet map
© H. Burch and B. Cheswick

The Internet today



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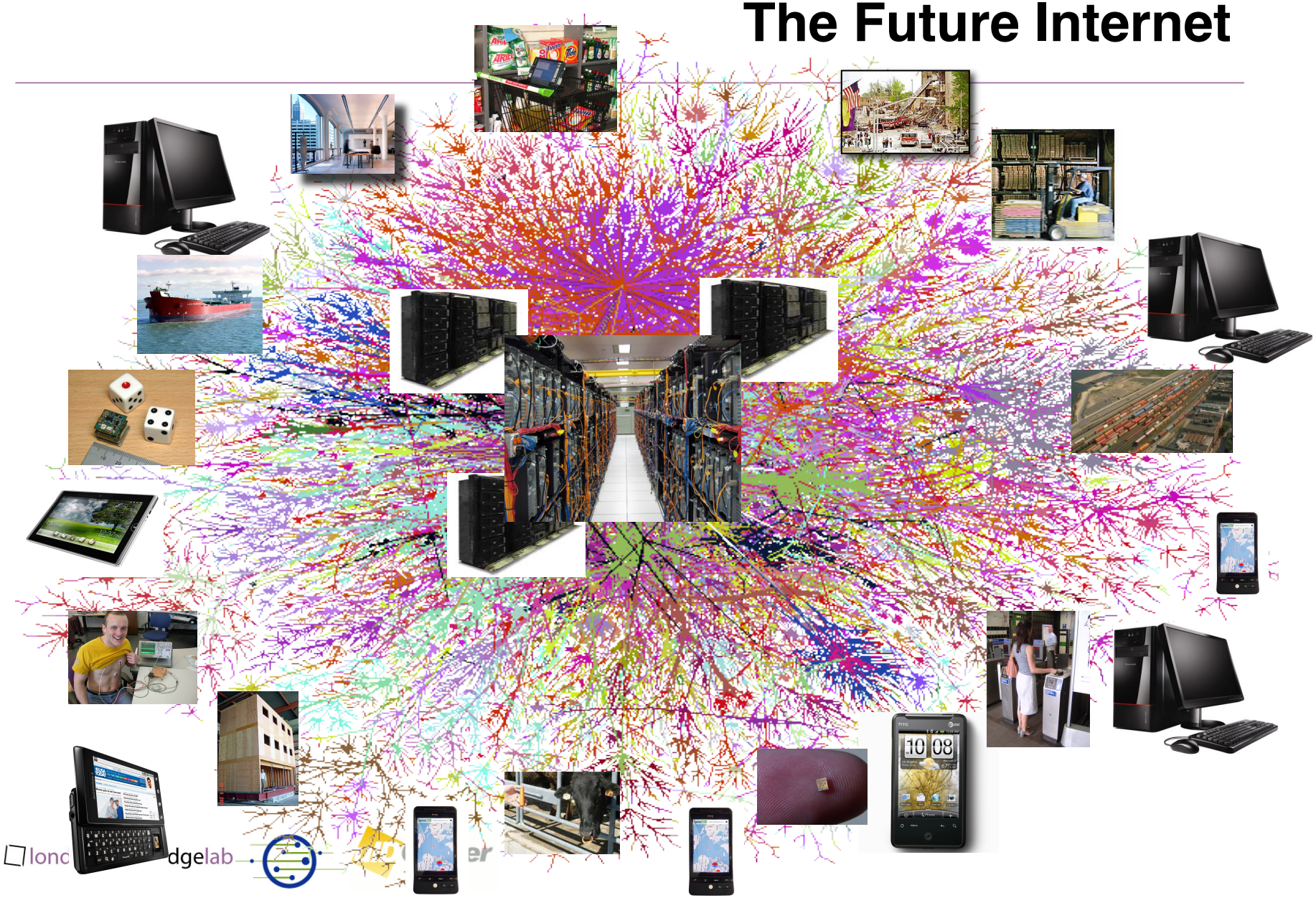
The Future Internet



