Moving off the Desktop: Pervasive Computing

IAT351

Week 7 Lecture 1
27.02.2008

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SCHOOL OF INTERACTIVE ARTS + TECHNOLOGY

Today's agenda

- Introduction, history and definitions
- Devices and environments
- SENSORS

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The Course Project !!

- Your project proposal is due next week
  - Any kind of interaction technology challenge
- Project is a TEAM effort where team = 2 people
- Can be anything we cover in class - but you have to build something
  - Hardware/software/netware
  - Doesn't HAVE to be Java
  - DOES have to be a full-fledged programming environment

The Course Project !!

- Previous examples
  - A smart cooler (turned into a smart fridge project)
  - An RFID-based automatic sushi ordering/billing table
  - A click-wheel text entry system for a (simulated) cell phone
  - A notification "sleeve"

Introduction

- History of Mobile and Ubiquitous Computing
- Terminology e.g.
  - ubiquitous computing
  - pervasive computing
  - mobile computing
  - nomadic computing
  - location-aware computing
  - context-aware computing
  - autonomic computing
  - Invisible computing
- Context

Human-Computer Interaction

- Many existing issues of building user interfaces remain as in traditional systems
- New problems and challenges are introduced by characteristics of small devices:
  - Constraints of display
  - Input constraints
  - Heterogeneous platforms
- Ubiquitous and pervasive computing turn the notion of “interaction” on its ear
- New technologies for input and output are needed, as well as careful internal representation of data

Legal, Social, Ethical and Professional Issues

- Copyright issues
- Security (authentication, non-repudiation)
- Does ubiquitous computing mean ubiquitous surveillance (RFIDs)?
- Using (revealing) context data versus privacy

Definitions (and some history)

- Mobile and nomadic computing
- Location-aware computing
- Context-aware computing
- Ubiquitous or pervasive computing
- Ambient intelligence
- Autonomic computing
- Invisible computing
- Tangibles and Haptics (next week)

Mobile or nomadic computing

- Personal computing anytime, anywhere
  - Mobile = continuous, on the move
  - Nomadic = multiple static locations
- Working away from the desktop, in the places where tasks are actually performed
  - Mobile people
    - Migrating personal environments
    - Migrating applications
  - Mobile devices
    - laptops, PDAs, phones, …

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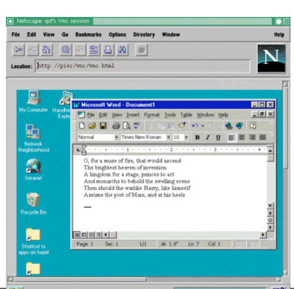
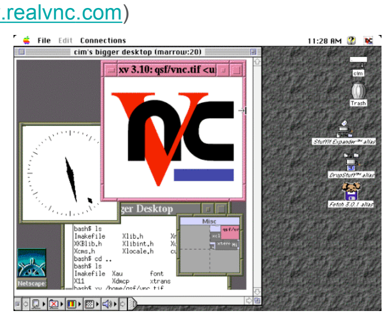
Mobile people

- 'Hot-desking'
  - Mobility within a connected environment
  - Access to 'home' environment from any device
  - 'Thin clients' e.g. VNC (http://www.realvnc.com)





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Mobile devices

- Network
  - Wireless communications
  - Addressing & routing issues
  - Trust, security & privacy
- Hardware:
  - Power management
  - Limited capabilities
- Software / Data
  - Synchronisation / replication
- **Are mobile applications just desktop apps in a smaller box?**

Definitions

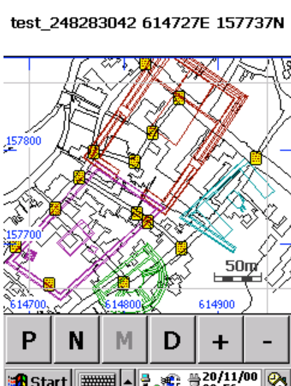
- Mobile and nomadic computing
- Location-aware computing
- Context-aware computing
- Ubiquitous or pervasive computing
- Ambient intelligence
- Autonomic computing
- Invisible computing

