Ubiquitous Computing

People-Oriented Computing

4.11.2019

Agenda

- Announcements
- CSCW challenges and approaches
- Ubiquitous Computing
  - Overview and history
  - Directions for ubicomp
  - Ubicomp methods and approaches

Announcements

- No lab this week
- Next lab in two weeks (18.11.2019)
- Sample exam questions posted on OLAT
  - Questions are representative of the types of questions you will see on the exam

Learning Goals

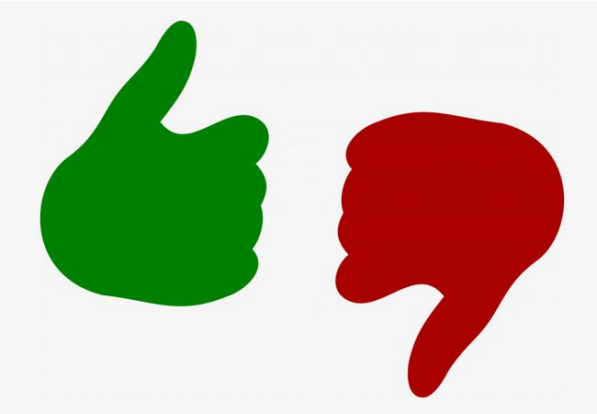
After this lecture you should:

- Be familiar with basic methods and approaches for informing CSCW design and evaluation
- Have an understanding of the field of ubiquitous computing and its origins
- Be aware of current directions for the development of ubicomp technologies
- Have a fundamental understanding of appropriate approaches for ubicomp design and evaluation

METHODS FOR INFORMING CSCW TECHNOLOGIES

Let's Try an Analysis

You are in charge of creating an application that allows meeting participants to give real time thumbs up/thumbs down feedback during a presentation. An aggregation of the last five minutes' of feedback data is displayed onscreen during the presentation



- Who are the potential primary, secondary, tertiary, and facilitating stakeholders?
- What kinds of challenges and effects might arise?

Challenges for CSCW

- Despite the ubiquity of CSCW tools in the workplace, many challenges still exist and a lot of potential is not yet fulfilled
  - Collaborative surfaces and other meeting room technologies not fully realized
  - Remote collaboration still impoverished compared to co-located
  - Many failed systems – expensive for organizations in terms of time and resources

Challenges for CSCW

- Difficult to model and analyze groups
- Difficult to predict effects on all parties
- Many groups of stakeholders affected
- Disparity between work and benefit
- Difficult to attain critical mass
- Effects on social processes and norms
- Exception handling
- Obtrusiveness of social features
- Failure of intuition
- Difficulty of evaluation

How to Address Challenges of CSCW?

