Ubiquitous Computing/Tangible Interaction

Don Platt
dplatt@fit.edu
Outline

• Evolution of computing beyond the desktop
• Invisible computers
• From paper to electronic...
• Intent recognition
• Context-aware systems
• RFIDs
• Privacy, trust, ethics...
• Physicality of tangible interaction
What’s the main idea?

• In mainframe computing,
  – many people share one computer
• In desktop computing,
  – one person, one computer
• In ubiquitous computing,
  – many computers serve each person
Major trends in computing...

(Weiser, 1996)

http://www.ubiq.com/hypertext/weiser/NomadicInteractive/sld003.htm
History

• Ubiquitous Computing
  – Mark Weiser first mentions the term in ’88
  – Builds on his earlier research on human-computer interaction
  – Influenced by Xerox PARC’s work in networking and history of envisioning future environments
  – Influenced by late 80s critique of traditional HCI (see CSCW lecture)
  – Influenced by advances in graphical user interface research

• A field with a strong vision, from the beginning:
  – ‘a new way of thinking about computers in the world, one that takes into account the natural human environment’
  – ‘vanish into the background’
  – ‘themselves into the fabric of everyday life until they are indistinguishable from it’
Beyond the desktop...

• Technology view
  – Computers are embedded everywhere in the environment, designed to sense users’ presence and act accordingly
  – Mobile computers (mobile phones, PDAs, Tablets, etc.) are designed to interact both with the user and with this ‘digital environment’
  – Blend of intelligent environments, context awareness, mobile computing, networking, information appliances, etc

• Human view
  – Invisible, computing blends into the background
  – Augmenting human abilities

• Ubiquitous Computing poses a number of important issues
  – Social issues
  – Personal issues
  – Privacy issues
  – Environmental issues

• ...that we won’t deal with today
How to achieve ubiquity?

• This is about embedded systems (YouTube)
• Computers are embedded everywhere in the environment
• Appliances
• Information access and communication possible everywhere
• Devices can be connected and networked
Ubiquitous

- Existing and being everywhere at the same time
  - Constantly encountered
  - Widespread
- Omnipresent, allover, universal, constantly available
- Pervasive to the point of subconscious

Disappearing Computer
Ubiquitous computing in computer science

• Four key motivators (Langheinrich, 2001)
  – Ubiquity: The infrastructure will be everywhere consequently affecting every aspect of life.
  – Invisibility: The infrastructure will be cognitively or physically invisible to the user – the user will have no idea when or where they are using the computer.
  – Sensing: Input to the ever-present invisible computer will be everything we do or say, rather than everything we type.

• Memory amplification: Every aspect of these interactions, no matter how personal, has the potential to be stored, queried and replayed.

Disappearing Computer → Privacy, Trust and Security Issues

Marc Langeheinrich, Privacy by Design – Principles of Privacy Aware Ubiquitous Systems, in UBICOMP 2001, LNCS 2201, pp 273 291
How to achieve ubiquity?

• Make computing mobile and connected
• Instrument the person
• Instrument the physical surroundings
Ubiquitous computing (ubicomp)

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

• Pervasive computing environment
  – An environment saturated with computing and communication capability, yet so gracefully integrated with users that it becomes a “technology that disappears”

• Subsumes distributed computing and mobile computing
Enabling technologies

• Processing
  – Cheaper, faster, smaller, more energy efficient

• Storage
  – Big and fast

• Networking
  – Global, local, ad-hoc, low power, high bandwidth, low latency

• Displays
  – Projection, flexible material, low power

• Sensors
  – Types, speed, accuracy, price, robustness

• Actuators
  – Computer controlled
Appliance computing

• Dedicated devices
  – Mobile phones, digital camera, VCR, PDA

• Multi-modal input
  – GUIs, speech, pen, touch screen

• Zero maintenance
  – Pre-configured, rare failures
What is the difference?
Paul Dourish on Computer Science

- Spectacularly successful engineering discipline
- Also a philosophical enterprise
  - world representation
  - models of reality, people, and action
- A philosophical approach of HCI
- “Embodied interaction”
  - HCI that emphasizes skilled, engaged practice rather than disembodied rationality
  - Reflects phenomenological approaches of Martin Heidegger, Ludwig Wittgenstein, and other twentieth-century philosophers
The phenomenological tradition

- Primacy of natural practice over abstract cognition in everyday activity
- Dourish shows how this perspective can shed light on the foundational underpinnings of current research on embodied interaction
- Dourish looks in particular at how tangible and social approaches to interaction are related, how they can be used to analyze and understand embodied interaction, and how they could affect the design of future interactive systems
From paper to electronic...