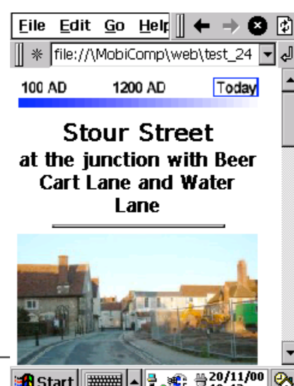
Location awareness

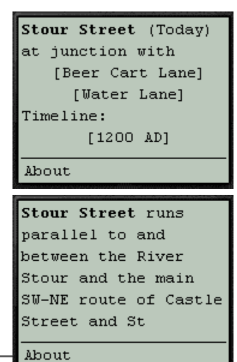
- systems aware of, and respond to, their location
  - Location tracking
  - Access to location-specific resources and information
  - Location-appropriate behaviour
  - http://www.cs.kent.ac.uk/projects/mobicomp/Fieldwork/
  - Socio-ec(h)o SIAT

Location awareness

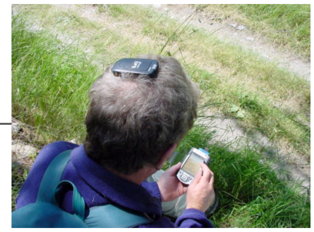
- A Tourist Guide







Location awareness



- Location technologies
  - Outdoors
    - Global Positioning System (GPS)
    - Phone cell methods
  - Indoors
    - Infra-red
    - Ultrasonic
    - Radio
    - Wireless LAN

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Context awareness

- Systems “aware” of, and respond to, their context (situation, environment)

• Physical context
- location
- orientation
- date and time
- temperature
- humidity
- device capabilities

• Logical context
- interests
- work / leisure
- activity
- user preferences

Privacy issues in context awareness

- Who can access your contextual information?
- How and where is context sensed and stored?
  - Infrastructure *vs* Device
  - Centralised *vs* Distributed
  - Public *vs* Private
  - e.g. Active badge *vs* GPS, phone *vs* base-station
- But, potential benefits from shared access
- So, how can we control who accesses our context?

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Ubiquitous or pervasive computing

- Weiser's vision: a 3rd age of computing?

1	Centralised mainframes	1 computer many users
2	Personal computing	1 computer for each user
growth of the Internet, widespread distributed computing		
3	Ubicomp	Many computers per user

- M. Wesier & J. Seely Brown (1997). The Coming Age of Calm Technology. In Denning & Metcalfe (Eds.). *Beyond Calculation: The Next 50 Years of Computing*. Springer-Verlag. http://www.ubiq.com/hypertext/weiser/acmfuture2endnote.htm

Terminology: ubiquity?

- Ubiquitous
  - www.m-w.com: existing or being everywhere at the same time : constantly encountered : widespread
  - omnipresent, allover, universal, constantly available
  - pervasive to the point of subconscious

How to achieve ubiquity?

- Make computing available beyond desktop
- Make it **mobile** and **connected**
- **Instrument** the person
- **Instrument** the physical surroundings
- Traditional computing vs pervasive computing
- Traditional computing: distance from user to subject matter ->∞
- Pervasive computing: distance from user to subject matter ->0

Related areas

- Pervasive computing
- Wearable computing
- Intelligent environments
- Augmented reality

- All will be referred to by umbrella term of Ubiquitous Computing (ubicomp)

Common features of ubicomp applications

- Transparent Interaction
  - Remove physical interface between user and the work to be accomplished via the computer
  - Examples : freeform pen interaction, speech, tangible user interfaces, manipulation interfaces

- Context-Awareness
  - Have information about the environment in which the application operates and react accordingly

- Automated Capture
  - Capture everyday experiences and make record available for later use

Ubicomp 2

- Keywords/phrases from Weiser’s vision:
  - ‘Calm’ technology
  - Disappearing, Invisible
  - Devices in the periphery of our senses
- The computer is *not* the centre of attraction.
  - The best tools are (almost) invisible to their users
  - Human-human and human-computer relationships
  - Hardware and software should merge into "underware"

Ubicomp 3

- Computing devices everywhere
  - On (in?) the person
  - In vehicles
  - In the fabric of buildings
  - In furniture
  - In consumer products
  - …
- Ranging from passive tags to networked information appliances

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Ubicomp 4

- We already have embedded processors and sensors in
  - Domestic appliances
  - Cars
  - Phones
  - …..
- But, mostly, they are not
  - Networked
  - Interoperable
  - Context-aware

The purist view of Ubicomp

Ubicomp is NOT

- Virtual Reality
  - May provide and augmented or augmentable reality
- Multimedia
  - Opposite of invisibility
- HCI, voice input, wearables, Tangible User Interfaces (TUIs)
  - Again, interaction opposes invisibility, calmness
- Intelligent agents
  - Implies a close human-computer relationship
- If there is a distinction, Pervasive is Ubicomp plus these