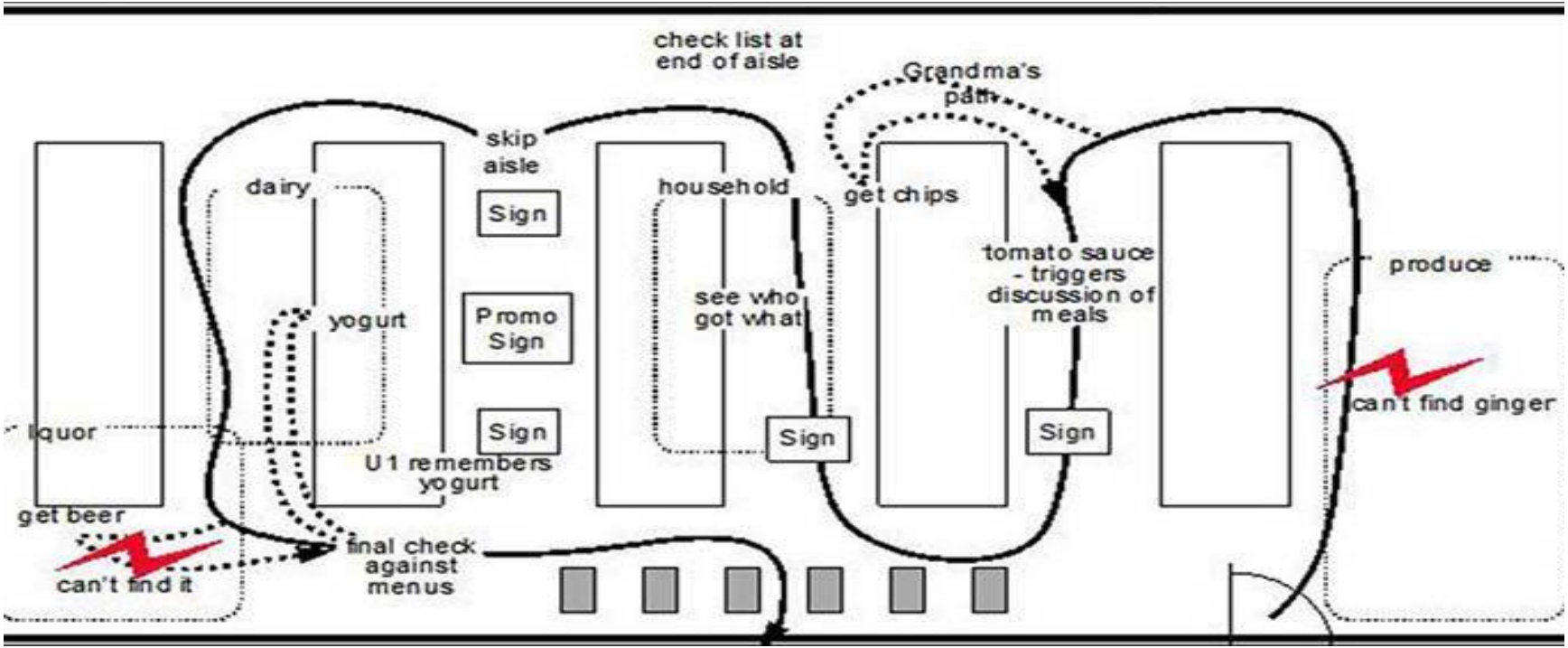
- Creating and understanding CSCW technologies requires complex approaches
- Methods should be appropriate for understanding complex groups and organizations
- Methods should involve multiple stakeholder groups
- Should provide input of others to decision makers

Ethnography

Ethnographic Methods

- Focuses on studying work practice in situ
- Based on premise that work can only be understood if it is observed while it is happening
  - Asking people what they do will not yield the whole truth
- Detailed recording of interactions among people and between people and the environment
- Takes an unbiased view and open-ended view of the situation
  - Goal is to describe the situation, not necessarily to look for solutions

Contextual Inquiry



Contextual Inquiry

- Based on similar ideas as ethnographic inquiry but geared towards interpretation and system design
- Investigator studies work in situ, takes apprentice role to learn about users' work
- Makes use of observation and interviews

