Wearable and Mobile Human Computer Interaction

Professor Thad Starner
Contextual Computing Group
GVU Center, Georgia Tech

What If You Could…

- Reference the world's knowledge anytime, anywhere?
- Be reminded of your past experiences when you most needed them?
- Communicate with anyone, anywhere, at anytime?
- See critiques, historical information, diagnostics, etc. overlaid in appropriate places in the physical world?

Georgia Tech/MIT Cyborgs: a living experiment

The Mobile Advantage

- "Augmented memory"
- "Augmented reality"
- "Intellectual advantages"

Outline

Vision
A bit of history
Human Computer Interface
Challenges of Mobility
Text entry
Displays
Gesture systems
Experiments

Science Is Beginning to Look Like Science Fiction

- Science fiction writers are paying attention and provide good scenarios/motivation based on current research!
- Synthetic Serendipity, Fast Times at Fairmont High (Vinge)
- Historical Crisis (Kingsbury) in Far Futures anthology (Benford)
- The Diamond Age, Snowcrash (Stephenson)
- Islands in the Net (Stirling)

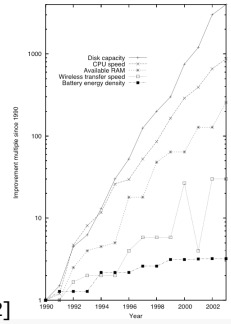
Wearable Computing Vision

- Pocket or clothing based computing
  - Core unit: CPU, RAM, storage, on-body network, off-body network, and battery (Intel's personal server)
- Runs entire day
- Wireless peripherals distributed on the body
  - Choose peripherals for the task
    - MP3 player: +headphones
    - Wireless messaging: +keyboard
    - Email & web browsing: +display
    - Camcorder: +camera
  - Allows rapid testing of interfaces in market

Mobile Technology Trends (1990-2003)

- Exponential technology improvement
  - 256X RAM
  - 900X CPU
  - 4000X disk
- Lagging technology
  - 30X wireless speed
  - 3X battery

[IEEE Computer2002]



On-body Computing Outsells "Personal Computers" in 2003

- 533M mobile phones
- 24M MP3 players
- 164M laptops, desktops, and servers (Gartner, IDC)

- More e-mail sent via phone in Japan than home PC (Newsweek)
- Motorola: "We don't make phones, we make wearable computers."

Brief History

1961


1966


1977


1981


1986


1991


1991


1992

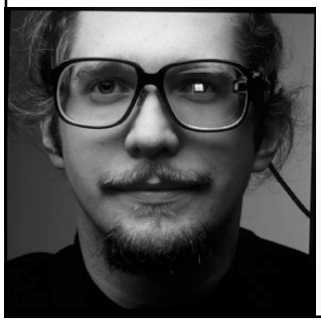

1993


1993


1996

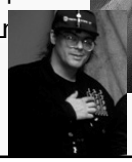
Miniature Head-up Displays

MicroOptical prescription display eyeglasses



Keyboards

- Twiddler
  - Chording
  - In 5 min. alphabet
  - In 1 hr touch typing
  - Speeds >60 wpm
- Embroider it in jacket!



CharmIT Wearable Computer

266MHz Intel Pentium or 800MHz Transmeta Crusoe

(www.charmed.com)

Quick Survey

- How many people
  - Own one?

Quick Survey

- How many people
  - Own one?
  - Have it with you?

Quick Survey

- How many people
  - Own one?
  - Have it with them?
- On average in my talks
  - ~50% own
  - ~25-50% of owners have it with them
- Many problems - interface is key

Why not a PDA?

- Too much cognitive load
  - Augment, not replace task
  - Two hands, both eyes
- Socially awkward
- Low functionality
  - Input speed
  - Data storage
  - "Hot sync" effect
  - Applications

Vertical Markets

- Warehouse picking
- Inspection
- Maintenance
- Repair
- "Line-busting"
- Security
- Military (Land Warrior/Pacific Consultants)

What is HCI?

The study of people and computing technology and the way they influence each other

Why study HCI?

We are surrounded by unusable and ineffective systems!

It's not the user's fault!

Costs are high in $$, time, frustration, missed opportunities

"Folk HCI" isn't the answer

Concepts, Principles, Guidelines

- No "cookbooks"
- No simple, universal checklists
- There are many concepts, principles, and guidelines
- **Understand** the higher level principles that apply across situations, display types, etc.
- **Implement** the standards and guidelines

UI Design Principles (Dix et al.)

