Summary

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Contextualized Computing and Ambient Intelligent Systems

medieninformatik
IMAI – Institut für Mathematik und Angewandte Informatik

Exam Dates

- Data and Process Visualization
  - First exam: Wednesday, 01.08., 14:00-16:00
  - Second exam: Wednesday, 27.09., 14:00-16:00
- Closed-book exam
- What do you want it to look like?

1 Definitions & Theory

1.1 Mediality, Codality & Modality

Focus
We can describe media and interactivity with different foci

- **Presentation** & Recording
  - The "technical side"
  - Means for input and output
  - Devices such as microphones, cameras, loudspeaker
- **Coding**
  - The "meaning" side
  - The representation
  - What signs are used for the information?
- **Perception** & Production
  - The "human side"
  - What senses are used?

Tiers: Example

- **Presentation/Recording – Mediality**
  - Radio: mono-medial
  - TV: multi-medial
- **Coding – Codality**
  - Text only, graphics only: mono-codal

- Mixed: multi-codal

- **Perception/Production – Modality**
  - Only making use of eyes: mono-modal
  - Making use of eyes and ears: multi-modal

Problem: Different use in different contexts and disciplines

Mediality, Codality and Modality

Multi-mediality: Systems that make use of different media types (such as text, images, video) are called *multi-medial* systems

Multi-codality: Systems that encode the same information in different representations are called *multi-codal* systems

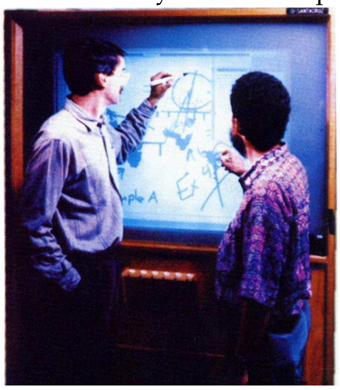
Multi-modality: Systems that make use of different sensual channels for input or output in a coordinated and parallel fashion are called *multimodal* systems

- Mediality: focus on technical presentation
- Codality: focus on semantic representation
- Modality: focus on human senses

Ubiquitous Computing

"The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it." (Weiser [1991], *The Computer for the 21st Century*)

"This then is Phase I of ubiquitous computing: to construct, deploy, and learn from a computing environment consisting of tabs, pads, and boards. This is only Phase I, because it is unlikely to achieve optimal invisibility."



(Weiser [1993], *Some Computer Science Issues in Ubiquitous Computing*)

1.2 Context

Context

- We generally refer to intelligent behaviour as being contextually appropriate.
- An ability to accurately read context is important for any animal if it is to survive, but it is especially important to social animals.
- In humans, such an ability is tightly linked to reasoning and cognition [Cohnitz, 2000; Leake, 1995].
- A situation is a confused, obscure, and conflicting thing, that a human reasoner attempts to make sense of through the use of context.

Working with Context

Context Awareness
Trying to **detect** the situation the system is in.

- **Example:** An ambient intelligent system for supporting health personnel figures out that the user is on a ward-round because of the time of the day, the location, and the other persons present.

Context Sensitivity
Acting according to the situation the system thinks it is in.

- **Example:** the same system fetches the newest versions of electronic patient records of all patients in the room from the hospital systems. When the user stands close to the bed of a patient, the system automatically displays them.

Best Practice Context Models

- **Environmental context:** This part captures the users surroundings, such as things, services, people, and information accessed by the user.
- **Personal context:** This part describes the mental and physical information about the user, such as mood, expertise and disabilities.
- **Social context:** This describes the social aspects of the user, such as information about the different roles a user can assume.
- **Task context:** the task context describe what the user is doing, it can describe the user's goals, tasks and activities.
- **Spatio-temporal context:** This type of context is concerned with attributes like: time, location and the community present.

1.3 Ambient Intelligent Systems

Ambient Intelligent Systems

> At the core of an ambient intelligent system lies the ability to **appreciate the system's environment**, be **aware of persons** in this environment, and **respond intelligently to their needs** (Ducatel et al. [2001], *ISTAG Scenarios for AmI in 2010*).

- **Perception:** The initial act of perceiving the world that the system inhabits
- **Context Awareness:** Being aware of the environment and reasoning about ongoing situations
- **Context Sensitivity:** Exhibit appropriate behaviour in ongoing situations
- **Action:** Changing the environment according to context

Assignment 2.2: Collecting Examples

- For the next two weeks, you should collect interesting examples of ambient or contextualised systems you come across
- You should use the framework introduced to describe the different systems
- You should be able to present one or two examples
  - Classification according to the framework
  - Shortfalls of the framework
- Deliverable:
  - Monday, 23.4., 18:00, learnweb
  - Monday, 23.4., in the course

Assignment 3.5: New Lab Room

- Form groups of 3-6
- Develop the outline of a project idea to change A120 into a room you would like to use:
  - Today, traditional computer lab
  - How to change it?
    * Interior decor
    * Furniture
    * Technology
  - Possible technologies:
    * Tab, Pads & Boards
    * Behavioural interfaces
    * Natural language processing
- Pitch your idea in the course

Required Reading Tie-ins

- Weiser, M. (1991). *The computer for the 21st century*. Scientific American, pages 94–104.
- Aarts, E., R. Harwig, and M. Schuurmans. 2001. Ambient Intelligence. In *The Invisible Future: The Seamless Integration of Technology into Everyday Life*, ed. P. J. Denning, pp 235-250. New York: McGraw-Hill Companies.
- Dourish, Paul. "What we talk about when we talk about context." Personal and ubiquitous computing 8, no. 1 (2004): 19-30.
- De Ruyter, Boris, and Emile Aarts. "Experience research: a methodology for developing human-centered interfaces." In Handbook of ambient intelligence and smart environments, pp. 1039-1067. Springer, Boston, MA, 2010.

Weiser

- Pads, tabs and boards
  - Try it out in the lab
- Only disappearing things help us focus
- Have to be trustworthy
- Information overload handled by machines
- Metaphor: utilities, electrical systems disappeared
- Physical and virtual relations
- No advanced AI needed
- Interaction
  - Explicit vs. implicit
- Bridging the physical digital divide
  - example: awareness systems

Aarts, Harwig, Schuurmans

- Aspects
  - Ubiquity
  - Transparency (natural interaction?)
  - Intelligence
    - Emotions
- Challenges
  - Technical
  - Economic
  - Social
- Productivity & Personal Time
  - Interaction technology
  - Experience economy
  - Ambient culture

Dourish

- Viewpoints
  - context as a data representation issue
    - Look at parameters
  - context is not static
    - Look at activities
- Question: what is ordinary?
  - Static aspects and dynamic creation of ordinariness
- Dialectic relation of top-down and bottom-up
  - We learn about structures and use them
  - Aspects
    - information vs. relation
    - statically vs. dynamically defined
    - stable vs. occasionally changing
    - context separate vs. part of activity

de Ruyter & Aarts

Ambient Intelligence refers to the embedding of technologies into electronic environments that are sensitive and responsive to the presence of people.

- **Ambience** refers to technology being embedded on a large scale in such a way that it becomes unobtrusively integrated into everyday life and environments. Hence, the ambient characteristic of AmI has both a physical and social meaning.
- **Intelligence** reflects the situation in which the digital surroundings exhibit specific forms of cognition, i.e. the environments should be able to recognize the people that inhabit them, personalize according to individual preferences, adapt themselves to the users, learn from their behavior and possibly act upon their behalf.

