RAS/IFRR Summer School on
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Introduction to

Human-Computer Interaction (HCI)

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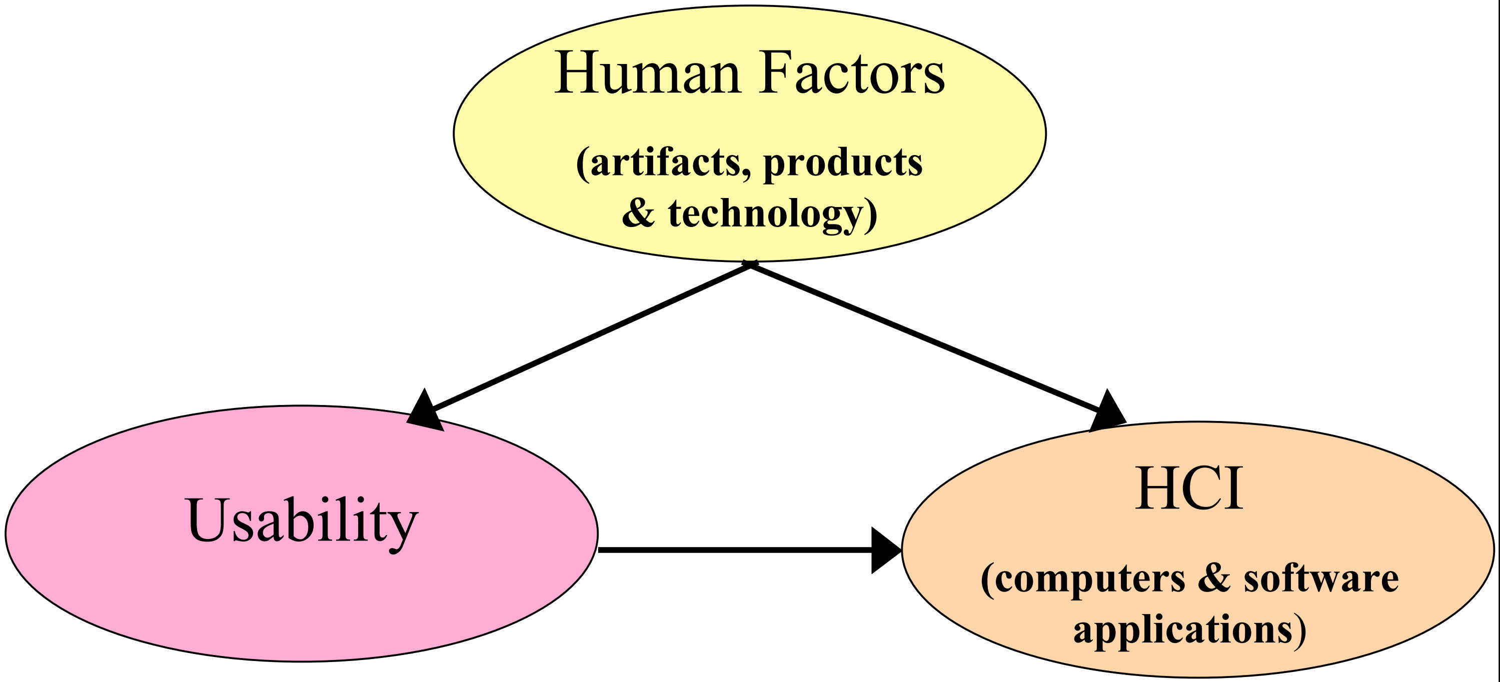
Human Factors

- Originated within US military during WW2
- Badly designed weapons can kill your own forces instead of the enemy ➔the birth of usability
- Applied to industry and product development

Components of Human Factors

- Study of human beings:
  - Understanding the advantages & limitations of the human body and mind
  - Understanding how human performance is affected by environmental factors
- Multidisciplinary:
  - Psychology
  - Anthropometry
  - Environmental medicine
  - Engineering
  - Statistics
  - Industrial design

Overview I


Human Factors
(artifacts, products & technology)
Usability
HCI
(computers & software applications)

What is HCI?

- The study of relationships between people and computers/computer-mediated information
- The design, development and evaluation of models, systems, techniques and applications from a human-centered perspective

ACM Taxonomy of HCI

Use and Context

- Social Organization and Work
- Application Areas
- Human-Machine Fit and Adaptation

Human

- Human Info Processing
- Language, Communication and Interaction
- Ergonomics

Computer

- Input and Output Devices
- Dialog Techniques and Types
- Computer Graphics – Interface Screen Design

Development Process

- Design Approaches
- Implementation Techniques and Tools
- Evaluation Techniques

Typical Topics in HCI

Human cognition

- perception; visual/auditory cognition; ecological interfaces; motion cognition; memory and attention; meaning and representation; learning; language understanding; mental models and metaphors

Designing for collaboration & communication

- information visualization; online communities; dialog models; presentation styles; group dynamics; groupware and discussion-ware

Typical Topics in HCI (cont'd)

Understanding how interfaces/technology affect users

- ergonomics; safety-critical systems; work environments; social and behavioral impact (individual and group); diversity and the digital divide

User-centered approaches to interaction design

- identify needs and establish requirements; integrate users into design, prototyping and construction phases

Typical Topics in HCI (cont'd)

Usability evaluation

- observing users; testing and modeling users; expert evaluations

Interaction styles

- direct manipulation; virtual environments; menus and forms; commands and natural language; hands-free input; heads-up displays

Interaction devices

- keyboard, pointing devices, speech I/O, image and video I/O, other sensory devices, mobile devices

Why Do We Need HCI?

- Software forgets
- Software is lazy
- Software is inflexible
- Software blames and abuses users
- Software won’t take responsibility
- Software will thwart your goals and ambitions

What’s the Problem, Anyway?

“To be a good programmer, one must be sympathetic to the nature and needs of the computer.
But the nature and needs of the computer are utterly alien to the nature and needs of the human being who will eventually use it.”

“In the programmer’s mind, the demands of the programming process not only supercede any demands from the outside world of users, but the very languages of the two worlds are at odds with each other.”

- Alan Cooper, *The Inmates are Running the Asylum*

What’s the Problem, Anyway?

“When the creators of software-based products examine their handiwork, they overlook how bad it is.

Instead, they see its awesome power and flexibility. They see how rich the product is in features and functions.

They ignore how excruciatingly difficult it is to use, how many mind-numbing hours it takes to learn, or how it diminishes and degrades the people who must use it in their everyday lives.”