- Categories
  1. Learnability
     - support for learning for users of all levels
  2. Flexibility
     - support for multiple ways of doing tasks
  3. Robustness
     - support for recovery

Frameworks for HCI

- "Folk HCI"
- Humans as sensory processors
  - Human factors, experimental psych
- Humans as interpreters/predictors
  - Cognitive psych, AI
- Humans as actors in environment
  - Activity theory, ethnography, ecol psych

What makes a system "usable"

- Humans as sensory processors
  - Fit with human limits
- Humans are interpreters/predictors
  - Fit with knowledge and task
- Humans as actors
  - Fit with task environment and social context

HCI Methods

- Humans as sensory processors
  - Quantitative evaluation
- Humans are interpreters/predictors
  - Task analysis, Cognitive walkthrough
- Humans as actors
  - Ethnographic field work, participatory design

Cognitive Frameworks

- Model-Human Processor (Card, Moran and Newell)
- Situated Action (Suchman)
- Activity Theory (Vygotsky, Nardi)
- Distributed Cognition (Hutchins)

Two view of interaction

- Interaction *with*
  - Software as a tool or machine
  - Interface is usability-engineered membrane
  - Human as processor & interpreter models
- Interaction *through*
  - Software as medium to interact with task objects or people
  - Interface plays a role in social context
  - Human as interpreter & actor models

Paradigm shifts

Networks and time-sharing
Video display units
Programming toolkits
Personal computing
Windows
Metaphors

Direct manipulation
Language vs. action (agents)
Hypertext/WWW
Multi-modality
CSCW
Ubiquitous computing

# People/# Computers	In/Out	Tech	Style

Paradigm Shifter: Vannevar Bush

- "As We May Think" - 1945 *Atlantic Monthly*
  "…publication has been extended far beyond our present ability to make real use of the record."
- Postulated **Memex** device
  - Stores *all* records/articles/communications
  - Items retrieved by indexing, keywords, cross references (now called hyperlinks)
  - (Envisioned as microfilm, not computer)
- Interactive and nonlinear components are key

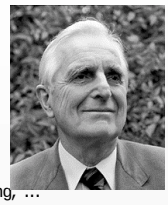
Paradigm Shifter: J.R. Licklider

- 1960 - Postulated "man-computer symbiosis"
- Couple human brains and computing machines tightly to revolutionize information handling

Paradigm Shifter: Ivan Sutherland

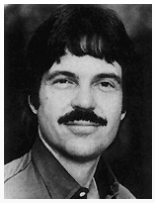
- **SketchPad** - '63 PhD thesis at MIT
  - Hierarchy - pictures & subpictures
  - Master picture with instances (ie, OOP)
  - Constraints
  - Icons
  - Copying
  - Light pen for input
  - Recursive operations

Paradigm Shifter: Douglas Engelbart



- Landmark system/demo:
  - **Mouse, windows**
  - Hypertext
  - Multimedia
  - High-res display,
  - Shared files, CSCW,
  - Electronic messaging, teleconferencing, ...
- Inventor of mouse and a chording keyboard

Paradigm Shifter: Alan Kay



- "Personal Computing"
- Dynabook: Notebook sized computer loaded with multimedia and can store everything
- Desktop interface metaphor

Paradigm Shifter: Ted Nelson

- Computers can help *people*, not just business
- Coined term "hypertext"

WIMP

- **W**indows, **I**cons, **M**enus, **P**ointers
- Timesharing = multi-users; now we need *multitasking*
- WIMP interface allows you to do several things simultaneously
- Has become the familiar GUI interface
- Xerox Alto, Star; early Apples

Direct Manipulation

- '82 Shneiderman describes appeal of graphically-based interaction
  - object visibility
  - incremental action and rapid feedback
  - reversibility encourages exploration
  - replace language with action
  - syntactic correctness of all actions
- WYSIWYG, Apple Mac

Metaphor

- All use is problem-solving or learning to some extent
- Relating computing to real-world activity is effective learning mechanism
  - File management on office desktop
  - Financial analysis as spreadsheets

Speech, Language?

- Actions do not always speak louder than words
- Interface as mediator or agent
- Language paradigm
- How good does it need to be?
  - "Tricks", vocabulary, domains
- How "human" do we want it to be?
  - (HAL, Bob, PaperClip)

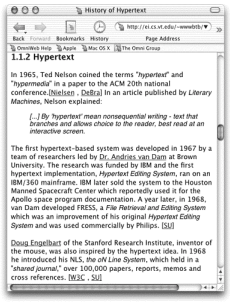
Multimodality

- Mode is a human communciation channe
  - Not just the senses
    e.g., speech and non-speech audi
    are two modes

- Emphasis on simultaneous use of multiple channels for I/O

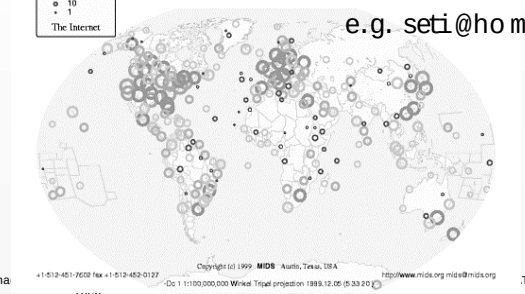
Hypertext

- Think of information not as linear flow but as interconnected nodes
- Nelson's hypertext
- Bush's MEMEX
- Non-linear browsing
- WWW '93
- Hyper media