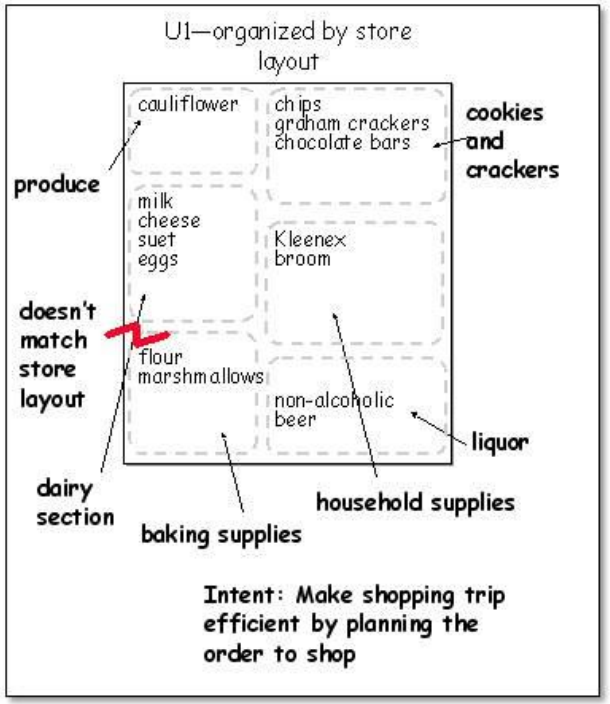
Contextual Inquiry

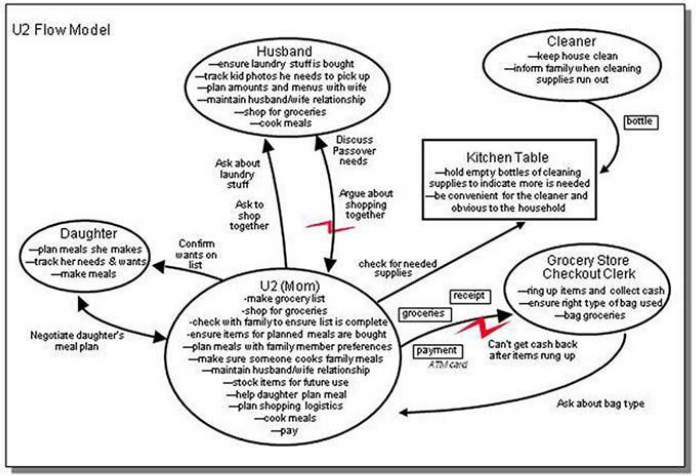
Develops models to represent knowledge about the work environment

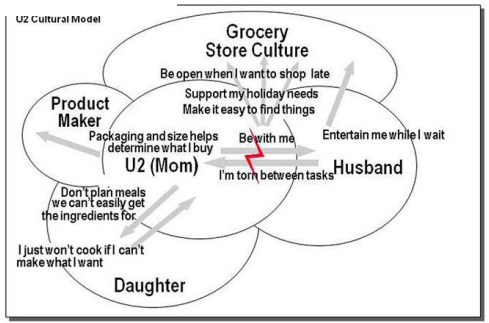
- **Task models** – specify required steps for work tasks
- **Physical model** – represents physical work environment and its impact on practice
- **Flow model** – shows lines of coordination and communication between people
- **Cultural model** – reflects influences of work culture and policy including official and unofficial codes of behavior and expectations
- **Artifact model** – describes structure and use of artifacts within work processes

Data is interpreted and used to shape design

Contextual Inquiry







Participatory Design

Participatory Design Method

- Philosophy that encompasses entire design cycle
- Users involved not only as subjects or consultants, but as members of design team and active collaborators
- Users treated as experts in the domain

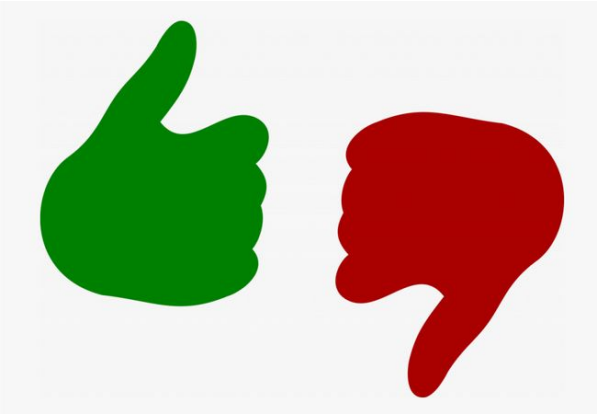
Participatory Design Method

Can entail many processes, including:

- **Brainstorming** – involving participants in pooling ideas an informal and unstructured process
- **Storyboarding** – creating representations of users' day-to-day activities
- **Workshops** – focused activities to fill in missing knowledge and allow for mutual inquiry between designers and users
- **Pencil and paper exercises** – creation and discussion of designs with low overhead and low risk

How Might we Apply these Approaches?

Imagine an application that allows meeting participants to give real time thumbs up/thumbs down feedback during a presentation. The feedback is shown onscreen.



- What methods might you employ during your process of designing, deploying, and evaluating your system? What challenges would you try to address with these approaches? What questions would you try to answer?