2 Descriptive Framework & Examples

Descriptive Framework Version 4

Contextualisation

- Contextual Parameter
  - Environment – things, services, people
  - Personal – mental & physical information about user
  - Social – roles & relations
  - Task – what is the user doing
  - Spatio-Temporal – when & where are we
  - Other
- Process of Contextualisation
  - Awareness – what aspects are taken into account?
  - Sensitivity – what aspects are changed?

Descriptive Framework Version 4

Intelligence

- System Intelligence
  - Personalized – tailored to individual needs
  - Adaptive – changing in response to user needs
  - Anticipatory – can act on its own on user's behalf
- Social Intelligence
  - Socialized – compliant to social conventions
  - Empathic – take user's inner states into account
  - Conscious – introspection, has inner state

Descriptive Framework Version 4

Ambience

- Perception
  - Mediality – media types
  - Codality – semantic representation
  - Modality – human senses
- Reasoning
  - *Context Awareness*
  - *Context Sensitivity*
  - Other
- Action
  - Mediality – media types
  - Codality – semantic representation
  - Modality – human senses

Descriptive Framework Version 4

Interaction

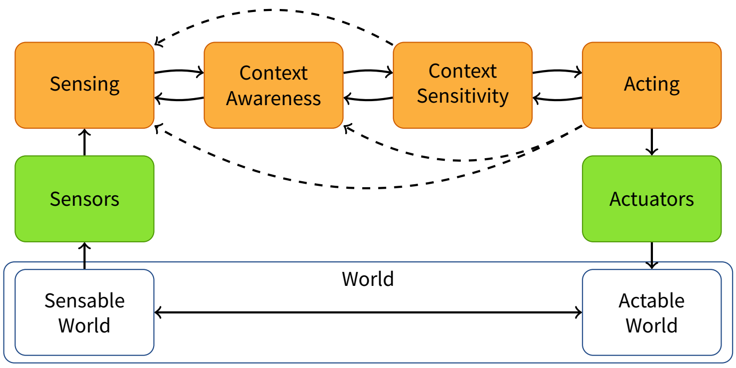
- Implicit vs. Explicit
  - Implicit input – through behaviour not primarily aimed at interacting with the computerised system (walking through a door, using a whiteboard...)
  - Explicit input – primarily aimed at interacting with the computerised system (voice or gesture commands...)
  - Explicit output – designed to get the users' attention (voice output...)
  - Implicit output – change of material setting where the users' attention is not the primary goal (opening doors...)
- Emotion
  - Does the system sense emotions?
  - Does the system show emotions?

Descriptive Framework Version 4

Embeddedness

- Weaviness
  - Is the system woven into the background?
  - Is the interaction naturally/culturally sound?
- Enhancement
  - Does the system enhance or replace current solutions?
    - ∗ Current "technical" solutions – using (computerized) artefacts
    - ∗ Current "non-technical" solutions – not using (computerized) artefacts
- Social Interaction
  - Does the system enable/enhance social interaction amongst humans?
  - Is the system targetting at supporting individual users?

Architecture Version 1



General, simplified architecture

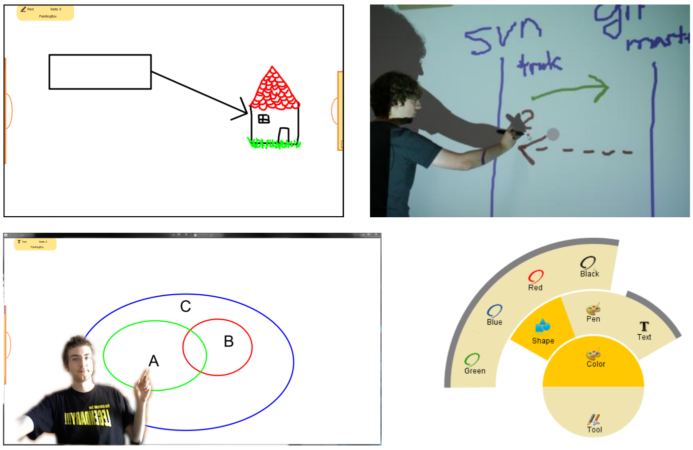
2.1 Research Systems

ShareBoard

- Building on top of existing projects
- Easy and cheap to use electronic whiteboards
  - Touchscreen or
  - video projector and screen

  - Wii remote controller and IR-Pen
  - Laptop with Webcam
  - Optional: kinect-like controller, leap motion controller
- Drawings on canvases
  - Freeform
  - Shapes
  - Text (handwriting, virtual keyboard, speech recognition)
- Audio and video communication with other parties
  - Automatic recognition of turn taking

Example: ShareBoard

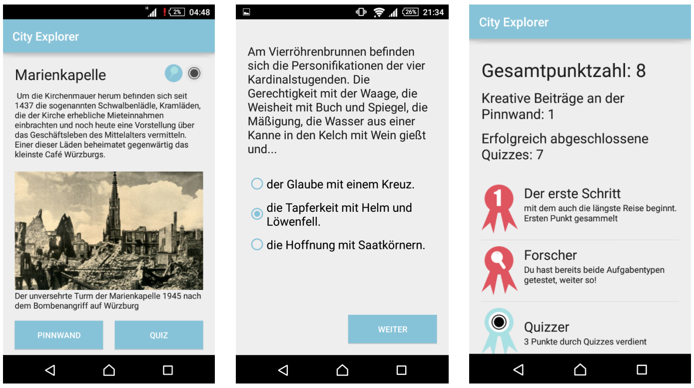


Pervasive Games & Environments

- Pervasive (Learning) Games & Environments
- Breaking the magic circle, extending
  - spatial
  - temporal
  - social

  boundaries of game play
- This media informatics research area is still starting up
- First examples
  - *Find It* – Learning by Caching
  - *City Explorer* – Discover Würzburg
  - *Uburzis* – competitive location-based game for school teams
- All designed and implemented taking instructional psychology into account
  - Serious Games – gaming with a learning goal

City Explorer – Screenshots



Sliding Doors

Built as part of the Masters thesis of John Sverre Solem

Semantics

- Semantics as meaning potential or "what the person can mean" [Halliday, 1979, p.72]
- Think of behaviour as semantic since there is a set of behaviours that are at the individual's disposal within a particular context
- There is a limit to how truly individual it can be in most social contexts if the intention is to share meaning
- To share meaning you must share the code
- **It should be possible to model the meaning potential available in a particular context**
- Because communicating is multimodal, intention will not always be signalled entirely by behaviour
- The task in modelling intention is to find (patterns of) behaviours which carry the most significant meaning

Behaviour in Context

- How behaviour creates meaning and how we assign meanings to behaviour is significantly related to situation and context
- Meaning is constituted in the interaction between the behavioural sign and its function within a context
- It is important to see expressive action as part of context and not as the product or effect of context
- We can only assign meaning to behaviour through its interaction with the context in which it is embedded
- If we are to find meaning in behaviour we primarily look to the dynamic relationship between the unfolding interaction and the context

Intention in Context

- Intention is something which is dynamic and emergent from interaction rather than a static and predetermined feature of interaction
- Intention can thus be considered context sensitive
- We have not attempted to model intention as a general or context free concept
- We have looked at the intention to walk through a door rather than intention in general
- Our model of intention may be generalisable to contextually similar situations (waiting for a bus or train)