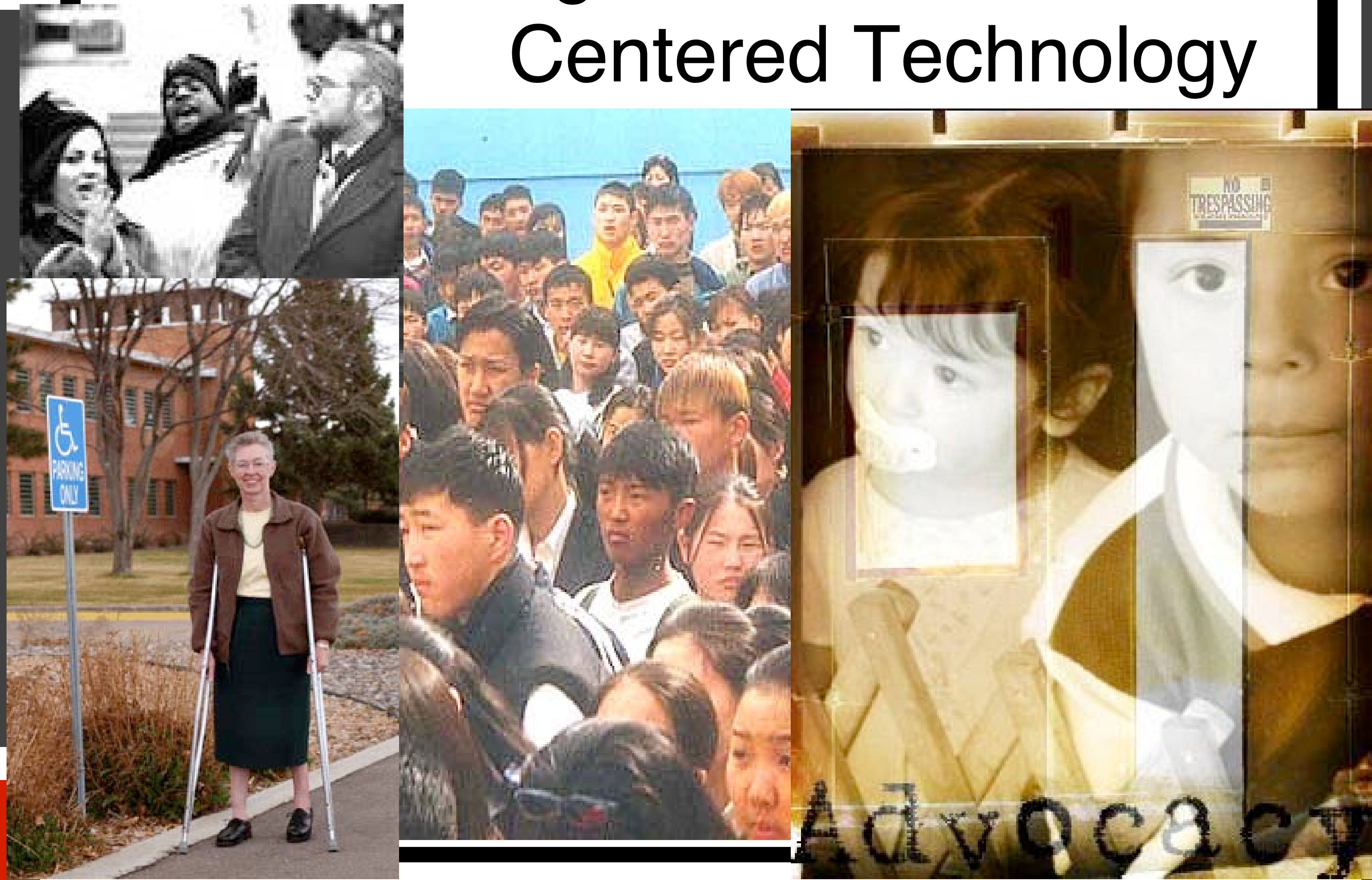
What’s the Problem, Anyway?

“Programmers aren’t evil. They work hard to make their software easy to use.

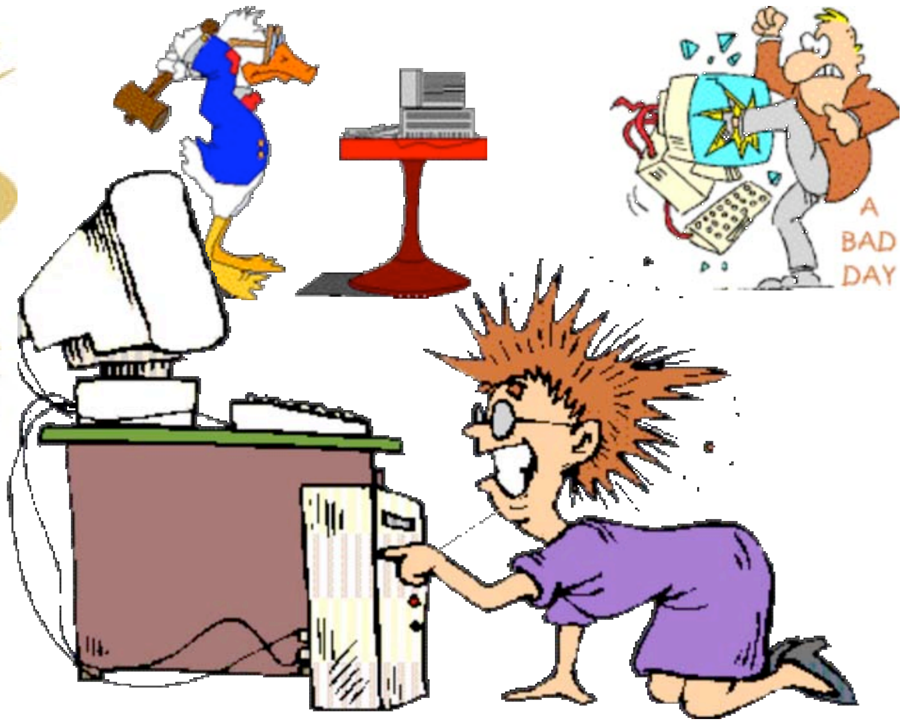
Unfortunately, their frame of reference is themselves, so they only make it easy to use for other software engineers, not for normal human beings.”

How Users Really Feel

Making the Case for User-Centered Technology



What is Usability?