UBIQUITOUS COMPUTING


I have no idea
what the future
will be!
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Technology and Societies

Profound changes in recent decades

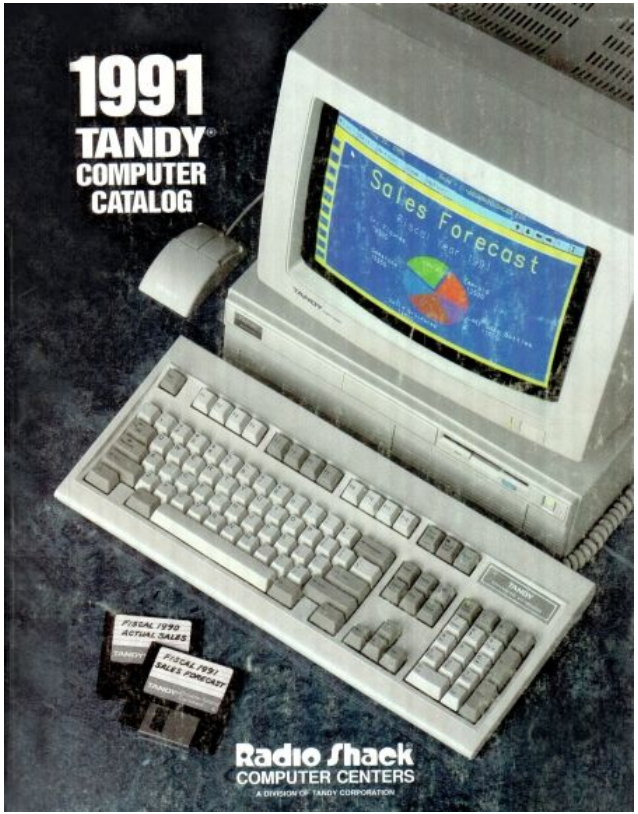
- Ubiquity of devices
- Abundance of data being collected and generated
- Concerns about data access and privacy
- Expectations about connectedness and communication
- Impact on work and study expectations
- Impact on social relationships
- Expectations regarding access to information
- Blurring of work and free time

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."*

- *Mark Weiser (1991), "The Computer for the 21st Century"*

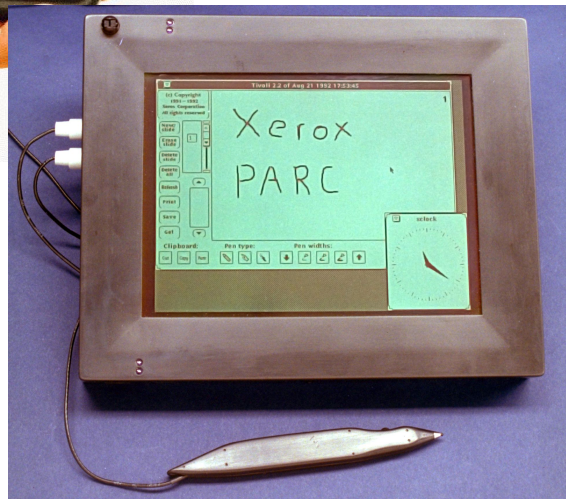
Computing in 1991

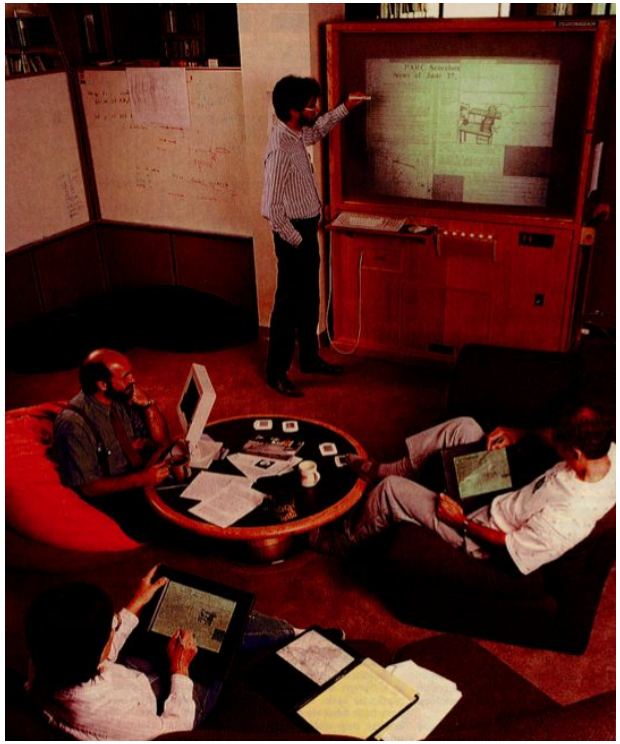


“The Computer for the 21st Century”