Ubicomp examples 1

- Dangling string
  - Designed by Natalie Jeremijenko, an artist
  - Small electric motor powered by network activity and attached to a plastic string
  - Visual and audible indication of network traffic

Ubicomp examples 2

- Mediacup
  - Developed at TECO, Karlsrühe
  - Temperature, and movement sensors
  - IR communication with
    - Other cups
    - Coffee machine
    - Infrastructure

http://mediacup.teco.edu/overview/engl/overview.html

Ubicomp examples 3

- Stanford iRoom
  - Meeting support
  - Multiple displays
  - Controlled by
    - Keyboard
    - Wireless mice
    - Handhelds

  http://iwork.stanford.edu/

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- Ambient intelligence/computing
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Ambient intelligence

- Favoured term in EC Framework 5/6 IST research programmes
- Just another name for ubicomp?

- Ambient devices can reason about their environments and the user needs within them

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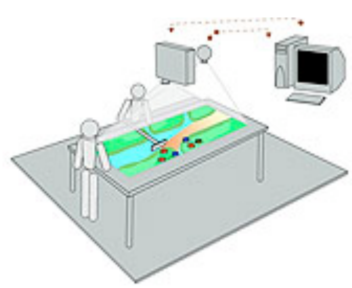
Autonomic computing

- Complex systems are difficult to manage
- A possible solution is to build systems that are:
  - Self-configuring
  - Self-governing
  - Self-protecting
  - Self-repairing…
- Does ubicomp need to be autonomic?
- Can safety-critical systems be autonomic?
- Can we do safety-critical ubicomp?
  - e.g. health care applications

Invisible Computing

- Technological infrastructure
  - Sensors
  - Processing systems
  - Projection systems
  - Displays
  - Interfaces
    - Movement recognition
    - Tangible interfaces
    - Voice
    - Mobile control
    - Augmented reality
    - Wearables



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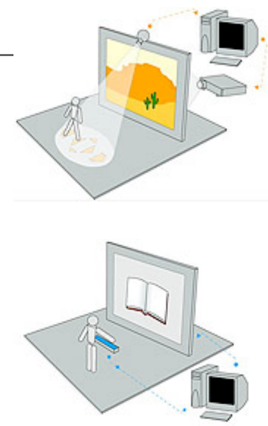
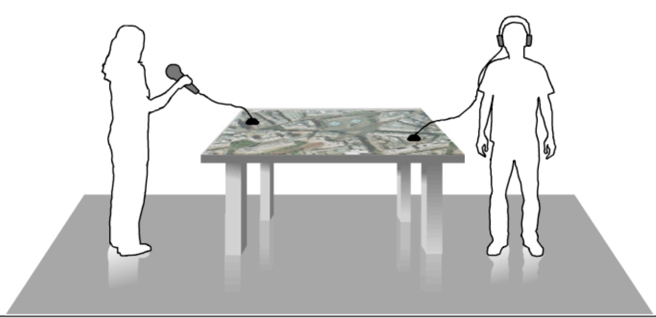
Invisible Computing

- Interfaces
  - Movement recognition



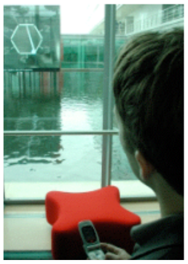
Invisible Computing

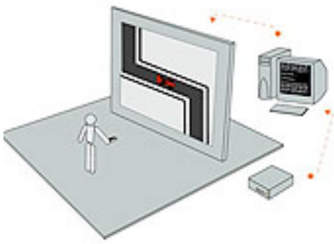
- Interfaces
  - Tangible interfaces and voice



Invisible Computing

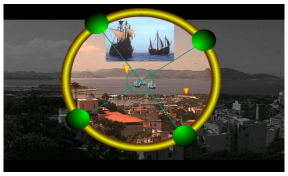
- Interfaces
  - Mobile control





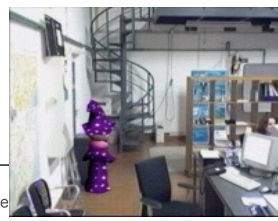
Invisible Computing

- Interfaces: augmented reality
  - Virtual sightseeing
    - Superimposition of text, images and videos on real images using a fixed device