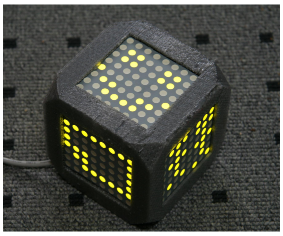
Sliding Doors

- Automatic sliding doors were chosen because of a rather restricted behavioural set
- Also, link between behaviour, intention and outcome is much clearer and simpler than in other typical, but more complex situations
  - The doors either open appropriately or they do not
- We were in no way suggesting that automatic doors should respond to intention
  - Proximity is a good approximation of intention to go through a door
- But other people thought it would be good, so we reconsidered that position

CAKE and MATe

- CAKE (Context Awareness and Knowledge Environment) is a *framework* for building contextualized ambient intelligent systems
- MATe (Mate for Awareness in Teams) is an *application* primarily aiming at improving situation awareness in work teams
- Designed to blend seamlessly with the team members' everyday routine, enabling unobtrusive in-situ interaction and facilitation of cooperation and communication
- Knowledge is modelled in a user-centred process
- Technologies employed come from the semantic web community as well as artificial intelligence in general and machine learning in particular

Example: Exploring the Design Space



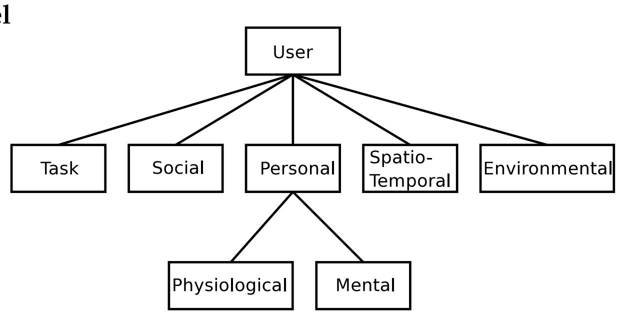
Very ambient, but hard to understand?
Very traditional, but easy to grasp?
Or something in between?

LADI

- LADI – Location-Aware Device Integration
- Cross-Device Integration (XDI)
- Utilises
  - Pads,
  - Tabs, and
  - Boards
- Location-centric, not network-centric
- Storage (for example) in "the cloud"
- Challenges:
  - Indoor-localisation
  - Media access
  - Access control
  - Device capabilities

Example: LADI in use

AmbieSense Context Model



User context in AmbieSense

Parts of the AmbieSense Context Model

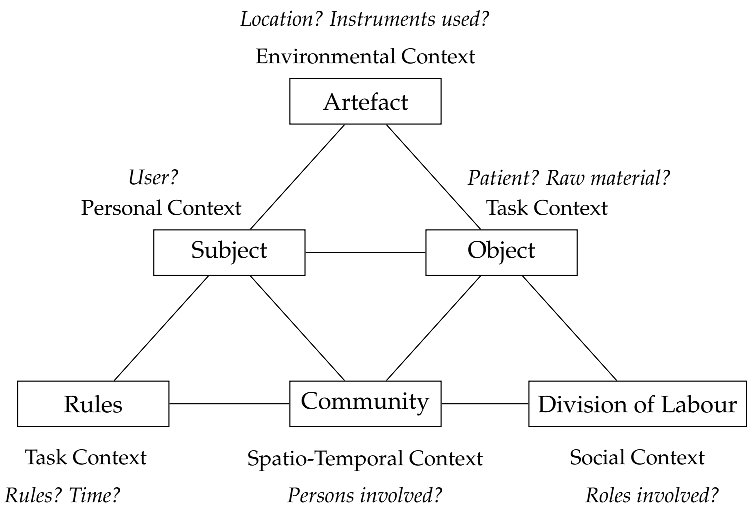
1. **Environmental context:** Captures the users surroundings, such as things, services, light, people, and information accessed by the user.
2. **Personal context:** Mental and physical information about the user, such as mood, expertise, disabilities and weight.
3. **Social context:** Social aspects of the user, such as information about friends, relatives and colleagues.

4. **Task context:** Describe what the user is doing, it can describe the user's goals, tasks, activities, etc.
5. **Spatio-temporal context:** This type of context is concerned with attributes like: time, location and movement. The different aspects of the contexts are attribute-value tuples that are associated with the appropriate contexts.

Two-fold Use of Activity Theory

- Knowledge engineering with "Activity-Theoretic Goggles": we try to understand the basic properties of the workplace using CHAT
- Two-fold use of the theory
  - Building the model: Building a knowledge model which can capture the basic concepts of AT
    * General knowledge about human work processes together with "best practice" knowledge is used to identify components of the context model
  - Populating the model: Using empirical evidence to fill the model
    * Results from Activity-Theoretic field studies can be used to generate an initial knowledge model (that can be enhanced by online learning)

Mapping



3 Implementing & Evaluating

Prevalent Paradigm

Prevalent computing paradigm designed for personal information management

- desktops and laptops with fixed configurations of mouse, keyboard, and monitor
- dedicated network services with fixed network addresses and locations
  - printers
  - file servers
  - ...
- direct manipulation interfaces
  - representation and manipulation of files, documents, and applications

Ambient Interaction

- interaction mode goes beyond the one-to-one model prevalent for PCs
  - many-to-many model where the same person uses multiple devices
  - and several persons may use the same device
- interaction may be implicit, invisible, or through sensing natural interactions such as speech, gesture, or presence
  - wide range of sensors is required, both sensors built into the devices as well as sensors embedded in the environment
- location tracking devices, cameras, and accelerometers can be used to detect who is in a place and deduce what they are doing
  - provide the user with information relevant in a specific location
  - adapt their device to a local environment or the local environment to them
- Networking is often wireless and ad hoc

Ambient Paradigm
Different paradigm of computing environment

- heterogeneous set of devices
  - invisible computers embedded in everyday objects such as cars and furniture
  - mobile devices such as smartphones
  - personal devices such as laptops
  - very large devices such as wall-sized displays and tabletop computers situated in the environments and buildings we inhabit
- All have different operating systems, networking interfaces, input capabilities, and displays
  - some are designed for end user interaction
  - other devices, such as sensors, are not used directly by end users

3.1 Topics & Challenges

Resource-Constrained Devices

- wide range of new devices are built and introduced, which often are resource-constrained
- devices such as mobile phones and music players have limited CPU, memory, and network connectivity compared to a standard PC
- embedded platforms such as sensor networks and smart cards are very limited compared to a PC or even a smartphone
- it is important to recognize the constraints of the target devices, and to recognize that hardware platforms are highly heterogeneous and incompatible with respect to
  - hardware specifications
  - operating system
  - input/output capabilities
  - network
  - ...