• An example in aeronautics
• The onboard operational documentation program at EURISCO
• Contributed to current onboard information system in the A380
<table>
<thead>
<tr>
<th>Classic Cockpit Generation</th>
<th>Glass Cockpit Generation</th>
<th>A380 Generation</th>
<th>Future Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed Indicator</td>
<td>Horizontal Situation Indicator</td>
<td>Flaps/Gear Limitation Performance Table</td>
<td>Flaps/Gear Limitations Performance Table</td>
</tr>
<tr>
<td>DIGITALISATION</td>
<td></td>
<td>Continuous availability of dynamic information anytime, anywhere</td>
<td></td>
</tr>
<tr>
<td>Amount of relevant information &gt; Display possibilities</td>
<td>What strategy for information management in the aviation domain ? (choice &amp; priority)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Flaps/Gear Limitations
- Performance Table
- Operational Documentation
La galaxie spirale NGC4414 située à 60 millions d’années lumière de la nôtre.

Electronic Operational Documentation possibilities:
Interactivity, multi-modality, contextualisation, integration with operational systems, integration with training material and systems, new hardware devices and ubiquitous computing.
<table>
<thead>
<tr>
<th>WHEN</th>
<th>WHAT</th>
<th>Definition</th>
<th>Deliverables</th>
</tr>
</thead>
</table>
| 1995-1997| DGAC - SFACT | Service de la Formation Aéronautique et du Contrôle Technique | • Study of procedures & checklists  
• ECAM & Operational documentation axis of improvements |
| 1997-1999| INFO         | Information Need for Flight Operations                                      | • Three Layers of information definition |
| 2000-2001| ArtiFACT     | Articulation between FCOM And Courseware/Training                          | • Study of communality between operational documentation and training documentation |
| 2002-2003| ArtiFACT II  | ArtiFACT phase II and Thesaurus project                                     | • Definition of categories of contextualisation  
• Contextualisation implementation guidelines for authors |
| 2004-2007| CRIIST@L     | Contextualised & Integrated Information System: Training @ Learning         | • Optimisation of operational documentation training strategy study  
• Study of the integration of operational documentation in operational use |
Example Scenario

• Paul is at Gate 25 of an airport and would like to email his edited files through wireless connection, but the bandwidth is miserable
• Genius, the pervasive computing environment, detects the situation, consults airport servers, and finds Gate 52 will have no flight in 1.5 hour
• Genius suggest Paul to go to Gate 52 and prioritize his email
• Paul accepts the suggestion
• Files are transmitted at Gate 52 and Genius informs Paul when he needs to be back to Gate 25
Example Scenario

- Helen has to walk to a meeting from her office to give a presentation, but she is not quite ready yet
- Helen grabs a handheld computer and starts walking to the meeting
- Genius transfers her state from desktop to handheld, and Helen does final editing with voice
- Genius infers Helen’s schedule, downloads materials to projection computer and warms up projector
- Room’s face detection system recognizes some unfamiliar faces and advises Helen not to show sensitive data
Key points

• Scenario 1
  – Pro-activity: Genius can estimate how long the whole process and look ahead on his behalf
  – Combining knowledge from different layers: wireless congestion and boarding time
  – Smart space: provide information of wireless bandwidth, flight time and gates, distance between gates

• Scenario 2
  – Moving execution state across diverse platforms
  – Automatic adjusting behavior to fit circumstances: voice input
  – Pro-activity and smart space
The Model

• Each user is immersed in a personal computing space that mediates all interactions with the pervasive computing elements in surroundings

• Design aspects
  – System design: Wearable computer? Personal assistant? What sensors and networking?
  – Context awareness: how to know user’s state and surrounding, and modify behavior?
  – How to cooperate and interact with infrastructure? With other persons?
  – How to roam and adapt? Reconfigurable?
    • PDA with 802.11b, Java
Smart Object Environment

• Provide services
  – System design: Which embedded system? Web sever? Sensors and actuators?
  – Naming, registration, discovery
  – Physical/virtual mapping
  – Mobility management, energy management
  – Service composition, I/O matching, adaptation, environment monitoring
Infrastructure Support

• Infrastructure in real life
  – e.g., electricity, roads, ...
  – Just there or even invisible, open platform

• Internet infrastructure
  – Domain name service (DNS registry)
  – Services: cooperating routers, time servers
  – Web standards

• Extend the Internet to everyday objects
Infrastructure for Smart Objects

• Guarantee
  – Security, privacy, availability, reliability

• Provide services
  – Location (Where am I?)
  – Context (Are we in a meeting?)
  – Event delivery (Tell me when... happens)
  – Brokering (Find something that ...)
  – Directory, discovery, registry
  – Mobility, roaming ...
User Intent

• A pervasive computing system must track user intent
  – Determine which actions will help, not hinder, user
  – e.g., suppose a user is viewing video over a network, whose bandwidth suddenly drops. Should the system
    • Reduce the fidelity of the video?
    • Pause briefly to find another higher-bandwidth connection?
    • Advise the user that the task can no longer be accomplished?
  – Correct choice depends on what user is trying to accomplish
User Intent

• Today’s applications either have no idea about user intent (e.g., to support adaptation and pro-activity), or do it badly

• Issues:
  – Can user intent be inferred, or does it have to be explicitly provided
  – How is use intent represented internally? What are represented?
  – How does one characterize accuracy of knowledge? Is incomplete or imprecise information useful?
  – Will obtaining intent place a burden on the user?
Adaptation strategy

• Necessary when there is significant mismatch between the supply and demand of a resource, e.g., bandwidth, energy, computing cycles, ...