Today's Internet: *Human-generated data*

Messaging

Email

File sharing

Financial

Social Networking

Video

Blogging

Maps

Weather

News

Sports

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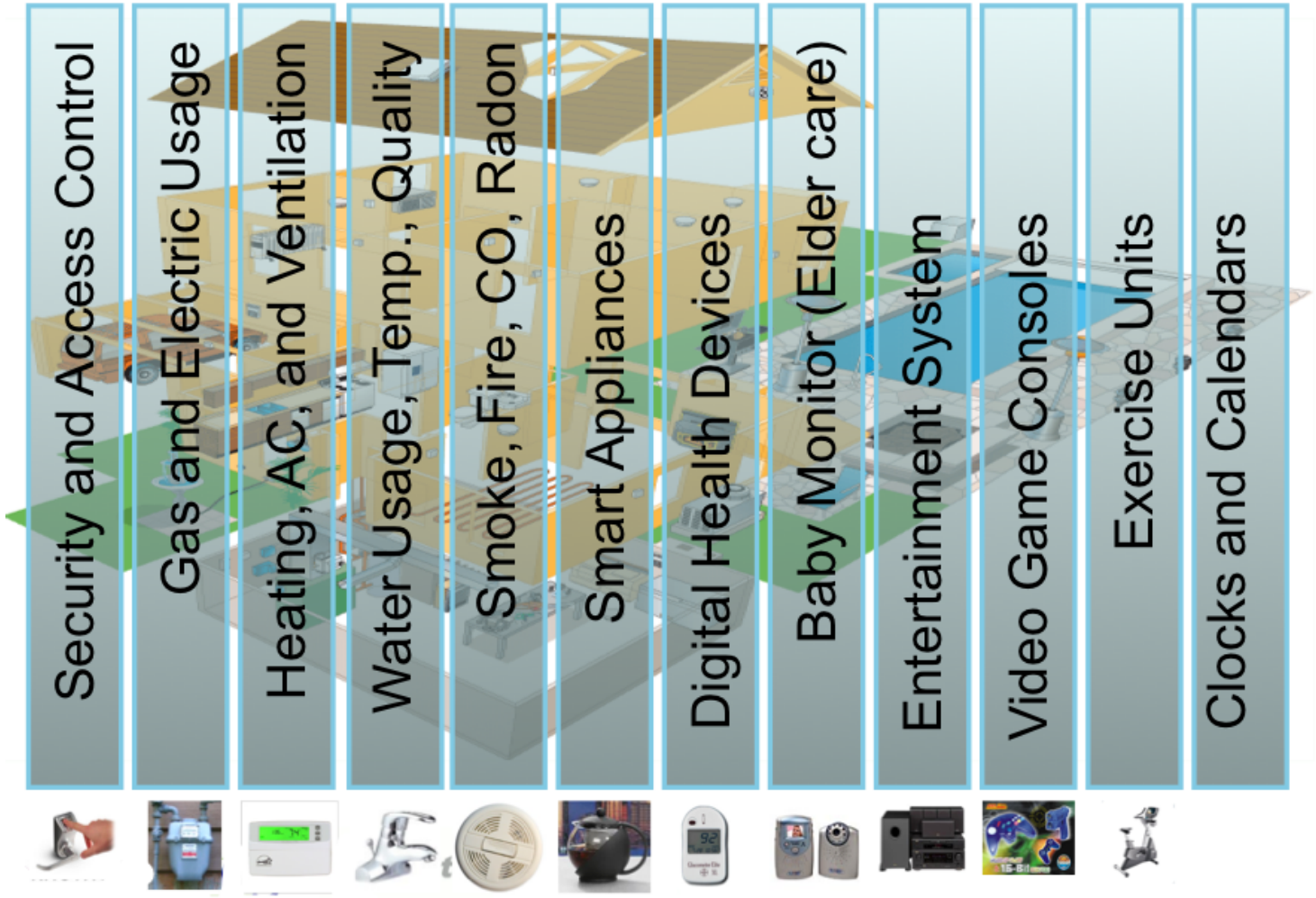
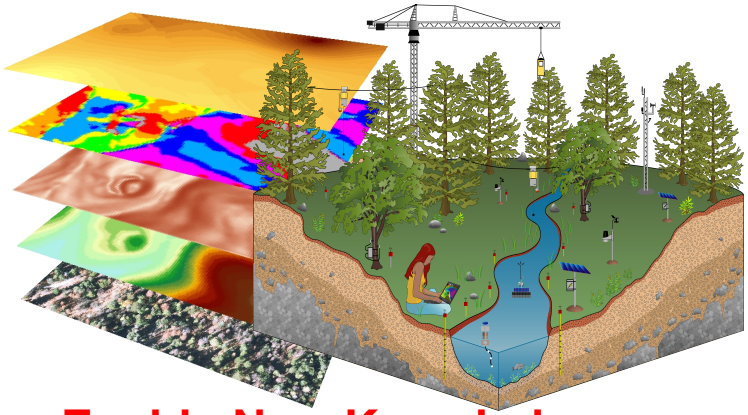
Most Real World Information is lost