Distribution

- systems often distributed; they entail interaction between different devices
  - mobile, embedded, or server-based
- these devices have different networking capabilities
- Spontaneous
  - devices continuously connect and disconnect
  - create and destroy communications links
- from a communication perspective, these devices may leave the room (or run out of battery) at any time
- therefore, communication between the mobile devices and the services in the smart room needs to gracefully handle such disconnection

Heterogeneous Execution Environments

- applications often involve a wide range of hardware, network technology, operating systems, input/output capabilities, resources, sensors, etc.
- in contrast to the traditional use of the term application, which typically refers to software that resides on one to three physical nodes, a ubiquitous application typically spans several devices, which need to interact closely and in concert in order to make up the application
  - a Smart Room is an application that relies on several devices, services, communication links, software components, and end user applications, which needs to work in complete concert
- handling heterogeneity is not only a matter of being able to compile, build, and deploy an application on different target platforms—such as building a desktop application to run on different versions of Windows, Mac OS, and Linux

Invisible Computing

- Handling and/or achieving invisibility is a core challenge
  - For example, monitoring human behaviour at home and providing smart home control of the heating systems
- In many of these cases, the computers are invisible to the users in a double sense
  - the computers are embedded into buildings, furniture, medical devices, etc., and are as such physically invisible to the human eye
  - Second, the computers operate in the periphery of the users' attention and are hence mentally invisible (imperceptible).
- From a systems perspective, obtaining and handling invisible computing is a fundamental change from traditional computing

Invisibility as Fundamental Change

- traditional systems rely heavily on having the users' attention;
  - users either use a computer or they don't
- This means, for example:
  - the system software can rely on sending notifications and error messages to users, and expect them to react
  - ask for input in the contingency where the system needs feedback in order to decide on further actions
  - ask the user to install hardware and/or software components
  - can ask the user to restart the device
- Moving toward invisible computing, these assumptions completely break down
- Mitigation strategies include autonomic computing, contingency management and graceful degradation

Security & Privacy: Trust

Trust
First, trust is often lowered in volatile systems because the principals whose components interact spontaneously may have no a priori knowledge of each other and may not have a trusted third party

- a new device that enters a hospital cannot be trusted to be used for displaying or storing sensitive medical data, and making the necessary configuration may be an administrative overhead that would prevent any sort of spontaneous use
- Hence, using the patient's mobile phone may be difficult to set up

Security & Privacy: Assumptions

Assumptions
Second, conventional security protocols tend to make assumptions about devices and connectivity that may not hold

- portable devices more easily stolen and tampered with
- resource-constrained embedded devices may not have sufficient computing resources for asymmetric public key cryptography
- software does often not get updated after initial release
  - "fire and forget"-strategy of vendors for cheap hardware
  - incompetence
- Many security protocols cannot rely on continuous online access to a server, which makes it hard to issue and revoke certificates

Security & Privacy: Context

Context
Third, the nature of ambient systems creates the need for a new type of security based on location and context; service authentication and authorization may be based on context and not the user

- people entering a cafe may be allowed to use the café's printer
- if a device wants to use the café's printer, it needs to be verified that this device indeed is inside the cafe
- it does not matter who uses the printer, the cafe cares only about where the user is
- Vice versa, the customer only cares that he connects to the printer in the café

Security & Privacy: User Data

Sensors
Fourth, new privacy challenges emerge

- By introducing sensor technology, ambient systems may gather extensive data on users including information on
  - location, activity, social interaction, speech, video, and biological data
- if these systems are invisible in the environment, people may not even notice that data are being collected
- hence, designing appropriate privacy protection mechanisms is central
- key challenge is to manage that users provide numerous identifiers to the environment while moving around and using services
  - networking IDs such as MAC, Bluetooth, and IP addresses
  - (user-) names
  - IDs of tags such as RFID tags
  - payment IDs such as credit card numbers

Security & Privacy: Fluctuations

Fluctuations
Fifth, the fluctuating usage scenarios also set up new challenges for security

- numerous devices, users continuously create new associations
- if all or some of these associations need to be secured, device and user authentication happens very often
- Existing user authentication mechanisms are, to a large degree, designed for few (1–2) and long-lived (hours) associations between a user and a device or service
  - a user logs into a PC and uses it for the whole workday
- in ambient scenarios, users may enter a smart room and use tens of devices and services in a short period (minutes)
  - traditional user authentication e.g. using user names and passwords not feasible
  - Moreover, if the devices are embedded or invisible, it may be difficult and awkward

3.2 Designing

Why?

- Prototyping future systems to explore ubiquity in practice
- Empirical exploration of user reactions
- Gathering datasets to tackle computational problems
- Creating experiences for public engagement or performance
- Creating research test beds to agglomerate activity and stimulate further research
- Explore a hypothesis more naturalistically
- Test the limits of computational technologies
- Addressing the perceived needs of a problem domain or pressing societal issue

Computational Knowledge

- One needs to decide
  - what knowledge a system will need about the real world to function
  - how it will get into the system
  - how to represent it
  - how this state will be maintained
  - what to do if it is incorrect
- Unless this knowledge is easy to sense, or trivial to reason with, one you must also decide
  - what the implications are if the knowledge is imperfect or
  - conclusions are erroneously reached

Computational Knowledge about Physical World
Key questions you should ask yourself are

1. What can be reliably sensed?
2. What can be reliably known?
3. What can be reliably inferred?

The degree to which you can answer these questions for the intended function of your system will help determine the feasible scope, or set some of the research challenges.

Mental Models

Key Question
What do you intend for the user to understand or perceive of the system in operation?

- To grow comfortable with it, adopt it, and potentially appropriate it, the user must be able to form a mental model of cause and effect or a plausible rationale for its behaviour
- Mental models on the user side can only be influenced by induction

Always Runtime

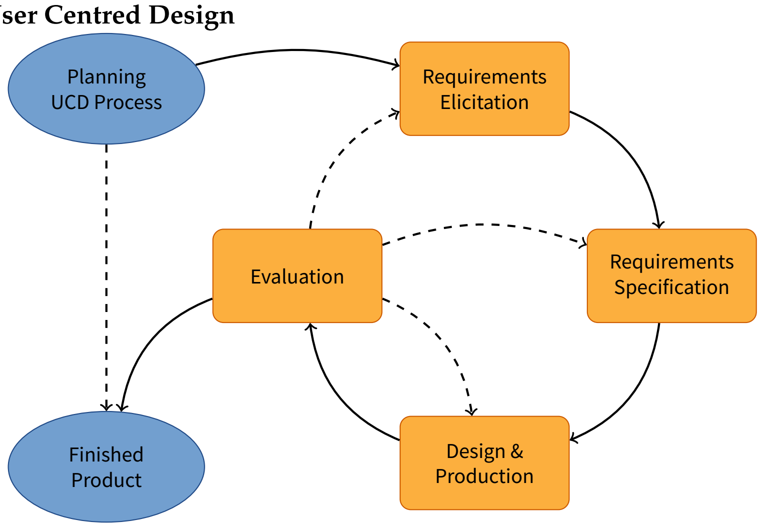
- ambient systems are composed of distributed, potentially disjoint, and partially connected elements (sensors, mobile devices, people, etc.)
- "partially connected" here reflects that these elements will often not be reliably or continuously connected to each other
- the system is the product of spontaneous exchanges of information when elements come together
- interaction patterns and duration will vary with the design and ambition of any given system, but it is important to consider a key precept:
  - once deployed, all changes happen at runtime
- typically no simultaneous access to all the elements to (for example) upgrade them or restart them

3.3 Implementing

UCD & Participatory Design

- Deploying systems for people to use is always a costly process
- Designing a system that meets peoples' expectations, and indeed, helping set those expectations requires great care and expertise
- The key is identifying the stakeholders and involving them in discussions from an early stage
  - User-Centred Design Processes
  - Participatory Design Processes
- many issues due to the real world an d organizational settings that can catch the unwary developer by surprise

User Centred Design



Participatory Design

☞ Public hearing in urban planning (cc-by-sa Kaihsu Tai)

Low-Fidelity Prototyping

- graphical storyboards of proposed interactions.
- simple scenarios that can be discussed
- paper prototypes
- models of devices

Anything that can add richness to the discussion of the system with potential users