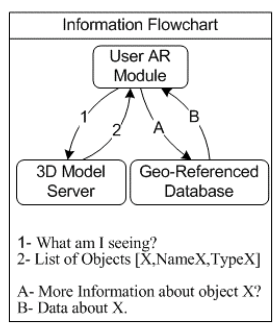
Invisible Computing

- Interfaces: augmented reality
  - Dynamic augmented reality
    - YDreams has developed a technology that enables the insertion and control of virtual elements in a real scene:
      - One can be a virtual actor in a real movie scene
      - One can participate in a car race driving a virtual car against real cars



Invisible Computing

- Interfaces: augmented reality
  - Mobile augmented reality
    - Superimposition of text and images over real images in real time using Head Mounted Displays and PDAs

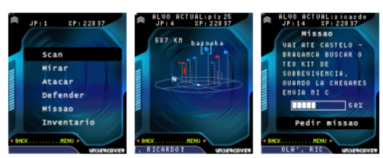


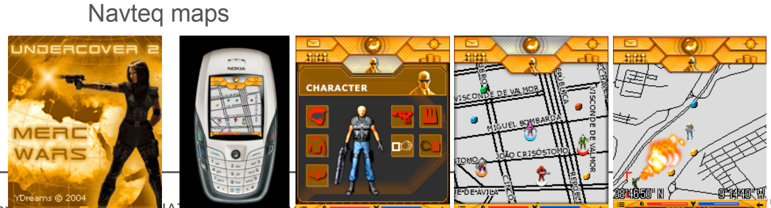
Invisible Computing

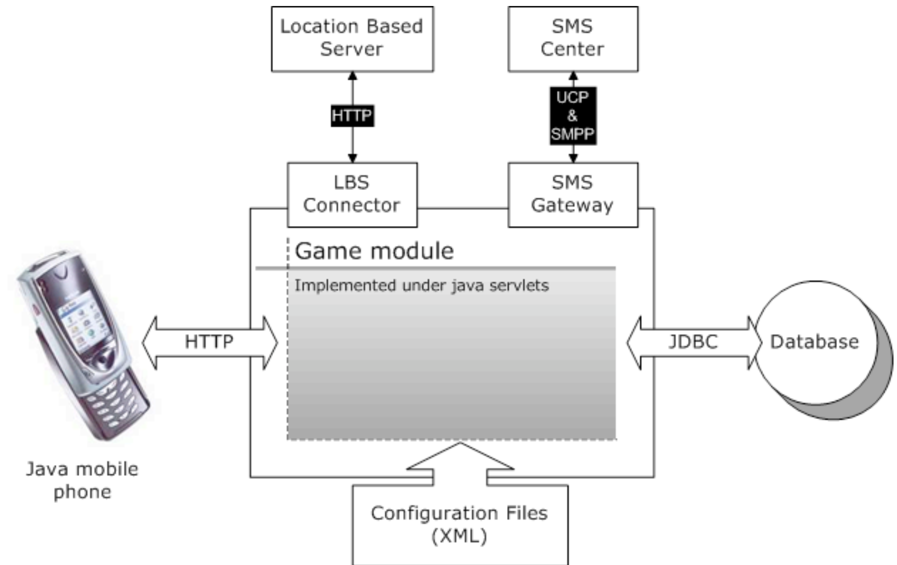
- Interfaces: augmented reality
  - Mobile augmented reality
    - PDA example

Invisible Computing

- Interfaces: wearables
  - Mobile devices
    - Location based gaming
      - Undercover and Undercover 2
      - Multi-player, strategy based games using Navteq maps