- **The ease, speed and *pleasantness* with which intended people can use a product**

Usability

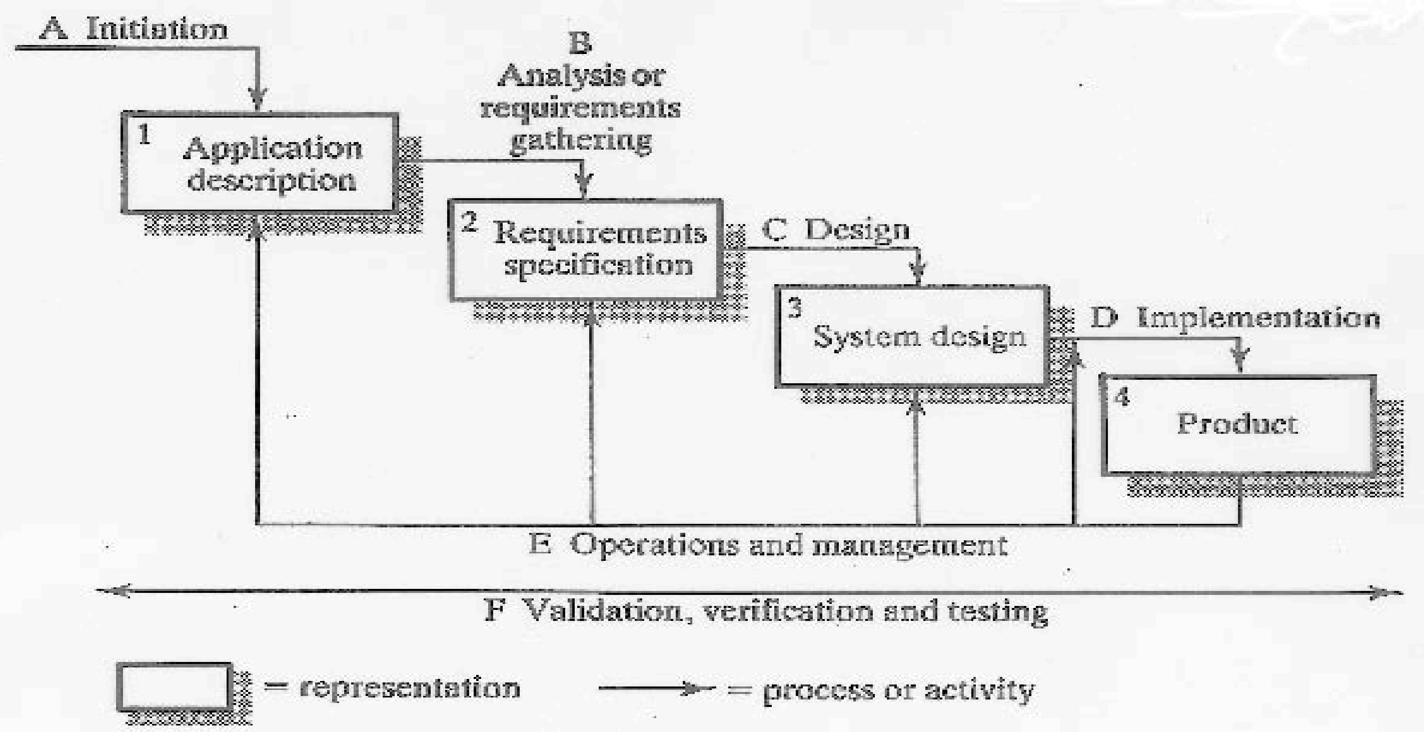
"is a measure of the *effectiveness, efficiency and satisfaction* with which specified users can achieve specified goals in a particular environment." (ISO 9241)

- **Usability as an outcome**: applications, websites (and robots?) that are usable
- **Usability as a process**: a methodology or approach (usually called "user-centered design")
- **Usability as a set of techniques**: usability testing, contextual inquiry, heuristic evaluation – there are many techniques whose aim is to improve usability
- **Usability as a philosophy**: where improved usability is a value that motivates the way in which products are developed

Usability Engineering

- A methodical approach to producing a user-centered application, web site or product
- A practical and systematic way to deliver a product that works for users
- Involves several methods, each applied at appropriate times, including gathering requirements, designing, developing and testing prototypes, evaluating design alternatives, analyzing usability problems, proposing solutions, and testing the interface with users.

Traditional Software Engineering



Traditional 'waterfall' model of system development.

User-Centered Development – How is it Different?

User-centric, not data-centric

- involves users in the entire process as much as possible

Highly interdisciplinary

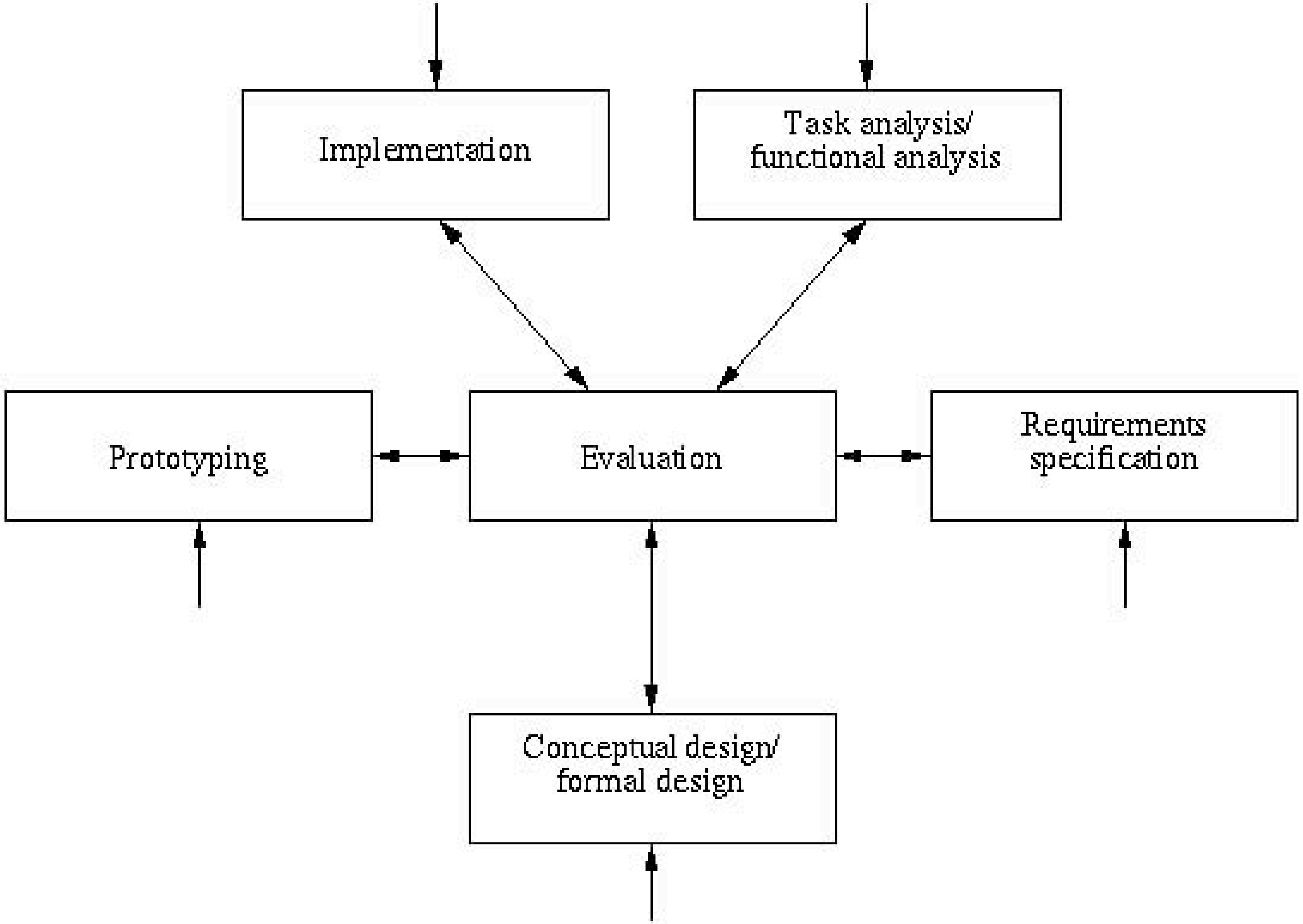
- draws on knowledge from a multitude of areas: art, psychology, technical writing, computer science, etc.