Medium-Fidelity Prototyping

- Video prototypes
  - can communicate the concepts in the system quite effectively
  - act as a useful reference for explaining the system later on
  - rapid prototypes of user interfaces using prototyping toolkits can afford a more realistic synthesis of the intended user experience
- Wizard of Oz
  - prototypes of parts of the system
  - not implemented parts are simulated by human
  - behaviour of the system to be emulated and thus experienced by others

High-Fidelity Prototyping
Partially working systems

- Horizontal prototype
  - all the intended functionality, but only at the top level
  - Example: initiate a shopping spree, but cannot order
  - Good for testing high level goals and action plans
- Vertical prototype
  - only one or two tasks are implemented in detail
  - Example: shop til you drop, but cannot see shipping information
  - Good when only few tasks are seen as particularly complex or important
- Chauffered prototype
  - Considerable functionality, but little or no error detection
  - How: A well trained assistant accepts and executes requests on behalf of the actual test user
  - Orthogonal to vertical and horizontal

Real-World Issues

- The need to comply with health and safety or disabilities legislation, which can constrain the citing of equipment and place certain usability requirements for disabled users
- To be sensitive to data protection legislation, which may impact what data you can store, whether users have the right to opt-in, opt-out, or declare (e.g., with notices) that the system is in operation
- Environmental factors (including weather, pollution, etc.) can have a devastating effect on equipment that is not adequately protected
- Privacy and organizational sensitivity
  - potentially open vulnerabilities (perceived or actual) to expose private information or interfere with existing systems or processes
  - particularly true for organizations managing sensitive data or in high-pressure situations, such as healthcare and emergency services

3.4 Evaluating

Evaluation

- Simulation
  - In particular object-oriented simulations
  - Agents with particular goals, believes, intentions interact via simulated sensors with the real software
  - Data and/or modelling necessary
- Proof-of-concepts
  - field studies as done by Marc Weiser at PARC
  - Rudimentary and/or incomplete (see prototypes)
- Implementing and Evaluating Applications
  - Large-scale implementations
  - Long running systems
  - significant amount of users
  - Field-study

Proof of Concept

- A PoC is a rudimentary and/or incomplete realization of a certain technical concept or design to prove that it can actually be realized and built, while also to some degree demonstrating its feasibility in a real implementation
- Not a theoretical (mathematical) proof of anything; it is merely a proof that the technical idea can actually be designed, implemented, and run
- Creating PoCs is the most prevalent evaluation strategy in ambient systems
  - Weiser's tabs, pads and boards
- A PoC is a somewhat weak evaluation strategy
- It basically shows only that the technical concept or idea can be implemented and realized
- Actually, however, a PoC tells us very little about how well this technical solution meets the overall goals and motivation of the research

End-User Applications

- A stronger evaluation approach is to build end user applications using ambient systems component and infrastructures, and then put these applications into subsequent evaluation
- These applications can then be evaluated by end users in either a simulated environment or in a real-world deployment

Released Systems

- The strongest evaluation of ambient systems components is to release them for third party use, for example, as open source
- In this manner, the system research is used and evaluated by other than its original designers, and the degree to which the system components helps the application programmers to achieve their goals directly reflects the qualities of the system components
- One may even argue that there is a direct correlation between the number of application developers and researchers using the system in their work, and the value and merits of the workReleasing and maintaining systems software does, however, require a substantial and continuing effort

Required Reading Tie-ins

- Weiser, M. (1991). *The computer for the 21st century*. Scientific American, pages 94–104.
- Davies, N., & Gellersen, H. W. (2002). "Beyond prototypes: Challenges in deploying ubiquitous systems." IEEE Pervasive computing, 1(1), 26-35.
- Hansen, T. R., Bardram, J. E., & Soegaard, M. (2006). "Moving out of the lab: Deploying pervasive technologies in a hospital." IEEE Pervasive Computing, 5(3), 24-31.
- Abowd, Gregory D., Elizabeth D. Mynatt, and Tom Rodden. "The human experience" IEEE pervasive computing 1.1 (2002): 48-57.
- De Ruyter, Boris, and Emile Aarts. "Experience research: a methodology for developing human-centered interfaces." In Handbook of ambient intelligence and smart environments, pp. 1039-1067. Springer, Boston, MA, 2010.

Hansen, Bardram, Soegaard

- Hospital room for operating room scheduling
  - Not ubicomp, but having ubicomp aspects
  - Awareness media
- Challenges
  - No added value for everyone
  - Concerns of privacy → reduced resolution, no-track-areas
  - Space for devices difficult to find
  - Reliability an issue → reliable over features
- Iterative development
  - Guerilla teaching
  - Deployment
- Consider implicit & explicit organisational change
- Table with concerns

Davies & Gellersen

- Comments on Weiser
- Individual technology is developed, something missing
  - Major problem: lack of integration
  - Walled gardens
  - How about interoperability certifications?
- Whole is more than sum of parts, what are the issues?
  - Technology

  - Social & legal
  - Economic
- Important to move past prototypes
  - Envisioned use cases not realized
  - Users find uses not envisioned
- Difficult to evaluate invisible technology without deployment
- What is the value proposition of AmI?
  - individual solutions only sell individual systems
  - Examples: Xerox, Lancaster, mediacup
- Research Challenges

Abowd, Mynatt, Rodden

- Activity vs. task
  - Task: beginning and end, sequence of doing
  - Activity: Continuation of tasks, interruptions expected
- Differences traditional and new
  - Traditional HCI example: HTA
  - Cognitive view: how do we act in the world
- Examples for theories
  - Activity Theory
    * hierarchical structure of activities, use of artefacts
  - Situated Action
    * improvised behaviour, use of external cues
  - Distributed Cognition
    * Humans part of a larger systems
  - Actor-Network Theory
    * Inscribing human programs in artefacts
  - Systemic-Functional Theory of Language
    * Language in use, generic structure potential

de Ruyter & Aarts

- Levels of system intelligence
  - Context awareness & sensitivity
  - Personalised
  - Adaptive
  - Anticipatory
- Facets of social intelligence
  - Socialised
    * Pleasant to interact with
  - Empathic
    * View on internal state of human
  - Conscious
    * Introspection of internal states
- Definition of AmI

- Three-step approach to development
  - Context studies
  - Lab studies
  - Field studies

4 Human & Computer

Artificial Intelligence

- Intelligent software applications are systems that realize artificial intelligence in software:

What is Artifical Intelligence (AI)?
"It is the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable." [McCarthy, 2007]

Intelligence

- No universally accepted answer, but few would argue that intelligence is a capacity displayed by humans.

What is Intelligence?
"Intelligence is a very general mental capability that, among other things, involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience. It is not merely book learning, a narrow academic skill, or test-taking smarts. Rather, it reflects a broader and deeper capability for comprehending our surroundings – 'catching on,' 'making sense' of things, or 'figuring out' what to do." [Gottfredson, 1997]

Ambient Intelligent Systems

What is Ambient Intelligence?
At the core of an ambient intelligent system lies the ability to **appreciate the system's environment**, be **aware of persons** in this environment, and **respond intelligently to their needs** (Ducatel et al. [2001], *ISTAG Scenarios for AmI in 2010*).