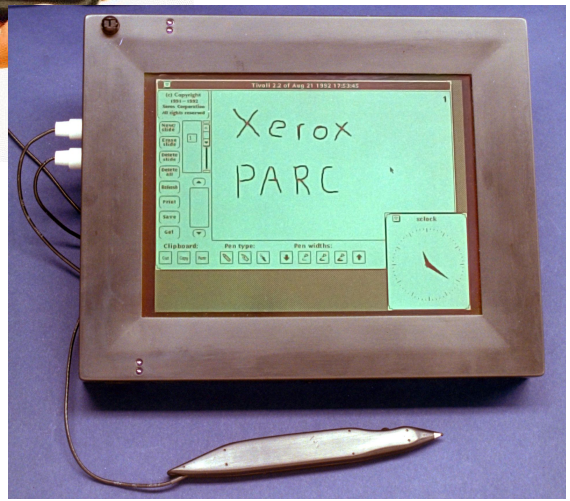
- Introduced a revolutionary vision for computing
- Computing at different scales
  - Pads
  - Tabs
  - Boards
- Third wave of computing – high ratio of devices to humans

Pads, Tabs, and Boards





Pads, Tabs, and Boards?



“The Computer for the 21st Century”

Weiser focused not only on new technologies but on the impact of ubicomp on the human experience

> *“Machines that fit the human environment instead of forcing humans to enter theirs will make using a computer as refreshing as a walk in the woods.”*
>
> *“We wanted to put computing back in its place, to reposition it into the environmental background, to concentrate on human-to-human interfaces and less on human-to-computer ones.”*

Ubiquitous Computing

Often referred to as “off-the-desktop” computing – a move away from interaction with a single workstation

- Mobile devices
- Large interactive screens
- Alternative means of interaction including voice, vision, gestures
- Interactive environments
- Sensor-based interactions

Has Weiser's Vision Been Realized?

DIRECTIONS FOR UBIQUITOUS COMPUTING

Ubiquitous Computing

What is necessary to realize the **human-centered vision of ubicomp**?

Defining the appropriate physical interaction experience

Discovering general application features

Theories for designing and evaluating the human experience

Ubiquitous Computing

What is necessary to realize the **human-centered vision of ubicomp**?

Defining the appropriate physical interaction experience

What **form** does the interaction take? How do we interact with the system?

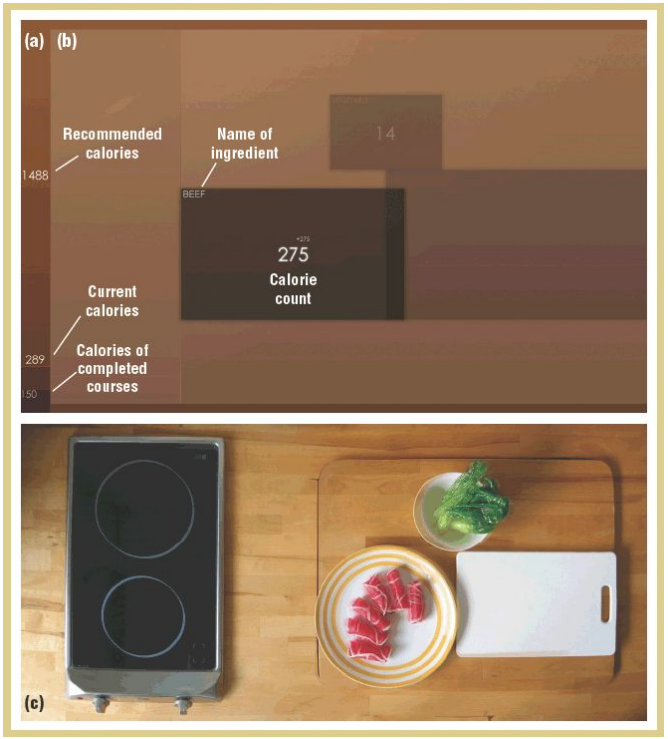
Defining Appropriate Physical Interaction Experience