Highly iterative

- involves as much testing and revision as possible, especially before final implementation

The star life cycle

Order is less important than evaluation of ALL phases of development.



User-Centered Development

- Data Collection
- Data Analysis
- User Modeling
- Design
- Prototyping
- Evaluation

Data Collection Techniques

Quantitative Methods

- Benchmark tasks (time on task and error rates)
- Surveys
- User Questionnaires
- Statistical Analysis
- Good for market analysis, certain kinds of performance analysis

Data Collection Techniques cont'd

Qualitative Methods

- User Questionnaires (open-ended)
- Structured and semi-structured interviews
  - Stakeholder interviews
  - Subject matter expert (SME) interviews
  - User and customer interviews
- Literature review
- Product/prototype and competitive audits
- Focus groups

Data Collection Techniques cont'd

- Think aloud – running commentary while performing a task
- Talk right after
- Card sorting
- Role playing
- Cueing recall with videotape
- Contextual Inquiry
- User observation/ethnographic field studies
  - Immersive observation, artifact analysis and directed interview techniques

User-Centered Development

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Data Analysis Techniques/Stages

Needs Analysis

- Usually a one-paragraph overview

User Analysis

- Characterize the people who will use your product

Task Analysis

- What are the steps users take to accomplish their goals? A set of methods for decomposing people's tasks in order to understand the procedures better

Data Analysis Techniques cont'd

Environment Analysis

- Where will the product be used?

Functional Analysis

- What does the system need to do to help the users carry out their tasks? What aspects of the tasks should be automated vs. completed by humans?

Data Analysis Techniques cont'd

Requirements Analysis

- Formal specifications including data dictionaries, entity-relationship diagrams, object-oriented modeling, etc. (typically where SE begins…)

Protocol Analysis

- Apply (pre-specified or custom-designed) codes to user statements in order to detect patterns and to perform higher-level analyses

User Analysis

Physical Differences

- Age, gender, colorblindness and physical disabilities

Cultural Differences

- Ethnic background, education, profession, corporate style

Interaction Familiarity and Preferences

- Menus, popups, search commands, frames, mouse vs. keyboard, speech

User Analysis

Knowledge of Jobs

- Training, specialized vocabulary, tasks performed, potential impact of product on the workflow (technology doesn’t always improve things!)

Application Familiarity

- Novice, advanced beginner, competent performer, expert

Task Analysis Methods

Goals

- What do the people want to accomplish with your product? E.g., send a report to a branch office

Tasks and Actions

- What are the mechanisms used to accomplish the goals? E.g., find FedEx envelope, fill out air bill, put report in envelope and call for pickup

Task Analysis Methods

Job Analysis

- What a single person does in a period of time (a day, a week, etc.)

Workflow Analysis

- How work gets done when several people are involved

Environment Analysis

What does the physical layout look like?

- Offices vs. cubicles
- How close are co-workers to each other? (will sound be disturbing?)
- Will the computer be located on a normal desk?
- Does the person have both hands available for the computer?

What about ambient noise?
What are the lighting conditions?
Are there many interruptions?