- **Perception:** The initial act of perceiving the world that the system inhabits
- **Context Awareness:** Being aware of the environment and reasoning about ongoing situations
- **Context Sensitivity:** Exhibit appropriate behaviour in ongoing situations
- **Action:** Changing the environment according to context

4.1 Trust

Trust: Typology

- McKnight and Chervany [2001] develop a typology of trust based on literature survey and identify core characteristics: benevolence, integrity, competence, and predictability.
  - "**Benevolence** means caring and being motivated to act in one's interest rather than acting opportunistically.
  - **Integrity** means making good faith agreements, telling the truth, and fulfilling promises.
  - **Competence** means having the ability or power to do for one what one needs done.
  - **Predictability** means trustee actions (good or bad) that are consistent enough to be forecasted in a given situation."
- They also organise trust by conceptual type, "such as attitude, intention, belief, expectancy, behavior, disposition, and institutional/structural."

Danger vs. Risk

- Let's step back a bit and look at some basic properties, as defined by sociologist Niklas Luhmann.
- He looks at the risk or dangers (of not reaching a goal) involved when taking certain decisions:

  "[...] uncertainty exists in relation to future loss. There are then two possibilities. The potential loss is either regarded as a consequence of the decision, that is to say, it is attributed to the decision. We then speak of **risk** [Risiko] – to be more exact of the risk of decision. Or the possible loss is considered to have been caused externally, that is to say, it is attributed to the environment. In this case we speak of **danger** [Gefahr]." [Luhmann, 1993]

Choice and Alternatives

"... an attribution can be made to a decision only if a choice between alternatives is conceivable and appears to be reasonable, regardless of whether the decision maker has, in any individual instance, perceived the risk and the alternative, or whether he has overlooked them." [Luhmann, 1993]

- Luhmann thinks it is essential for regarding something as a risk that there are alternatives to be considered, whether considered in practice or not.
- If a user chooses to use a system, he deliberately takes the risk of failure.
  - Using the system is the result of an (potential) *analysis*.
- If he is bound to use it, he has the object of danger.
  - Using the system is grounded in *habit*.

Familiarity and Trust

- Luhmann [1979] distinguishes several types of trust relations.
- First of all, he distinguishes between familiarity [Vertrautheit] and trust [Vertrauen]:

  "*Familiarity* reduces complexity by an orientation towards the past. Things that we see as familiar, because 'it has always been like that', are accepted – we do engage in relations with those – and things that we see as unfamiliar are rejected – we do not engage in relations with those." Pieters [2008]

- For example, especially elderly people often refuse to use ATM's, precisely because they are not used to them.
- Trust, on the contrary, has an orientation towards the future: it involves expectations. We trust in something because we expect something.

Trust and Confidence

- Luhmann [1988] also distinguishes trust [Vertrauen] and confidence [Zutrauen].
- Both involve expectations with respect to future events.

  "According to Luhmann, trust is always based on assessment of risks, and a decision whether or not to accept those. Confidence differs from trust in the sense that it does not presuppose a situation of risk. Confidence, instead, neglects the possibility of disappointment, not only because this case is rare, but also because there is not really a choice. This is a situation of danger, not risk." Pieters [2008]

- Only when we chose to use a system, we talk about trust.

4.2 Explanations

Why bother to explain?

- Important vehicle to convey information between communicating people in everyday human to human interaction.
- Enhance the knowledge of the participants in such a way that they accept certain statements and gain a better understanding of the actions of the other persons involved and their motivations.
- They understand more, allowing them to make better informed decisions themselves.
- Explanations are the most common method used by humans to support their decision making [Schank, 1986].

Explanations in Intelligent Systems

System Centric View
Explanation as **part of the reasoning process** itself.

- **Example:** a knowledge intensive case-based reasoning system can use its domain knowledge to explain the absence or variation of feature values.

User Centric View
Giving explanations of the found solution, its application, or the reasoning process **to the user**.

- **Example:** in an engine failure diagnosis system, the user gets an explanation on why a particular case was matched.

Explanations for {Trust | Confidence}

- Systems being able to explain their behaviour and reasoning increase the user's perception of the system's *competence* and *integrity*.
- This in turns support building up trust and confidence [McKnight and Chervany, 2001].
- Looking for a model describing the relation between explanation and {trust | confidence} as well as possible points of failure.
- Taking a actor network perspective: looking at the translation and delegations processes involving system and user as actors.

4.3 Black Boxing

Black Boxes
Pieters [2011] introduces the concept of black boxing with regard to explanations:

- In different IT settings, the black box character of systems lacking explanations is often mentioned.
- This concept can mean very different things.
- In the common sense meaning, a black box is something that outputs something based on certain inputs, but that we do not know the inner workings of.
- In a more philosophical sense, a black box is something that has been "blackboxed"; a theory or technology of which the supporting network of actants has become invisible. [Latour, 1999]

Explanation Programs

- Latour associates the process of blackboxing with three other phenomena: translation, composition and delegation.
  - **Composition** means that actants in a network form a composite actant to which actions can be attributed.
  - **Translation** denotes that the "action program", the intentions and possibilities for action, change when actants join forces. A man plus a gun has different action possibilities than a man or a gun alone.
  - **Delegation** is the the process in which parts of an action program are delegated to different actants. The responsibility of delivering hotel keys at the reception can be delegated to large pieces of metal.
  - We "translate" these concepts to explanation and trust.
- Actants have an explanation program: when they are asked to explain something about a theory or system, they have certain intentions and possibilities for explaining in a certain way.

Explanation for {Trust | Confidence}

- Explanation may serve different purposes.
- It can either aim at acquiring confidence or at acquiring trust.
- *Explanation-for-trust* is contrasted with *explanation-for-confidence*

  Explanation-for-trust is explanation of how a system works: the black box of the system is opened.
  Explanation-for-confidence is explanation that makes the user feel comfortable in using the system: the black box is not opened.

Black Boxes and Trust

- A black box cannot acquire trust, but only confidence.
- Black boxes can explain things to their environment, but only as an *explanation-for-confidence*.
- Black boxes can be opened when trust is required instead of confidence; this opening produces an *explanation-for-trust* of how the system or network does what it is supposed to do.
- It reveals part of the inner workings, thereby reveals part of the risks, and thereby trades confidence for (possible) trust.
- If the explanation program of the network around a technology is strong enough, the black box of the inner mechanisms of the technology itself may not need to be opened.

Levels of Detail
We can map levels of detail to different results of explanations:

level of detail	result
too low	explanation fails
low	explanation-for-confidence, justification
high	explanation-for-trust, transparency
too high	explanation fails

Please note that level of detail is a simplification ignoring the qualitative aspects (what kind of explanations are needed to open the black box, and are they different from those not opening it?).

4.4 Context

Contextualisation for {Trust | Confidence}

- Contextually adequate behaviour increases the user's perception of the system's *competence* and *predictability*.
- This in turns supports building up trust and confidence [McKnight and Chervany, 2001].
- Looking for a model describing contextually adequate behaviour and possible points of failure.
- Taking a semiotic perspective: looking at the meaning making processes involving system and user as actors.