- New approaches to input and output
  - Implicit input
  - Multi-scale and distributed output
  - Seamless integration of physical and virtual worlds

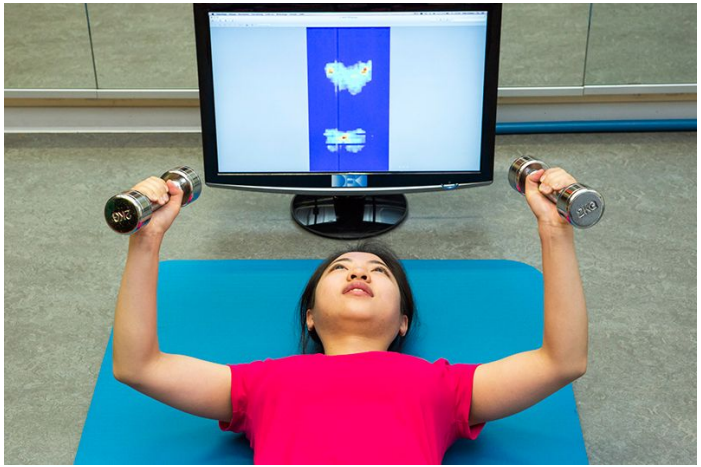
Implicit Input

- Input technologies are becoming increasingly diverse, and along with it increasingly implicit
- Natural interactions with the environment can provide sufficient interaction to a variety of services without explicit user interaction, e.g.:
  - Interfaces that recognize when people are present in the room and respond
  - Surfaces (tables or whiteboards) that automatically capture work done on them
  - Fitness trackers that collect data about your activities

Implicit Input Examples

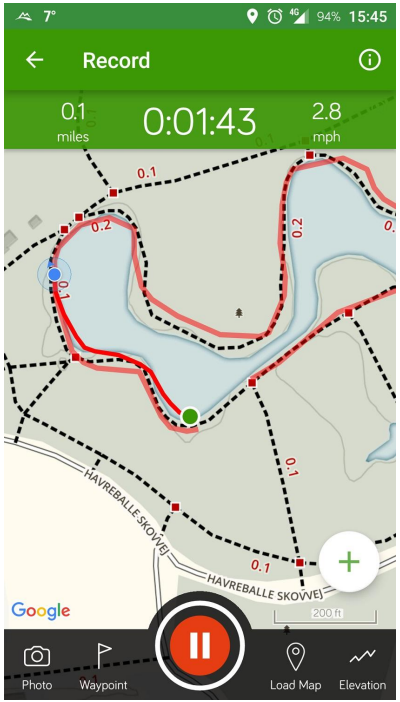


Calorie Aware Kitchen, NTU 2008



Smart Mat Fitness Trainer, DFKI 2015

Implicit Input



Multi-scale and Distributed Output

- Ubiquitous computing requires novel output technologies and techniques
- Output technology design needs to move beyond visual displays and consider form and aesthetic appeal
- Ambient displays, displays of varying scales, audio output

Multi-scale and Distributed Output

Real time snowboard training,
RWTH Aachen 2009

Spectacle Computing, CMU 2011

Seamless Integration of Physical and Virtual Worlds

Ubicomp attempts to merge computational artifacts with physical artifacts by **merging the two worlds**

- Input can be merged by incorporating physical objects and digital objects (**tangible interfaces**)
- Output can be merged by overlaying digital information on the real world (**augmented reality**)

Seamless Integration of Physical and Virtual Worlds

Tangeo – University of Auckland, 2013

Seamless Integration of Physical and Virtual Worlds

IKEA Place app, 2017

Examples from life

Take a few minutes and think about technologies that you have used.
Which ones make use of the following input/output approaches, and how?