User-Centered Development

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Modeling Aspects of Users

- Cognitive Modeling
- Mental Models
- Personas

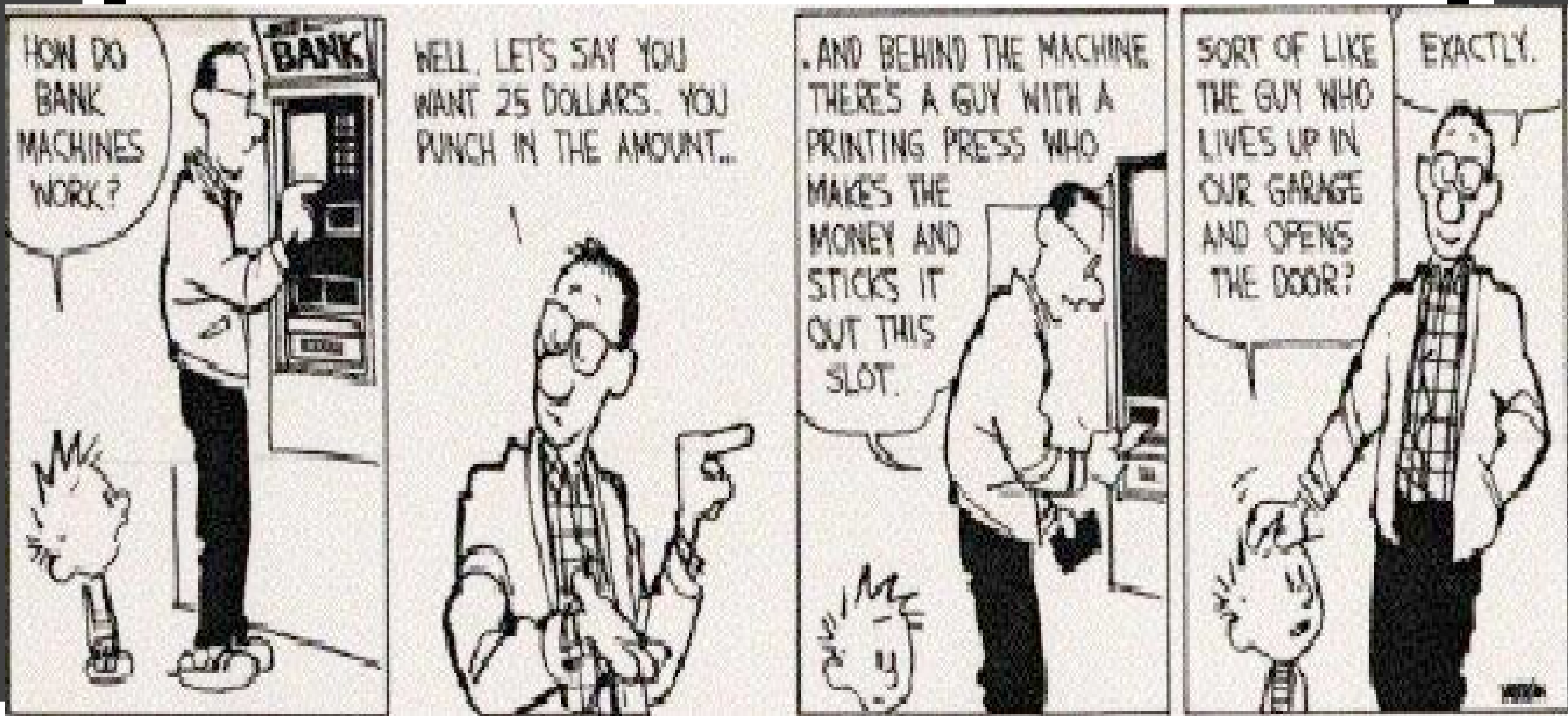
Cognitive Modeling

- Producing a computational model for how people perform tasks and solve problems, based on psychological principles.
- For example, GOMS is a family of techniques for modeling and representing the knowledge necessary for a person to perform a task. The acronym stands for Goals, Operators, Methods, and Selection Rules, the components of which are used as the building blocks for a GOMS model.

Mental Models

- Mental representations of how an object/system operates
- Help us predict the outcomes of our actions
- Help us identify and fix problems
- Developed by experience (trial and error), training and feedback
- Interaction with system should help user develop an accurate mental model of how the system works and what to expect

Mental Models cont'd



Personas

- Composite archetypes based on behavioral data gathered from many actual users through ethnographic interviews
- Hypothesize personas from preliminary data as the basis for the initial interviewing process; refine as new information becomes available
- Personas + Goals = Models of Archetypal users and their purposes
- Goals are the “what” and Tasks are the “how”
- Scenarios are used to step the personas through tasks in order to achieve goals

Personas cont’d

- What different sorts of people might use this product?
- How might their needs and behaviors vary?
- What ranges of behavior and types of environments need to be explored?

- Roles in business and consumer domains
- Behavioral and demographic variables
- Domain expertise vs. technical expertise
- Environmental considerations

Goals

Corporate goals

- Increase profit and market share
- Defeat competition
- Hire more people
- Offer more products

Personal goals

- Not feel stupid
- Not make mistakes
- Get an adequate amount of work done
- Have fun (or at least not be too bored)

Practical goals

(bridge gap between personal and corporate goals)

- Avoid meetings
- Handle the client's demands

User-Centered Development

- Data Collection
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Design Activities

- Coupled with early systems analysis activities such as needs, task and functional analyses
- Early and continual involvement of representative users
- Guided by well-established design guidelines and principles (e.g., consistency, use of real-world metaphors, human memory limits, screen layout, etc.)
- Includes setting Usability Specifications
  - Performance measures and preference measures – specify a target for each measure
- BUT guidelines do not eliminate the need for usability evaluation

Interface vs. Interaction Design

Interface design

- answers the question "how should this product present itself?" It tells us how the product should look in order maximize readability for the user, and includes the aesthetics of the product.

Interaction design

- answers the question "how should this product work?" It tells us how the elements of the product work together in order to both make its functioning clear and enable the user to undertake her most important tasks easily.

User-Centered Development

- Data Collection
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Prototyping

- Rapid prototypes are early and inexpensive ways to identify usability problems before committing lots of resources
- Low-fidelity prototypes (e.g., paper & pencil) have been found to be very useful in the early stages
- Iteratively higher-fidelity (computer-based) prototypes
- “Wizard-of-Oz” techniques (big, scary machine with little guy inside running the effects)

User-Centered Development

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Usability Testing & Evaluation

- Part of the process of usability engineering
- Includes a range of methods for having users try out one (or more) versions of a system
- In a typical usability test, users perform a variety of tasks with a prototype (or other system) while observers record notes on what each user does and says.
- Typical tests are conducted with one user at a time or two users working together.

Usability Testing & Evaluation

- Testing may include collecting data on the paths users take to do tasks, the errors they make, when and where they are confused or frustrated, how fast they do a task, whether they succeed in doing the task, and how satisfied they are with the experience.
- The goal of most usability testing is to uncover any problems that users may encounter so those problems can be fixed.