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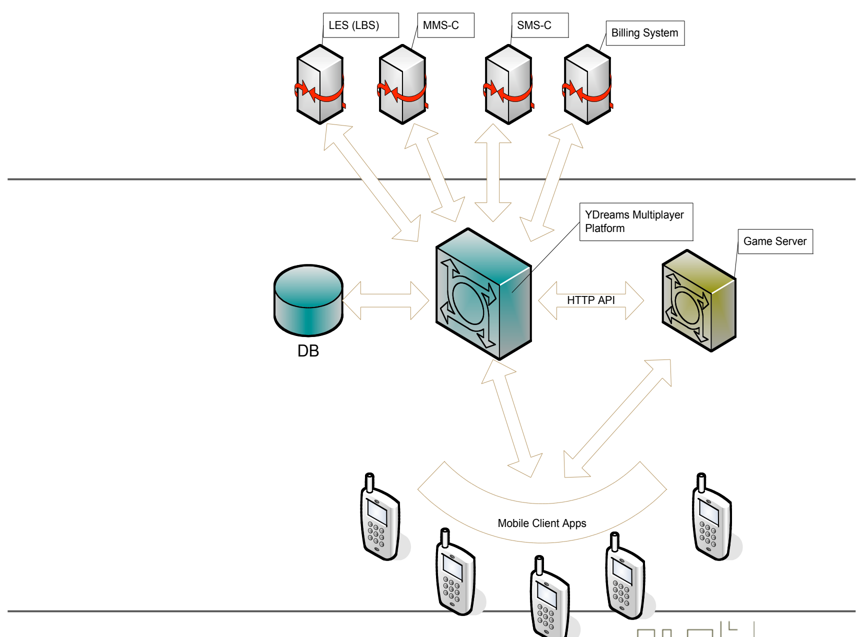

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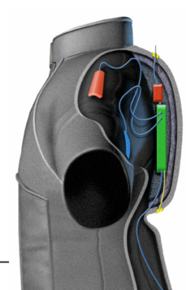
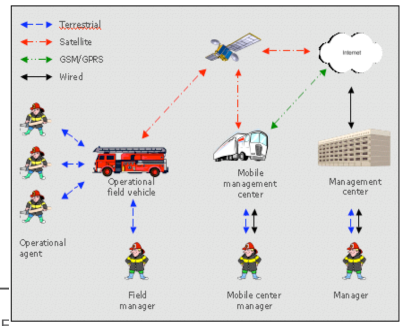
Invisible Computing

- Interfaces: wearables
  - Intelligent garment
    - Positioning, vital and environmental sensors, communication devices and PDAs embedded in garment





Conclusions

- Mobile phones will become scanners of a micro-geographic world where every object will be radio-tagged and sensors will be pervasive
- Human communication will be complemented by human-object communication
- One transition pre-programmed computing may not be digital
- Interfaces will increasingly follow the invisible computing paradigm

Device technologies

- Phones
- PDAs
- Tangibles
- Wearable computers
- Embedded computers
- Sensors
- Etc.

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Programming Small Devices

- Characterising small devices : PDAs, phones and smart-cards.
- Java Micro Edition (JavaME) and its configurations, profiles and optional packages.
- Building GUIs, communicating and storing data for JavaME CLDC/MIDP.
- JavaCard – programming for really small devices
- Sun Spots – small, autonomous, radio-enabled Java devices

Enabling Communication Technologies

- Communication technologies
  - Wireless networks
    - Satellite
    - Telephony
      - Mobile Phone Networking (GSM, GPRS, 3G)
    - Local wireless networks
      - WiFi (IEEE 802.11)
        - » Free(-ish) building-scale networks for larger devices
        - » ZigBee
    - Personal networks
      - Bluetooth
  - Wired networks
    - What role might these play?

Communication architectures

- Client-server
  - Jini
    - Java-based architecture for flexible networks; service-oriented
- Peer-to-peer
  - UPnP (universal plug-and-play)
    - Internet (standard)-based peer-to-peer network architecture

PDAs (Personal Digital Assistants)

- A screen, a stylus, sometimes a keyboard.
- ARM has cornered the processor market.
- Microsoft, Palm (and Symbian) are fighting in the Operating Systems market.
- All have intermittent connectivity (mostly for synchronisation), most have IrDA. Bluetooth is common, as is WiFi.
- Battery life improving, but remains a significant issue, especially with WiFi and back-lit colour screens.

Cellphones

- Increasingly converging with PDAs
- Probably the most common general-purpose computers in the world – selling over 600 million units a year to 1.5 billion users. (around 200 million PCs sold annually)
- Increasingly including Java virtual machines
  - Cut-down version of Java
  - “Over the air” installation of applications
  - Gives network and application providers platform independence.

iButtons

- A processor-in-a-tin, with a 1-wire (power and data together) interface.
- Costs $2-$100, depending on functionality.
- The simplest versions just report their ID, or contents of their NVRAM/EPROM (1-64kb), or implement the SHA1 Challenge-response algorithm.
- More complex iButtons include
  - Temperature and humidity loggers
  - A Java Card JVM.

Java Smart Cards

- Typically 1K RAM, 16K EEPROM/Flash, 32K ROM.
- Contain an (even more) cut down version of the Java Virtual Machine: no floating point, very little `java.lang`, loads of crypto.
- Service providers can download applications and run them on the card.
- Content security provided by the standard Java mechanisms.