- Implicit input
- Multi-scale or distributed output
- Integration of physical and virtual worlds

Ubiquitous Computing

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Ubiquitous Computing

What is necessary to realize the **human-centered vision of ubicomp**?

How should the technology **work**? How does it **function** and what does it **support**?

Discovering general application features

Discovering General Application Features

Functions that support daily activity

- Context-aware computing
- Automated capture and access
- Continuous interaction

Context-aware Computing

- Using **implicitly sensed context from physical and electronic environment** to determine the correct behavior of a service
- Intended to make interactions with services **more seamless and less distracting** from everyday activities
  - E.g., cars that recognize the driver and adjust the environment to him/her
  - Smart thermostat systems that learn your schedule and adjust the heat in your home accordingly

Context-aware Computing

Context-aware computing can make use of different types of information

- Where - Location of people
- Who - Identity of people
- When - Routines or time spent
- What - Sensing of specific activities – often requires interpretation
- Why - Reasons or other context, e.g., mood, heart rate, etc.

Automated Capture and Access

- Human recording and retrieval of information is generally inefficient, incomplete, and error prone, especially when there are multiple relevant streams of data
- Automated recording of information from events has long been regarded as both valuable and dangerous
- Computational tools can remove or reduce the burden of recording and organizing information

Automated Capture and Access

- Focuses on **preservation and recording of live experiences** for **review or access** by user in the future as well as **access interfaces**
  - E.g., classroom activities, meetings, special events, conversations, traffic cameras
- Vannevar Bush's idea for the Memex was an early example of a capture and access technology for textual artifacts and other documents

Continuous Interaction

- Providing **continuous interaction** moves computing from localized tools to **constant, ubiquitous presence**
- Focuses on informal daily activities (rather than goal-oriented tasks)
- E.g., fitness trackers, notifications on a smart watch, mindfulness technologies, health monitoring technologies

Continuous Interaction

Informal daily activities present new challenges for design

- Rarely have a clear beginning or end point so design cannot assume common starting point or closure
- Interruptions should be expected
- Multiple activities operate concurrently and may need to be loosely coordinated
- May consist of a number of subtasks that are loosely bundled

Examples from life

What technologies have you used that exemplify the following approaches, and how?

- Context aware computing
- Automated capture and access
- Continuous interaction

Ubiquitous Computing

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Ubiquitous Computing

What is necessary to realize the **human-centered vision of ubicomp**?

How do we understand the problems we are trying to address?
How do we understand the impact and effects of the technology?

Theories for designing and evaluating the human experience

Understanding Interaction in Ubicomp

- As with CSCW, understanding ubicomp interaction is more complicated than understanding interactions between a single user and a single machine
- Various models and methods are applicable to ubicomp, including:
  - Activity Theory
  - Situated Action
  - Distributed Cognition
  - Ethnography
  - Cultural Probes

Knowledge in the World

- Traditional models of cognition and interaction (e.g., Model Human Processor) focus on internal cognition
  - Three independent units for sensing, cognition, and motor activity, each with its own memory
- Complexity of ubicomp systems lends itself to models that consider both "**knowledge in the head**" and "**knowledge in the world**"

Activity Theory

- A descriptive theory that recognizes traditional concepts such as **goals**, **actions**, and **operations**
- Treats goals and actions as fluid **based on the changing state of the world** rather than a priori plans
- Emphasizes the **transformational properties of objects** that carry knowledge and traditions
- Ubicomp systems informed by activity theory would focus on transformational properties of artifacts and fluid execution of actions and operations

Situated Action

- Theory that **rejects the notion of pre-planned goals** as the motivation for action
- Emphasizes the **improvisational nature of human behavior** based on the changing world
- Ubicomp systems informed by situated action would emphasize improvisation and seek to add useful knowledge to the world to shape actions
- Evaluation of systems would **emphasize real-time observation** and **reject post-hoc explanation**