Usability Evaluation Methods

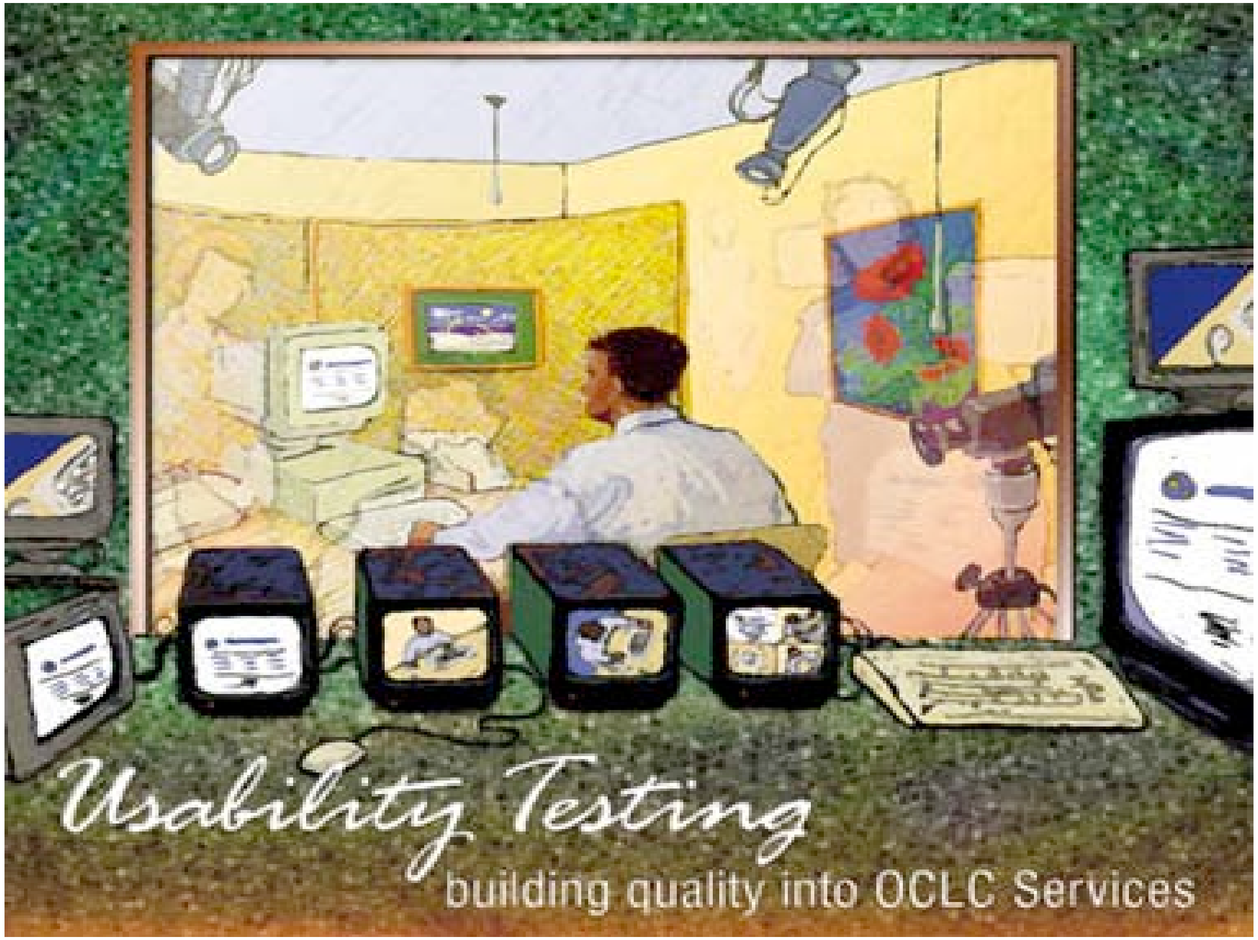
Participant-Based Methods

- Participatory Design
- Focus Group Research
- Surveys
- Field Studies
- Usability Testing

Expert-Based (Inspection) Methods

- Expert Reviews/Usage Simulations
- Heuristic Evaluation
- Walkthroughs
- Standards Inspection
- Consistency Inspection

Usability Evaluation Labs



User-Based Evaluation

Summative evaluation

- Used to make judgments about a finished product
- Statistical significance is an issue

Formative evaluation

- Used to detect and fix usability problems before interaction design is coded
- Relies on both quantitative and qualitative data

Contributions of User-Centered Development

- Multiple techniques for data collection
- Numerous methodologies for data analysis
- New kinds of user models
- New paradigms for software engineering
- Principles, guidelines and heuristics

Have these led to more effectiveness, efficiency and satisfaction for the users of software?

We're still working on it… !!

New Directions for HCI

- Need to move beyond WIMP (windows, icons, menus, pointer) interfaces
- "Every citizen" will not tolerate training courses, user manuals or on-line help to operate everyday objects
- Social impact – high risks if interfaces are threatening, intimidating or difficult to use
- When human factors was first adapted to user interfaces, ergonomics was largely filtered out – now it will need to be re-integrated

New Directions for HCI cont'd

- Ongoing need for new high-impact usability design and evaluation methods –
  - Cost-effective
  - Applicable to a wide variety of application types
  - Applicable to many new interaction styles (e.g., virtual environments)
  - Suitable for gathering usability data from remote and distributed user communities
- Develop "usability database" tools to capture methods, analyses and results for reuse
  - commonly accessible repository of a science base for the community and a practical knowledge base for exemplar usability problems, solutions and costs

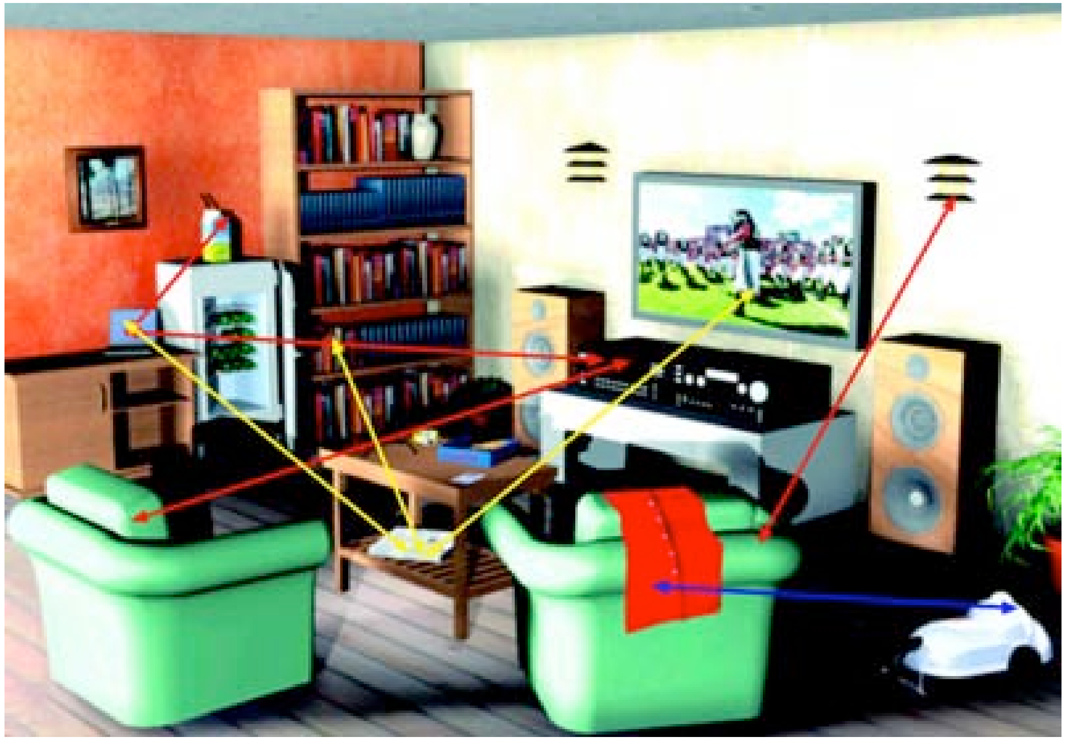
New Areas of HCI

- Groupware and computer-supported cooperative work
- Multimedia
- Interface access for the disabled or impaired persons
- Educational technology
- Hypermedia, Internet and cyberspace