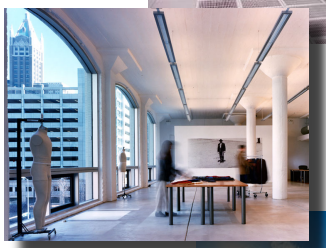
Real-world information is important

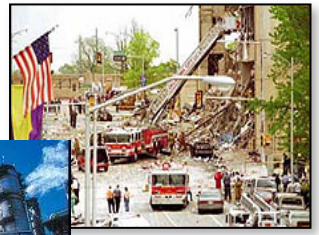


Enable New Knowledge

Save Resources

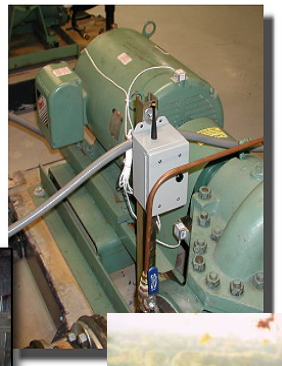
Improve Productivity





Increase Comfort

Preventing Failures



Improve Food & H20

Protect Health

Enhance Safety & Security

High-Confidence Transport

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Interaction Design

- The interface
  - Very small interface
  - Tangible interface
  - No interface
  - Everywhere interface
- Overcoming real-estate shortage
  - new devices, voice / video input (e.g gestures)
  - intelligence
- How to address many systems rather than computers (without going insane)
- Context-awareness

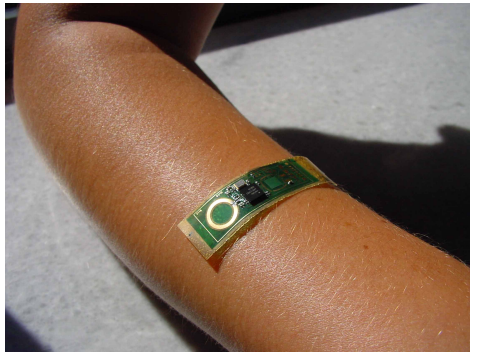
Trust

- wireless systems
- pervasive access points to network
- implementing surveillance
- overcoming surveillance

- control
- trust vs. trustworthiness

Communications & Networking

- home networks, personal area networks, ad-hoc networks, consumer electronics networks, building networks, public access networks
- new media (e.g. sound, chemicals, bio-sensing, feelings)
- new ways of using existing media
- new metrics: bits/s/m^3
- How to leverage all the available networks to provide **global** services (scope, scalability, standardization)



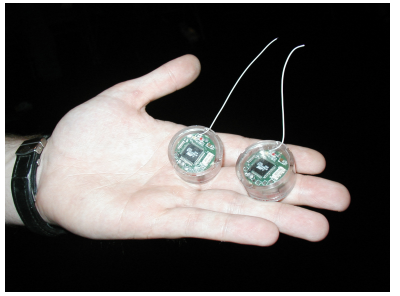
Operating Systems & Middleware

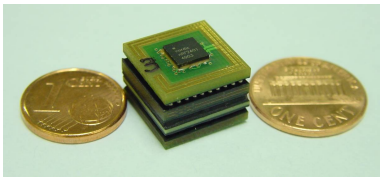
- Resources
  - Limited resources
  - Power-aware, heat dissipation
  - Resource management
- Generic vs. specialized

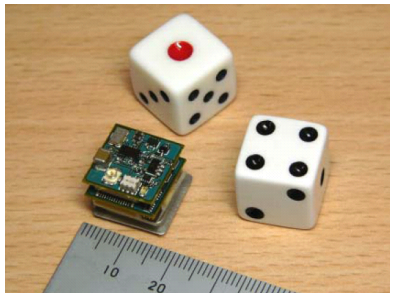
- Dependable (complexity, validation, verification)
- Mobile (time, performance, location, disconnection)
- Real-time DSP

Hardware Design

- Small size, low weight, low power
- May have to be deployed in harsh environments
- Production: extreme cost sensitivity
- Fast product cycles
- New sensing capabilities