RFID

- RFID technologies use radio waves, to automatically identify people or objects
- RFID systems are already in place, or soon to be installed
  - many retailers are contemplating putting tracking chips on merchandise
  - U.S. Food and Drug Administration recently decided to let hospitals inject into patients RFID chips storing medical data
- There are many issues that still need to be addressed

Radio Frequency ID Tags (RFIDs)

- Derive power from the incoming (reader) radio signal.
- Broadcast data (typically <1 kilobit) back to reader.
- Read/write versions can contain decrementing counters as well as product codes and serial numbers.
- Readers can detect multiple tags (~200) simultaneously.
- Many different packages – smart cards to nails.
- Three different families – different frequencies, ranges, applications.
- Tag cost (currently ~$0.50 and falling) is high for low-value goods

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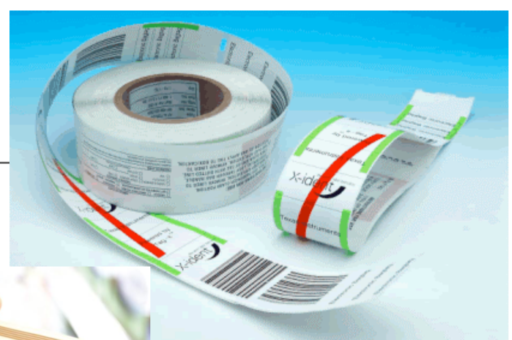
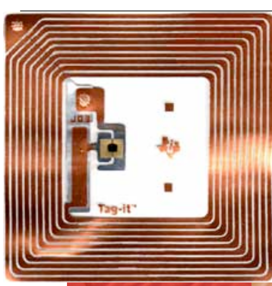
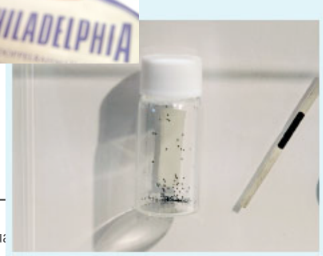
RFID tags







The black specks in the bottle are ultra-miniature RFID chips

Sensors

- Monitor state of objects/environments.
  - Temperature
  - Humidity
  - Light level
  - Location
  - Velocity
  - Orientation
- Wired or wireless
- Fixed or mobile
- Dumb or smart

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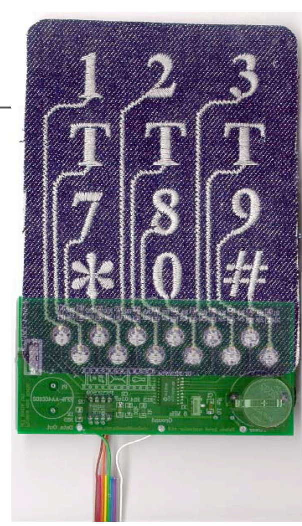
Smart Fabric

- Conductive fibres woven into normal fabric can sense contact, motion, temperature etc. as well as carrying (or generating?) power and data.
- Applications in security and environmental monitoring.
- The Blue Pants of Death?



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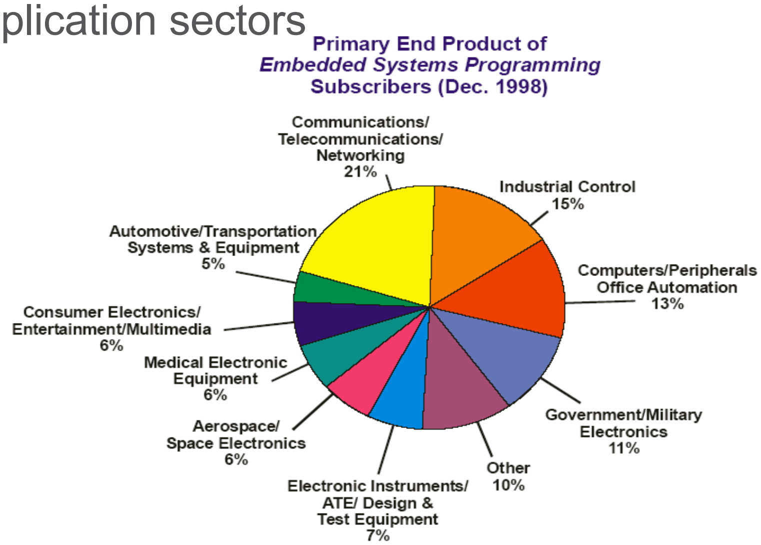
Source: http://web.media.mit.edu/~rehmi/fabric/