4.5 Systemic-Functional Theory of Language

SFL: Stratification

- **Stratification:** A stratified model of language systems including:
  - Sound Systems – phonetics, phonology, gesture, pixels etc.
  - Lexicogrammar – lexis/grammar; or wording and structure
  - Semantics – the meaning system
  - Context – culture and situation; elements of the social structure as they pertain to meaning

Example 1.
- Context: the situation we are in is a lecture
- Semantics: a lecturer standing in front of students and talking constitutes knowledge transfer
- Lexicogrammar: from the worked examples down to the sentences used
- Sound Systems: the phonemes said and gestures used

SFL: Register

- **Register:** Dialectic relation of system and instance
  - System – at the level of context the culture
  - Instance – at the level of context the situation that we are in
  - Register – dialectic relation
    - Abstraction of instances which typically share a similar structure
    - Concretisation of parts of the system

Example 2.
- System: the computational or linguistic system
- Instance: the concrete situation
- Register: the instantiation/generalization that allows the system to work in different concrete situations
  - This is a relation, not an entity

SFL: Metafunction

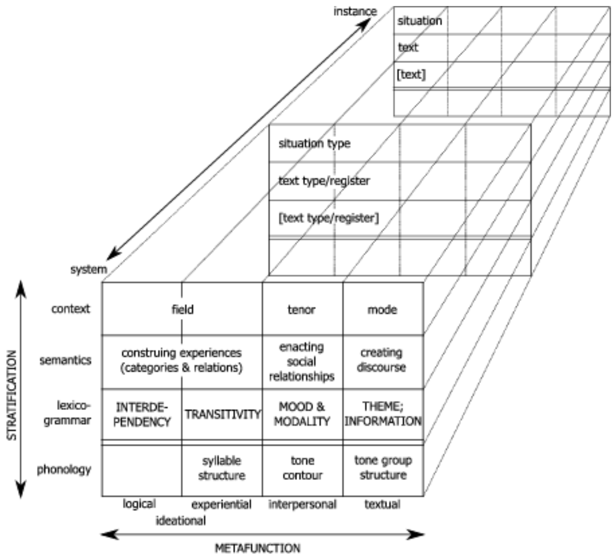
- **Metafunction:** What function do representations have:
  - Ideational – structure, relation of linguistic elements
    - Logical
    - Experiential
  - Interpersonal – relation of actors
  - Textual – content of discourse
- Together, these concepts span a space of exploration and description

Example 3.
- Ideational – using the field of discourse

- what is it about?

- Interpersonal – using the tenor of discourse
  - how do the actants interact?
- Textual – using the mode of discourse
  - what is being said and how?

Dimensions of Language



The dimensions of language – Halliday and Matthiessen [2004]

Field

> "The FIELD OF DISCOURSE refers to what is happening, to the nature of the social action that is taking place: what is it that the participants are engaged in, in which the language figures as some essential component?" [Halliday and Hasan, 1985]

- We are talking about **ideational** aspects.
  - What is the domain? What are the long term or short term goals? The experiential domain?
  - What is the structure, what are the networks of interaction?

Tenor

> "The TENOR OF DISCOURSE refers to who is taking part, to the nature of the participants, their status and roles: What kinds of role relationship obtain among the participants [. . .], both the types of speech role that they are taking on in the dialogue and the whole cluster of socially significant relationships in which they are involved?" [Halliday and Hasan, 1985]

- We are talking about **interpersonal** aspects.
  - What is the power structure between actors involved?
  - What is the agentive role?
  - What is the competence of the actors?

Mode

> "The MODE OF DISCOURSE refers to what part the language is playing, what is it that the participants are expecting to do for them in that situation: the symbolic organisation of the text, the status that it has, and its function in the context . . . and also the rhetorical mode, what is being achieved by the text in terms of such categories as persuasive, expository, didactic, and the like." [Halliday and Hasan, 1985]

- We are talking about **textual** aspects.
  - What medium is used?
  - What is the type of interaction (dialogic, monologic)?
  - What is the rhetorical thrust?

Context and Explanations

- The different actors being aligned in their perception of context will usually have an increasing or at least non-decreasing effect on trust and confidence.
- The different actors being misaligned in their perception of context will usually have an decreasing or at least non-increasing effect on trust and confidence.

Example 4. If the intelligent system misjudges the competence of the human user (misalignment in the TENOR), it might adjust the rhetorical thrust (leading to a misaligned MODE) and for example deliver an explanation-for-trust instead of an explanation-for-confidence, thereby risking to decrease confidence.

4.6 Abstract Concepts

Abstract Concepts

Example 5. Emergency in the hospital domain has meanings that are distinct from meanings in other domains. These might be:

- Hospital specific meanings (cultural specific)
- Activity specific meanings (situation specific)
- **Concrete:** Having a direct material referent of place, using the specific deictic (e.g. 'the emergency department') and having the potential to be used as a circumstance location spatial (e.g. 'in the emergency department').
- **Abstract:** Having no clear referent in the material setting but referring rather to a state, using the no specific deictic (e.g. 'an emergency') and having the potential to take the specific deictic in past tense (e.g. 'the emergency') (e.g. 'the emergency this morning').

Application: Culture-Based Emergency

Example 6. Culture based emergency (e.g. the doctor is called away from the ward round because of pressures from the wider hospital).

- **Response from artifact:** provide new information
- **Why:** a culture based emergency constitutes a change in context because the field (topic), tenor (relations) and possibly the mode (interactional features) have changed; this means that new information will be needed by the doctor.

Application: Context-Based Emergency

Example 7. Context based emergency (e.g. the doctor is required to resusitate a patient during ward round)

- **Response from artifact:** be quiet and await query – alternant modes may be needed
- **Why:** a context based emergency is a sequence shift and not a new context. There are only minor changes to the field, if any. This situation requires material action from the doctor but the device needs to be ready for queries.

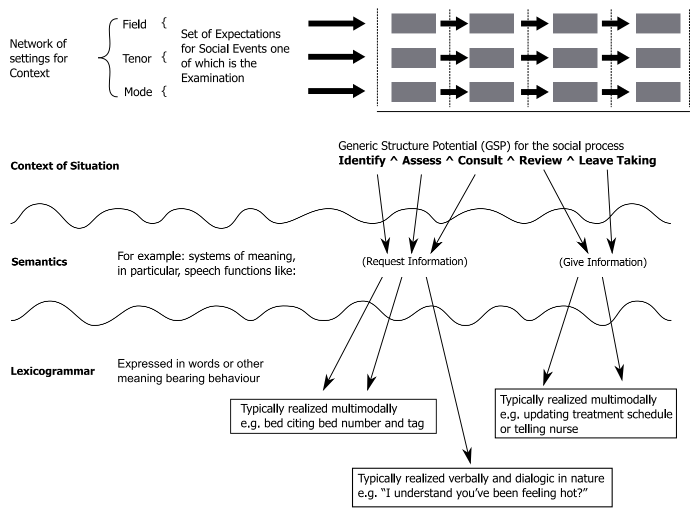
Semiotic Profile

- If the system acts contextually appropriate, user confidence in the system can be increased
  - If the user understands why, it can also increase trust
- How can we model such abstract concepts?
  - Not having a material grounding does not mean that there are no observable features
  - In particular, contextual appropriate behaviour follows certain "scripts"
  - Diversion from these scripts can be a sign for a change in context that is due to abstract concepts
- Here: Semiotic profiles and Generic Structure Potential
- We can try to model abstract concepts as unexpected context shifts

Generic Structure Potential

- Within certain recurring sets of texts then, coherence of structure is formed through obligatory and optional elements, the totality of which forms the Generic Structure Potential (GSP) for that set [Halliday and Hasan, 1985]
- In other words, there are certain obligatory elements that characterize the genre and other optional ones that add elaboration but are not necessary
- There is thus a *structure* to social interactions
- We can call it *potential* because it has a predictive quality that allows us to navigate these social situations almost unconsciously