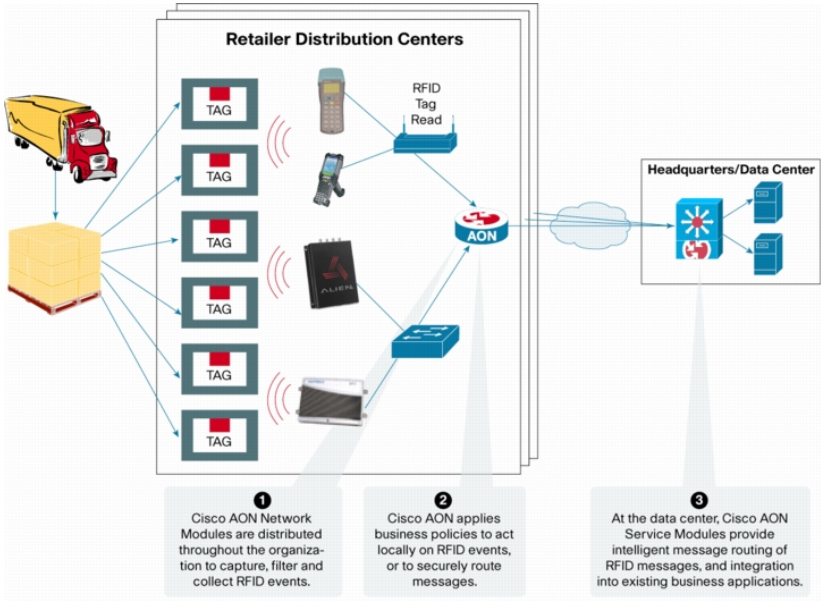






Software Design

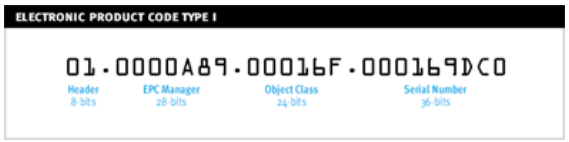
- Must cope with large variation in hardware
- Must cope with rapidly changing requirements
- Programming the system, rather than the devices
- How to partition the code so that it can be easily customized in different environments



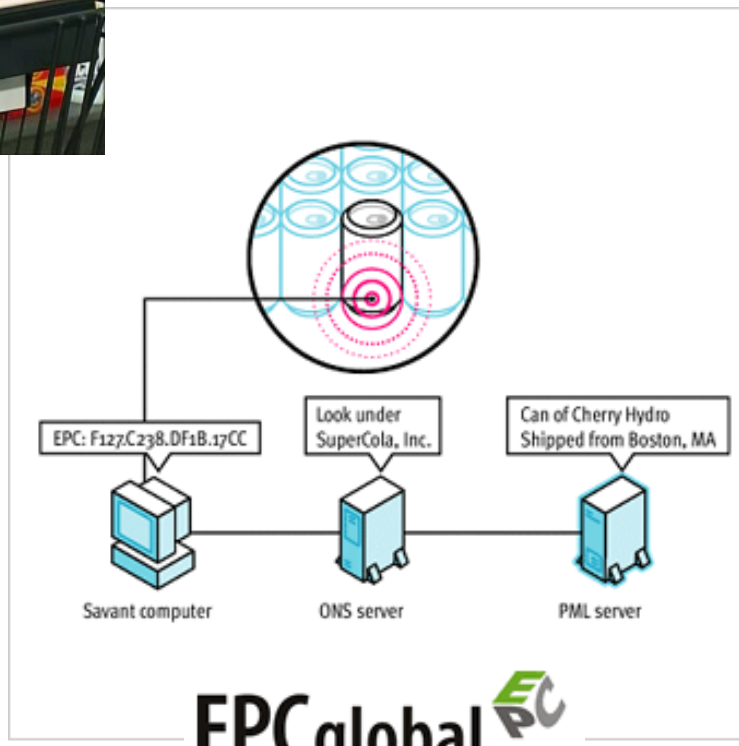
CISCO Application Oriented Networking

- New, hierarchical, multi-context architectures

Auto-Identification



- Middleware for improved RFID reading accuracy
- Caching strategies for ONS performance
- Location tracking using WLAN and RFID data
- Systems architecture for ERP integration