Distributed Cognition

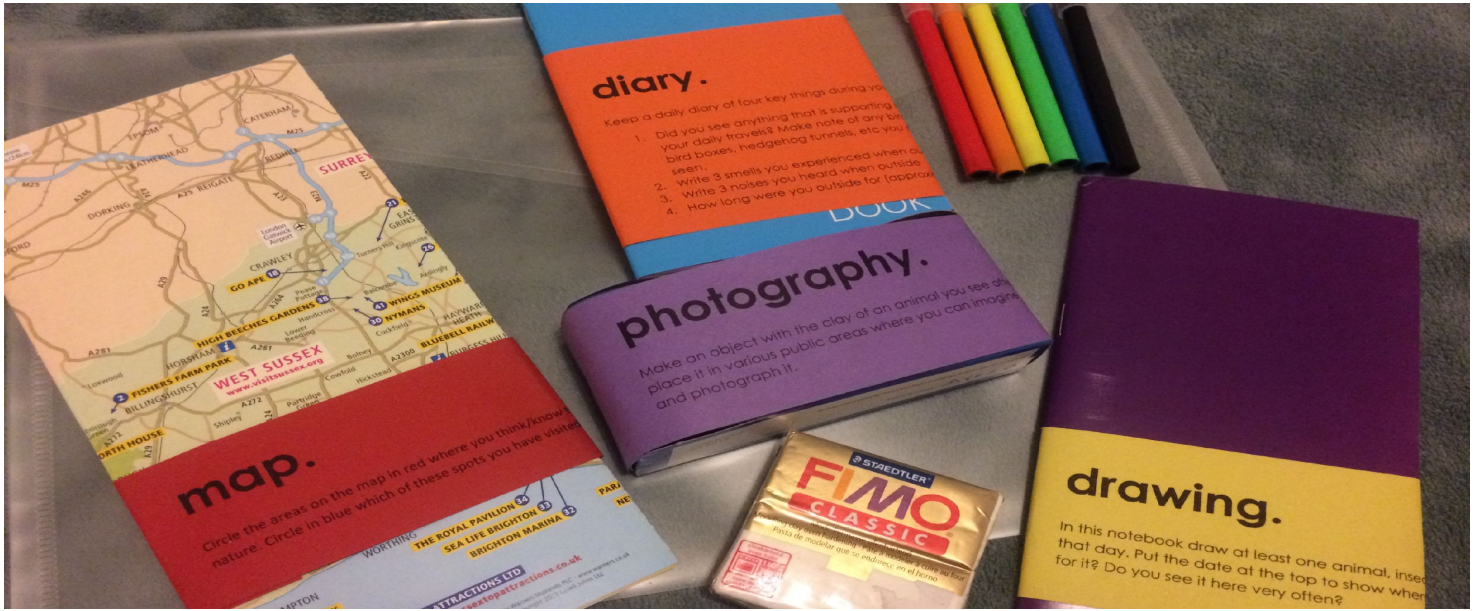
- Another theory that **de-emphasizes internal human cognition**
- Treats humans as a part of a larger system in which the **knowledge is distributed among the components**, including humans and objects
- Objects themselves act as triggers for action and reflect the state of the system
- Ubicomp systems informed by distributed cognition would focus on larger system goals rather than individual interactions or appliances and focus on how information is encoded in objects and transmitted

Ethnography

- Descriptive approach based in anthropology that focuses on observation of everyday practices in situ
- Recognizes that people’s conscious conceptions of what they do are incomplete and inaccurate
- Valuable for gaining rich understanding of settings and practices
- Used to inspire design rather than as a way of finding solutions

Cultural Probes

- Developed by Gaver as a way of of gathering rich data from people without the intrusion of observation



Cultural Probes

- Developed by Gaver as a way of of gathering rich data from people without the intrusion of observation
- Small packages of items with guidelines for use designed to provoke and record comments given to people to use in their own environments
    - E.g. drawing pads, single-use cameras, voice recorders, diaries, activity workbooks
- Used to understand what is significant for the people in the environment and to convey aspects of the environment's culture to designers

Evaluation of Ubicomp Systems

- Evaluation of Ubicomp systems is also more challenging than evaluation of single user-single machine interactions
  - Ubicomp often relies on cutting edge or novel technology that are not yet reliable and robust
  - Hard to test systems in real world deployments
  - Often long-term use in “living laboratories” or real world settings are necessary to understand their real impact

The Ubicomp Vision

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