Embedded systems

- Use of computers for automation and process control
  - Automated warehouse
  - Production lines
  - Nuclear Plants
  - Robots, flight controllers, lifts
  - Cars, bikes, washing machines, DVDs etc
  - Security systems
- Often real time
- Often safety critical
- Linked to physical sensors, transducers and actuators
- Use small microcontrollers

Application sectors



Embedded systems example

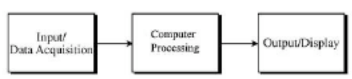
- 4 main Microcontrollers – Rider Info Display, ABS, Start, fuel injection
- All linked to several physical transducers and actuators
- All are real time, continuous but independent
- If throttle bodies not synchronised correctly fuel injection controller causes surging at around 4000 rpm

Maintenance is essential

And so is management (think about securing the IR codes)

A key technology:
the sensor

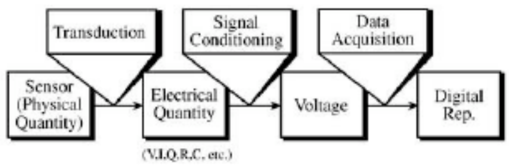
Generally …



- Data / input acquisition: the data may be temperature, light, humidity, displacement, or other physical parameter.
- The output signal from most sensors is not suitable for immediate display. Rather, some form of signal processing/amplification is usually needed.
- Finally, for the data to be utilized as useful information, there must be a display, data storage or control function.

Input (data acquisition)

- How information from the human/environment is passed to the "computer"



So exactly what are sensors?

- A **sensor** is a device which converts a physical phenomena into an electrical signal.
- Sensors represent part of the interface between the physical world and the world of electrical devices, such as computers.
- (the other part of this interface is represented by **actuators**, which convert electrical signals into physical phenomena).

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Choosing the right sensor

- Decide first what parameters of the external
- environment are important for our application
- (e.g.: temperature, humidity, pressure, light, etc).
- Determine what kind of sensor is optimal for
- measuring that parameter.

Types of sensors

Sensors can be categorized in many ways:

- by the underlying physics of their operation
- by the particular phenomenon they measure
- by a particular application

Types of sensors

- Analog: output is continuous, output is function of input.
  - Requires ADC for interfacing to computer
- Digital: the output is in form of digital signal
  - Active: need separate power source to obtain the output
  - Passive: these are self-generating, produce electrical signal when subjected to sensed quantity (piezoelectric, thermoelectric, radioactive, etc).

Quality parameters

- Transfer function
- the functional relationship between physical input signal and electrical output signal
- for expensive sensors which are individually calibrated, this might take the form of the *certified calibration curve*

Quality parameters

- Sensitivity

- is defined in terms of the relationship between input physical signal and output electrical signal
- the sensitivity is generally the ratio between a small change in electrical signal to a small change in physical signal.
- Example: a thermometer would have "high sensitivity" if a small temperature change resulted in a large voltage change.

Quality parameters

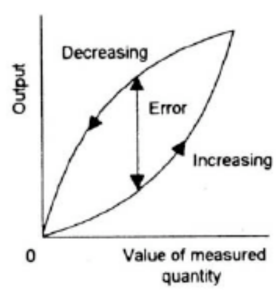
- Accuracy
  - a measure of difference between the measured value and actual value. Generally defined as percentage of actual value.
- Precision
  - the ability of an instrument to reproduce a certain set of readings within a given deviation.
- Repeatability
  - the ability to reproduce the output signal exactly when the same measured quantity is applied repeatedly under the same environmental conditions.

Quality parameters

- Range & span :
  - the limits between which inputs can vary. Span is maximum value minus the minimum value of the input.
- Stability (drift):
  - the ability to give same output when a constant input is measured over a period of time.
  - **Drift** is expressed as percentage of full range output.
- Dead band : is the range of input values for which there is no output.

Quality parameters

- Hysteresis:
  - Different output for increasing and decreasing value of input



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Quality parameters

- **Noise**

- All sensors produce some output noise in addition to the output signal. In some cases, the noise of the sensor is less than the noise of the next element in the circuit, or less than the fluctuations in the physical signal, in which case it is not important.