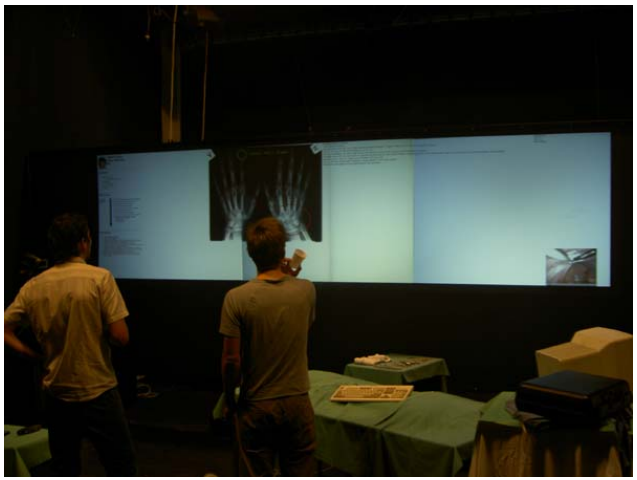


Context-Awareness

- The physical environment: user location, presence of other persons or objects in the same location, and the environmental conditions observed.
- Time — for example, whether a particular person is occupied by professional or personal concerns.
- Device and network characteristics
- Information context is the semantic knowledge regarding the domain being investigated—for example, the short-term information needs of the user as they might be expressed in a query. Information context also includes the user profiles that reveal long-term interests
- Social context

Applications 1

Active Theatre
Aarhus University



•The project focuses on novel ways of using computers before, during and after surgery

•Ambient displays are used to support collaborative work

http://www.pervasive-interaction.org/ActiveTheatre/

Applications 2

Aware Home

Georgia Tech

- Addresses challenges facing the future of domestic technologies
- The Gesture Pendant allows ordinary household devices to be controlled with the wave of a hand

http://www.awarehome.gatech.edu/

Applications 3

Urban Tapestries

Proboscis

•An experimental software platform for knowledge mapping and sharing ie. public authoring

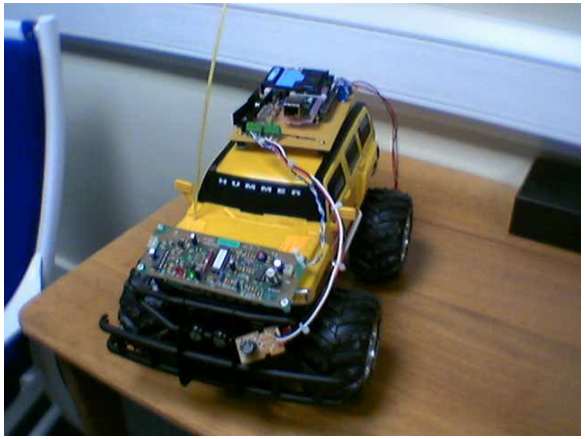
•It combines mobile and internet technologies with geographic information systems to allow people to build relationships between places and to associate stories, information, pictures, sounds and videos with them

http://urbantapestries.net/

Applications 4

Feral Robots v2

Birkbeck and Proboscis

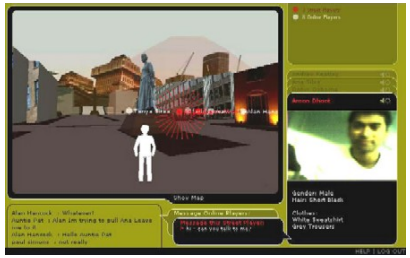


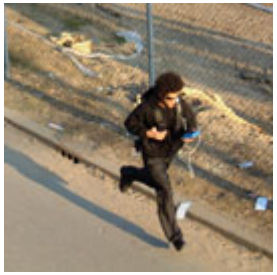
To design and create practical applications from commercially available technologies for social and cultural public benefit such as adapting a remote control toy car into a powerful sensing device for locating and identifying chemical pollution and radiation

http://socialtapestries.net/feralrobots/

Applications 5

Uncle Roy All Around You
Equator





Street Players use handheld computers to search for Uncle Roy, using the map and incoming messages to move through the city. Online Players cruise through a virtual map of the same area, searching for Street Players to help them find a secret destination.

http://www.uncleroyallaroundyou.co.uk/

Applications 6

Great Duck Island Project

UC Berkeley

Very large wireless sensor network deployment on Great Duck Island, Maine, aiming to monitor the microclimates in and around nesting burrows used by the Leach's Storm Petrel

http://www.greatduckisland.net/