New Areas in HCI cont'd

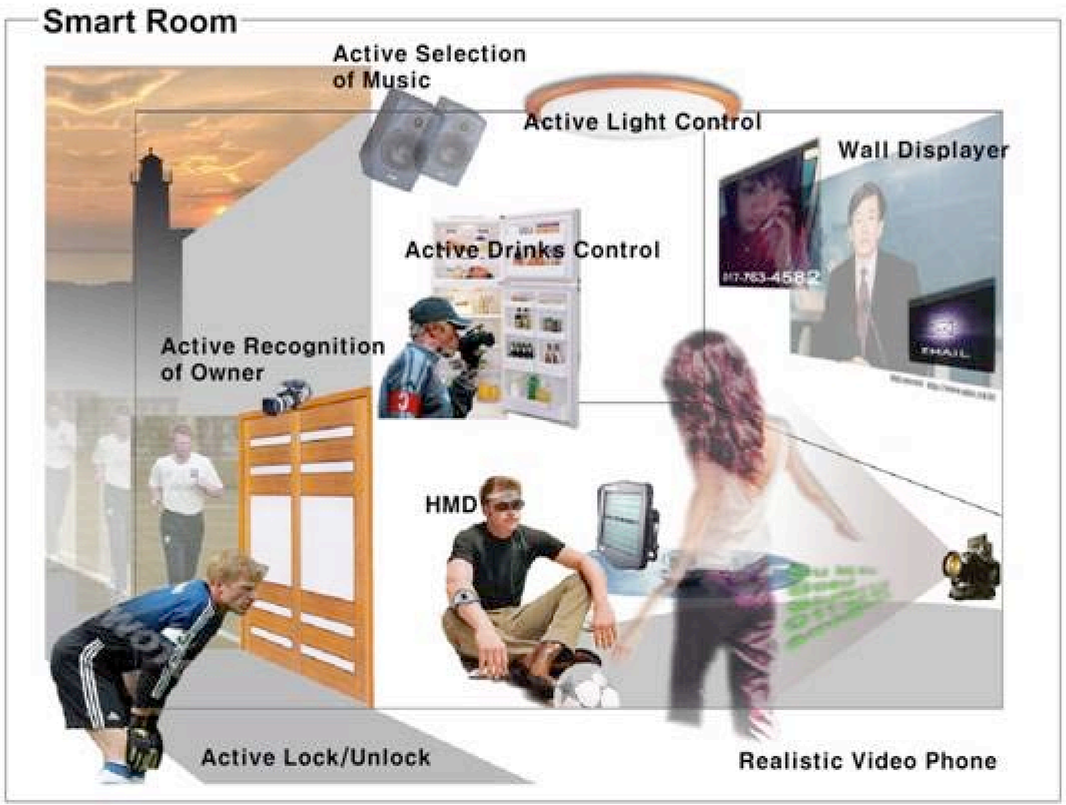
- Ubiquitous computing
- Pervasive computing
- Wearable computing
- Tangible bits, augmented reality and physical/virtual integration
- Attentive environments and transparent computing

Ubiquitous Computing



Technology is integrated seamlessly into the physical world in ways that extend human capabilities – should invisibly enhance the world

Pervasive Computing



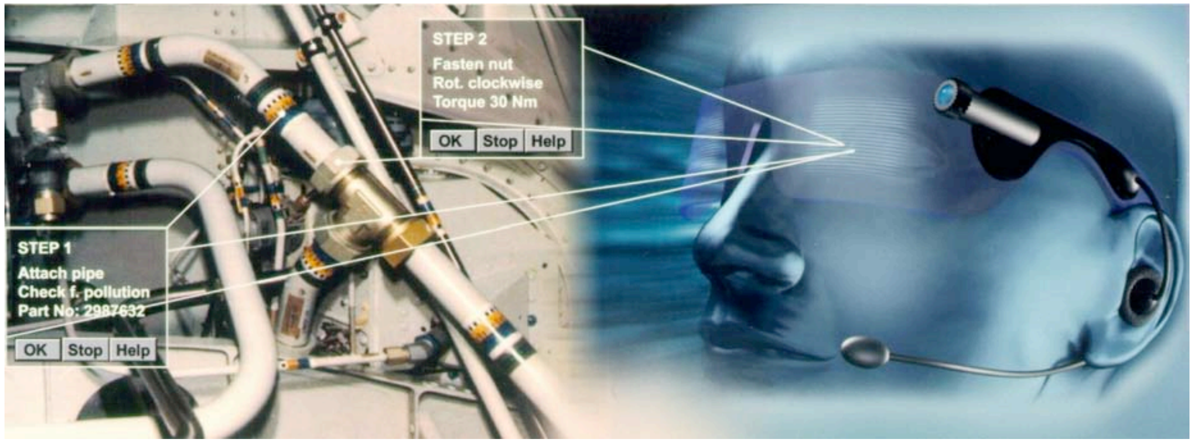
People should be able to access and interact with information any place and any time, using a seamless integration of technologies (e.g., smart appliances)

Wearable Computing

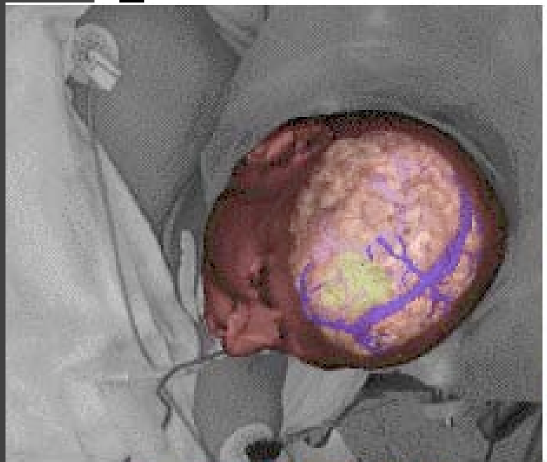
Embed multimedia and wireless technology on people in the clothes they wear

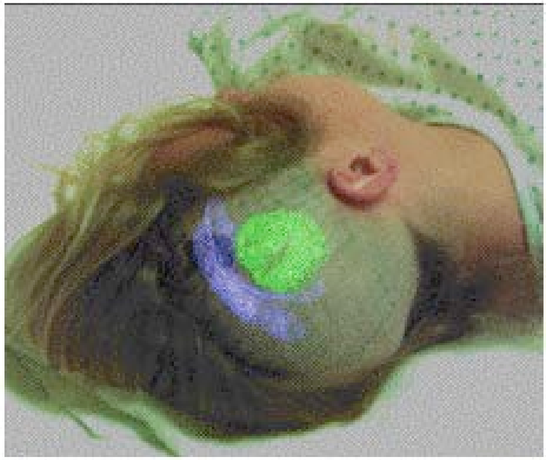
Augmented Physical/Virtual Environments

Combine digital information with physical objects and surfaces to allow people to carry out their everyday activities



Augmented Physical/Virtual Environments cont'd





Attentive Interfaces

- The computer should attend to the user's needs through anticipating what the user wants to do; i.e., interfaces respond to the user's expressions and gestures
- Space Odyssey 2001 – HAL
- Big Brother?

Evolution of Terminology

Interface Design

- Until early ‘90s, focus of HCI was primarily designing <u>interfaces</u> for single users

Computer-supported cooperative work

- Growing need to support multiple individuals working together using computer systems

Information systems

- Application of computing technology to domains like business, health, education

Interaction Design

- Newest term which encompasses a multiplicity of technology devices, end-users, domain needs

Interaction Design

Academic Disciplines

Ergonomics

Psychology/Cognitive Science

Informatics

Engineering

Computer Science/Software Engineering

Social Sciences

Design Practices

Graphic Design

Product Design

Artistic and Theatrical Design

Industrial Design

Film Industry

Interdisciplinary Fields

Human Factors

Cognitive Engineering

Human-Computer Interaction

CSCW

Cognitive Ergonomics

Information Systems

Hopes for HRI

Autonomous robots…need to carry out social and intellectual as well as physical tasks. Ideally, these robots will:

- Create a comfortable experience for people
- Gain their cooperation
- Encourage healthy rather than overly dependent behavior in clients, customers and co-workers
- Provide appropriate feedback to remote operators and others involved in the robotic system

Nielsen's Usability Heuristics

1. Visibility of system status
2. Match between system and real world
3. User control and freedom
4. Consistency and standards
5. Help users recognize, diagnose and recover from errors
6. Error prevention
7. Recognition rather than recall
8. Flexibility and efficiency of user
9. Aesthetic and minimalist design
10. Help and documentation

Why are Robots Different?