- **Many other cases exist in which the noise of the sensor limits the performance of the system based on the sensor.**

Quality parameters

- **Resolution**:
- The resolution of a sensor is defined as the minimum detectable signal fluctuation.

- Since fluctuations are temporal phenomena, there is some relationship between the timescale for the fluctuation and the minimum detectable amplitude.

- The definition of resolution must include some information about the nature of the measurement being carried out.

Quality parameters

- **Bandwidth**

- All sensors have finite response times to an instantaneous change in physical signal.
- In addition, many sensors have decay times, which would represent the time after a step change in physical signal for the sensor output to decay to its original value.
- The reciprocal of these times correspond to the upper and lower cutoff frequencies, respectively.
- The bandwidth of a sensor is the frequency range between these two frequencies.

Sources of sensor error

- **Sensors are inherently error-prone!**

- Error = the difference between the measured value and the true value.
- Types of errors:
  - Insertion errors
  - Application errors
  - Characteristic errors
  - Dynamic errors
  - Environmental errors

Sensor output

- Sensor output is generally in the form of resistance change or voltage change or capacitance change or current change when input quantity is changed.
- An appropriate circuit is required to measure the above changes.
- Pressure (piezoelectric)
  - force, flexure, acceleration, heat and acoustic vibrations
- Force sensing
  - Acceleration/deceleration (accelerometer)
- Temperature sensing
- Light sensing

Piezoelectric sensors

- Turns a mechanical pressure into an electrical charge
- The piezoelectric effect can measure **force, flexure, acceleration, heat**, and **acoustic vibrations**.
- Piezoelectric transducers find use both as speakers (voltage to mechanical) and microphones (mechanical to electrical).

SCHOOL OF INTERACTIVE ARTS + TECHNOLOGY

Force sensing resistors

- Force sensing resistors use the electrical property of resistance to measure the force (or pressure) applied to a sensor.

- Most common uses are in :
  - Force sensors (haptics, force feedback)
  - **accelerometers**

Force and pressure sensors

- Force and pressure are related concepts
  - Force F: vector quantity (it has both magnitude and direction of application).
- Basic methods to sense force:
- **Acceleration** methods: measure the acceleration of a known mass on which the unknown force operates.
  - Accelerometer
- **Gravity-balance** methods: compare the unknown force with the action of the gravitational force on a known Mass
  - gravitometer
- **Pressure-sensing methods**: convert the force to a fluid pressure, which is measured using a pressure transducer

Temperature sensing

- Several different sensors are commonly used to measure temperature:
- thermal resistors (RTDs and thermistors)
- thermocouples

Thermal resistors

- Electrically conductive elements that are designed to change electrical resistance in a predictable manner with changes in applied temperature.
  - **Resistance temperature devices (RTDs**) - based on the tendency of materials (naturally occurring materials) to change physical dimensions with changes in temperature.
  - **Thermistors** – made from a human-made substance, called semiconductor. Have a negative temperature coefficient (semiconductor's resistance decreases with an increase in temperature).

Thermocouples

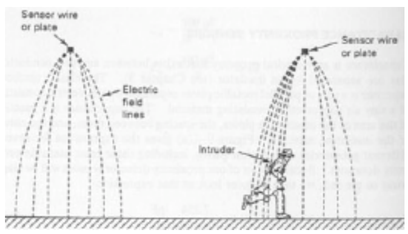
- Most popular temperature sensor
- Junction between 2 metals generates a voltage that is a function of temperature
- Standard metals are used with predictable output voltages and large temperature gradients

Light sensing

- Light = a form of electromagnetic radiation
- Light detectors essentially may be broken into two categories:
- **Quantum detectors** - convert incoming radiation directly into an electron in a semiconductor device, and process the resulting current with electronic circuitry.
  - Best performance
- **Thermal detectors** - simply absorb the energy and operate by measuring the change in temperature with a thermometer.
  - Perform in many more conditions in which quantum deetectors don't function

Proximity and Presence Sensors

- Proximity sensors are used for sensing the closeness of objects.
- Their range varies with the type of sensor, its sensitivity and the material being sensed.
- There are three basic types of proximity sensors: inductive, capacitive and ultrasonic.



Sensors are ubiquitous

Research is driving them to get:

- Smarter
  - Monitor more phenomena
  - Process information "on-board"
  - Self-power or reduced power
- Smaller
  - Decreased installation space (for sensor and power and network) means that sensors are installed in inaccessible places
  - Miniature sensors designed for high precision sensing