Semiotic Profile



Required Reading Tie-ins

- Dourish, Paul, and Ken Anderson. *Collective information practice: exploring privacy and security as social and cultural phenomena*. Human-computer interaction 21.3 (2006): 319-342.
- Tom Geller: "How Do You Feel? Your Computer Knows." Communications of the ACM Vol. 57(1), pp. 24-26. Jan. 2014
- Rosalind W. Picard: "Affective Computing". MIT Technical Reports – TR 321. Nov. 1995

Dourish & Anderson

- Privacy to be considered from start
- Not only technical problem
  - Always partly social/personal
- Three views
  - Economic rationality
  - Practical action
  - Discoursive practice
- Privacy and security strongly related
  - privacy is security of personal data
- Collective information practice
  - act of sharing vs. secrecy
  - embedded in context
    * Example: trucker
  - Cannot be designed, has to keep up with changes
    * Need for AI to keep track of complexity
    * Privacy-box at home
    * What about involuntarily sharing

Geller & Picard

- Emotion vs. mood
- Indicators
  - Face, voice, skin
- Internal state & expressed emotions & experienced emotion
- Limited communicative bandwidth
- Limited number of "base emotions"
- Songs and laws
  - society has laws, but cultural/emotional/tacit rules shape society as well
- Affective computing
  - Express and perceive emotions: 2x2 matrix
    * Computers than can perceive and express emotions are "user friendly"
- Applications
  - Summaries take emotions into account
  - Automatic video editing to express emotions
  - Item "see what you need"

5 Computing & Culture

Required Reading Tie-ins

- Palmer, Scott, and Sita Popat. "Dancing in the Streets: The sensuous manifold as a concept for designing experience." International Journal of Performance Arts and Digital Media 2, no. 3 (2007): 297-314.
- Cheok, Adrian David, Kok Hwee Goh, Wei Liu, Farzam Farbiz, Siew Wan Fong, Sze Lee Teo, Yu Li, and Xubo Yang. "Human Pacman: a mobile, wide-area entertainment system based on physical, social, and ubiquitous computing." Personal and ubiquitous computing 8, no. 2 (2004): 71-81.
- Lantz, Frank: PacManhattan. In: Montola, M., Stenros, J., & Waern, A. (2009). Pervasive games: theory and design. CRC Press.
- Dourish, P., & Bell, G. (2014). "Resistance is futile": reading science fiction alongside ubiquitous computing. Personal and Ubiquitous Computing, 18(4), 769-778.

Palmer & Popat

- Binary rhythm of transparency and reflectivity?
- No, the sensuous manifold
- User Interfaces are not only about Usable → User Experience
  - Desirable
  - Useful
  - Needed
  - Understandable
  - Appropriate
- If technology becomes human, fear can be taken away
- With focus on experience, technology becomes invisible
- Designing a choreography of humans & technology
- Process of design involves play
  - look, what people naturally do
- Magical experience, don't make me think, but will it last?

Pacman

- Human Pacman
  - high on technology
  - Augmented reality to see pills
  - Not a casual game
- PacManhattan
  - low on technology
  - only superpills visible
    - taped to lamp posts
  - Players on the street & in control centre

Dourish & Bell

- 5 TV-series, 5 years
  - Star Trek, Doctor Who, Blake's 7, The Hitchhiker's Guide to the Galaxy, Planet of the Apes
- Topics
  - Images of bureaucracy
  - Technological breakdown
  - Frontiers & Empires
- Implications
  - Surveillance
  - Role of the state
  - Equality, diversity, order
- In AmI research, often only technological side seen
- Technology is always social
  - Social forces not only after deployment
- Make social forces explicit

6 Required Reading

Course Facets

- **Definitions & Theory**
  - Context, Ambient Intelligence
- **Descriptive Framework & Examples**
  - Facets, Architectures, Examples
- **Implementation & Evaluation**
  - Challenges, Prototyping, Deployment, Evaluation
- **Human & Computer**
  - Interaction, Privacy, Emotion
  - *Trust*
    - *Explanations, Context*
- **Computing & Culture**
  - Arts & Games
- **Specific Issues**
  - Uncertainty, Privacy-respecting technologies

Required Reading

- Required reading for week 1
  - Weiser, M. (1991). *The computer for the 21st century*. Scientific American, pages 94–104.
- Required reading for week 2
  - Aarts, E., R. Harwig, and M. Schuurmans. 2001. Ambient Intelligence. In *The Invisible Future: The Seamless Integration of Technology into Everyday Life*, ed. P. J. Denning, pp 235-250. New York: McGraw-Hill Companies.
- Required reading for week 3
  - Dourish, Paul, and Ken Anderson. *Collective information practice: exploring privacy and security as social and cultural phenomena*. Human-computer interaction 21.3 (2006): 319-342.

- Required reading for week 4
  - Dourish, Paul. “What we talk about when we talk about context.” Personal and ubiquitous computing 8, no. 1 (2004): 19-30.
- Required reading for week 5
  - Tom Geller: “How Do You Feel? Your Computer Knows.” Communications of the ACM Vol. 57(1), pp. 24-26. Jan. 2014
  - Rosalind W. Picard: “Affective Computing”. MIT Technical Reports – TR 321. Nov. 1995
- Required reading for week 6
  - Davies, N., & Gellersen, H. W. (2002). “Beyond prototypes: Challenges in deploying ubiquitous systems.” IEEE Pervasive computing, 1(1), 26-35.
  - Hansen, T. R., Bardram, J. E., & Soegaard, M. (2006). “Moving out of the lab: Deploying pervasive technologies in a hospital.” IEEE Pervasive Computing, 5(3), 24-31.
- Required reading for week 7
  - Abowd, Gregory D., Elizabeth D. Mynatt, and Tom Rodden. “The human experience” IEEE pervasive computing 1.1 (2002): 48-57.
- Required reading for week 8
  - De Ruyter, Boris, and Emile Aarts. “Experience research: a methodology for developing human-centered interfaces.” In Handbook of ambient intelligence and smart environments, pp. 1039-1067. Springer, Boston, MA, 2010.
- Required reading for week 9
  - Palmer, Scott, and Sita Popat. “Dancing in the Streets: The sensuous manifold as a concept for designing experience.” International Journal of Performance Arts and Digital Media 2, no. 3 (2007): 297-314.
  - Cheok, Adrian David, Kok Hwee Goh, Wei Liu, Farzam Farbiz, Siew Wan Fong, Sze Lee Teo, Yu Li, and Xubo Yang. “Human Pacman: a mobile, wide-area entertainment system based on physical, social, and ubiquitous computing.” Personal and ubiquitous computing 8, no. 2 (2004): 71-81.
  - Lantz, Frank: PacManhattan. In: Montola, M., Stenros, J., & Waern, A. (2009). Pervasive games: theory and design. CRC Press.
- Required reading for week 10
  - Dourish, P., & Bell, G. (2014). “Resistance is futile”: reading science fiction alongside ubiquitous computing. Personal and Ubiquitous Computing, 18(4), 769-778.

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Pieters, W. (2008). *La Volonté Machinale: Understanding the Electronic Voting Controversy*. Phd thesis, Radboud University, Nijmegen, The Netherlands.

Pieters, W. (2011). Explanation and trust: what to tell the user in security and ai? *Ethics and information technology*, 13(1):53–64.

Schank, R. C. (1986). *Explanation Patterns – Understanding Mechanically and Creatively*. Lawrence Erlbaum, New York.

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Weiser, M. (1993). Some computer science issues in ubiquitous computing. *Communications of the ACM*, 36(7):75–84.