• Three strategies for adaptation
  – The client guides applications in changing their behavior
  – The client asks the environment to guarantee a certain level of resource
  – The client suggest a corrective action to the user
Adaptation strategy

• Issues

– How does a client choose between adaptation strategies? How strategies be changed seamlessly as user moves?
– How to do resource reservation in a smart space? What are appropriate admission control policies? What API are needed to make reservation?
– Will corrective actions be intrusive? How to do it, e.g., API, programming model?
– What is the relationship between fidelity and adaptation?
High-level Energy Management

• Necessary because low-level techniques, e.g., battery and circuit design, are insufficient

• Issues
  – What high-level systems can be managed for energy efficiency? (memory, application adaptation, ...)
  – Are they intrusive to the user? Can user intent help?
  – Can smart spaces be used to reduce energy demand on a mobile device?
  – How to tradeoff the energy used in remote execution with wireless connection?
Client availability

• How powerful does a mobile client need to be?
  – From bare-bones devices (high-resolution displays through wireless to servers) to full-function clients (standalone and disconnected operation)

• Issues
  – How to migrate application between clients of different thickness?
  – How to cooperate with infrastructure?
  – Can clients be reconfigurable to adapt to environment?
  – Semi-portable infrastructure for less hospitable environments
  – How to roam transparently? Especially from a benign environment to a poor one?
  – How to lower the cost of diversity in devices?
Context-aware computing

• Computing services sense aspects of environment (location, user emotion, ..) and tailor provided services

• Walk into conference room, mu email is projected on a big screen there
Context-awareness

• Needed for an environment minimally intrusive
  – Recognize user state and surroundings
  – Make decisions pro-actively, modify behavior accordingly

• Issues
  – Obtaining information needed to function
  – How to represent context internally? How to combine it with system and application state? Where to share?
  – How often to update and consult context information?
  – What services does the infrastructure have to provide?
  – How to track location? Sense surroundings?
Sixth Sense

- http://www.ted.com/talks/pattie_maes_demos_the_sixth_sense.html
How to open a car?
Intelligent space

• System for recognizing user moods from their facial expressions
• House where position is sensed and temperature adjusted automatically
Facial expressions
Pro-activity and Transparency

• How not to annoy a user in a pro-active system?
  – Self-tuning according to user expertise and experiences

• Issues
  – How are user preferences and tolerances specified and taken into account?
  – How to determine the right level of balance?
Privacy and Trust

• A pervasive computing environment needs to monitor user actions almost continuously in order to be effective
• Need mutual trust between environment and user
• Issues
  – Tradeoff between seamless system behavior and privacy/trust enforcement
  – Any appropriate authentication techniques
  – How to specify security constraints? How to specify one’s identity?
Impact on Layering

• Pervasive computing often requires merging information from different layers of a system
• Issues
  – Relationship between layering and pervasive computing
  – How to create a new layer?
e-GEM system in action
Tangible Interaction

• Tangible Interaction encompasses user interfaces and interaction approaches that emphasize
  – tangibility and materiality of the interface
  – physical embodiment of data
  – whole-body interaction
  – the embedding of the interface and the users' interaction in real spaces and contexts.
Tangible User Interface

- Originally conceived in the mid/late 90s
- Alternative to display screen interfaces
- Also, virtual reality separated people from real world
- Many industrial and household devices became “intelligent”
Embodiment

• Manifested in the physical world
  – Allows direct interaction with world
• Seek to capitalize on a new range of skills
  – the tactile and physical skills we use in the real world
  – exploit our natural skills if we focus on interacting with physical objects themselves
• The world lends form, substance, and meaning to interaction
Ready-to-hand and present-at-hand

• Using a computer mouse to select icons, menus and objects is “ready-to-hand.”

• When we have to move a mouse from the edge of the pad to get it to operate we switch to “present-at-hand” mode.

• It is the two possibilities, whether the interaction methodology is invisible or it is evident.
Haptics

• Haptic sense is touch combined with forces that act on our bodies and how we use these forces to perform everyday tasks
• Computer interaction has separated us from physical sensation we used to be accustomed to
• Use an under-utilized, media-independent channel, touch
Conclusions

• Ubiquitous computing encompasses
  – System infrastructures, networking, security, user interfaces, embedded systems, AI, perception, speech recognition, ...

• Systems integration is the key

• Tangible computing brings computers and interaction out into the physical world

• Many new and fascinating research problems are emerging