- People seem to perceive autonomous robots differently than they do most other computer technologies ➔ mental models are more anthropomorphic ➔ people may attribute human-like qualities and capabilities (e.g., Nass)
- Robots are likely to be fully mobile ➔ must consider physical interactions with people, objects and/or other robots; there may also be unexpected social interactions (e.g., Eklundh)
- Robots make independent decisions ➔ designers must consider physical, social and ethical implications of robots' autonomous behaviors

Case Study 1: Mobile Office Robot

User-centered iterative design of a fetch-and-carry robot for motion-impaired people in an office environment:

- Early stage questionnaire study to assess people's attitudes toward service robots
- Prefer "smart appliance", "personal assistant"
- Prefer robot that does only what it has been instructed to do, and does not act independently
- Most preferred speech interface, then touch screen, gestures and command language

Mobile Office Robot cont'd

- Adapted a framework for task analysis to find out about the users' needs and work tasks in the particular domain
  - Interviews with end users about their expectations and needs
  - Focus groups with people who are familiar with the domain
- Used these findings to guide development of prototype robot and interface components

Mobile Office Robot cont'd

- First prototype developed for simulation study – "Wizard of Oz" technique

•Results – users lacked sufficient feedback on the robot's state and where it was headed; users couldn't tell where the "front" of the robot was

•Users expected robot to respond to commands immediately, give instant feedback upon given commands, and perform tasks without errors

Mobile Office Robot cont'd

- New prototype developed with an industrial designer - combination of graphical user interface and spoken language interface

- Used "think aloud" walkthroughs to develop the GUI + interface heuristics & design guidelines

- Also included a life-like character attached to front of robot to help express robot state & "personality"

Mobile Office Robot cont'd

•Conducted 3-month field study with a typical user in a real office environment to test usability

•Unexpected results – other people (besides primary user) also get involved with the robot:

- •Impasse with cleaning trolley
- •Robot needs help completing task – must negotiate collaboration
- •Other people also try to communicate and interact with the robot, but robot just thinks of them as "obstacles"

Case Study 2: Moonlight in Miami

Center for Robot-Assisted Search and Rescue, University of South Florida, Tampa

- Field study of human-robot interaction in the context of urban search & rescue training exercise
- Training drill lasted 16 hours – data collection was opportunistic and observational – could not interfere with the exercise
- Focus on human side – rescue workers' reactions and experiences as they worked with robots
- Videotaped data collection – 2+1 cameras - robot's view + view of operator and operator control unit; when robot visible 3rd video recorded external view of robot in use

Moonlight in Miami cont'd

- Physical teaming: small robots carried in backpacks to the areas targeted to be searched, then are tethered

•Perceptual and cognitive teaming – people make decisions for robots and interpret the video, audio and thermal imaging data provided

•Ultimately people must fuse the robot info with other data sources and knowledge to identify victims and structural anomalies; conduct and coordinate the rescue efforts

Moonlight in Miami cont'd

- Resulting raw data - ~66 mins of videotape – transcription resulted in 502 statements
- Coding scheme developed to analyze the statements, then frequencies, percentages and correlations of the coding categories and elements generated to explore team process and communication
- Concepts used: mental models, situation awareness, protocol analysis
- Unexpected results – more time spent trying to understand situation awareness than in navigating the robots

Conclusions

- HCI has many contributions for HRI – standard techniques as well as more recent developments
  - How people perceive and think about computer-based technologies
  - Human constraints on interaction with machines
  - The factors that improve usability
  - The primary and secondary effects of technology on people and organizations
- But HCI is also evolving and must develop new techniques/methodologies for new paradigms
- HRI must start to be included in the circle of Interaction Design disciplines
- HRI has contributions to make to HCI as well

Exercise 1

- Goals:
  - Get to know more about each other in a constrained amount of time
  - Quick-and-dirty "field research" experience using human subjects
- Part 1 – Preparing to Collect Data
- Part 2 – Collecting the Data
- Part 3 – Summarize the Results
- Part 4 – Aggregate Your Information

Part 1 – Preparing to Collect Data

- Your task is to develop a brief interview questionnaire that will elicit the following information about your partner in 7 mins.
  - Brief professional description of your partner, including:
    - Personal experience of the HUMAN part of HRI (if any)
    - Would you rate this person's research as robot-centered or human-centered?
  - Brief personal description of your partner, including:
    - At least 2 interesting things about him/her

Part 2 – Collecting the Data

- Find a partner to work with – someone you don’t know at all
- Introduce yourselves and designate Partner 1 and Partner 2
- Partner 1 will first interview Partner 2. You have 7 minutes (including taking notes). (Time will be enforced!!)
- Then switch roles.
- Note that you should try to stick fairly closely to your interview questions.

Part 3 – Summarize the Results

- Write up a summary (1-2 pages max, format is up to you) of your interview results. This should be suitable to be read to the group. Your summary document will be used to introduce your partner to other people in the class, and will also be used for further data refinement. (10 minutes)

Part 4 – Aggregate Your Information

- Please sit at the big tables according to your Group ID (A, B, C or D)
- Each team of two should introduce each other by reading the summary of the interview (no summary should take more than 3 minutes!)
- Group goal: Try to develop a “Group Persona” that represents a “typical” student in your group.

Part 4 cont’d

- Recall, a “Persona” is a composite archetype of a group – description should best fit and represent overall group profile, even if some details don’t apply to everyone
- Your Persona should have the following:
  - A name
  - 3 sentences that describe the Persona personally
  - 3 sentences that describe the Persona professionally
  - 3 goals for this Persona for this week
- ~45 minutes

Discussion

- Persona presentation by each team
- Comments on the exercise:
  - Quantitative vs. qualitative data collection
  - Capturing information in a field setting?
  - Aggregation of data into Personas
  - Is any of this useful in your research?
- Other questions?

Some Resources

- http://usability.gov
- Papers from Special Issues on Human-Robot Interaction:
  - *Human-Computer Interaction*, 2004, Vol. 19
  - *IEEE Transactions on Systems, Man, and Cybernetics – Part C: Applications and Reviews, Special Issue on Human-Robot Interactions,* May 2004, Vol. 34, No. 2
- Hartson, H.R., "Trends in Human-Computer Interaction Research and Development", http://www.nap.edu/readingroom/books/screen/10.html
- http://www.csc.calpoly.edu/~erogers