The Interconnected Web

- The Network is the Computer
  e.g. seti@home



CSCW

- Computer-Supported Cooperative Work
- No longer single user/single system
- *Social* aspects are crucial (micro-social)
- E-mail as prominent success but other groupware still not widely used

Ubiquity

- Person is no longer user of virtual device but occupant of virtual, computationally-rich environment
- Can no longer neglect macro-social aspects
- Late '90s - PDAs, VEs, …

Copy Experiment

- Between-subjects design
- Pair-up (second hands?)
- Task 1: Copy "Thanks to" page
- Task 2: Copy "Ubiquity" page
- Two courses (A/B)
- NASA TLX

- [vest video; experiments in the field]

Controlled Studies

- CMU VuMan3 (Siewiorek/Smailagic)
  - Military inspection task
  - 2:1 savings in personnel
  - 40% faster
  - Custom design (many design generations)
- Georgia Tech Task Guidance (Ockerman)
  - Small airplane inspection by pilots
  - Basic manual emulation– no feedback
  - Wearable interface hindered expert!
    - Similar to checklist?
    - Providing context helped

Symbol Technologies WS series

Symbol's Success

- $5 million development costs
  - People sweat
  - Body armor
  - Plastic wears
  - Wearer buy-in through demonstration
- > 100,000 units; $3500-$5000 list
- Unique differentiator
- New markets

Speed of Access Experiment

- Pair up
- Person A: timer
- Person B: subject?

- Show of hands histogram

Application: Calendaring

- One of the most common PDA applications
- One of the most desired functions
- Occurs routinely in social conversation
  - One-on-one
  - Conferences
  - Meetings
- Anecdotal observation of

Scheduling Device Survey

- 138 subjects
  - Georgia Tech student center
  - 90% students; 88% age 18-25; 70% male
- Survey
  - What is your primary scheduling system while mobile?
  - 8 Likert scale questions on effectiveness, ease of use, speed, and reliability
  - Open response questions
- Schedule four appointments

Appointment Tasks

- "Could we meet sometime next Monday?"
- "Could we schedule a time to meet in the second week of February?" (three months in future)
- "Could we schedule a time to meet tomorrow?"
- "Could we reschedule our appointment in February from the 10th to the 11th?"

Videotaped Interactions

Scheduling device

Subject view

Timed retrieval, navigation, and entry

Actual vs. Claimed Usage

	Memory	Scrap	Planner	PDA	Other	# Used
Memory	24	9	16	4	4	57
Scrap	1	13	13	1	4	32
Planner			14	1	1	16
PDA				8		8
Other	1		1		6	8
#Claimed	26	22	44	14	15	121

Actual vs. Claimed Usage

	Memory	Scrap	Planner	PDA	Other	# Used
Memory	24	9	16	4	4	57
Scrap	1	13	13	1	4	32
Planner			14	1	1	16
PDA				8		8
Other	1		1		6	8
#Claimed	26	22	44	14	15	121

Actual vs. Claimed Usage

	Memory	Scrap	Planner	PDA	Other	# Used
Memory	24	9	16	4	4	57
Scrap	1	13	13	1	4	32
Planner			14	1	1	16
PDA				8		8
Other	1		1		6	8
#Claimed	26	22	44	14	15	121

Actual vs. Claimed Usage

	Memory	Scrap	Planner	PDA	Other	# Used
Memory	24	9	16	4	4	57
Scrap	1	13	13	1	4	32
Planner			14	1	1	16
PDA				8		8
Other	1		1		6	8
#Claimed	26	22	44	14	15	121

Thad Starner, GVU Center, Georgia Tech ICAT2004

Abandonment rates

- 43% of PDA users switched
- 68% of planner users switched
- Memory and scrap paper dominated

- Hypothesis: Users switch to mechanisms that are faster to access (similar to Miller68?)

Thad Starner, GVU Center, Georgia Tech ICAT2004

Timing (in seconds)

Device	Retrv.	Navig.	Retrv. + Navig.	Entry	Total
Scrap	17.8		17.8	18.1	35.9
Planner	11.8	7.6	19.4	12.5	31.9
PDA	11.0	12.7	23.7	14.0	37.7

Thad Starner, GVU Center, Georgia Tech ICAT2004

Timing (in seconds)

Device	Retrv.	Navig.	Retrv. + Navig.	Entry	Total
Scrap	17.8		17.8	18.1	35.9
Planner	11.8	7.6	19.4	12.5	31.9
PDA	11.0	12.7	23.7	14.0	37.7

Thad Starner, GVU Center, Georgia Tech ICAT2004

Timing (in seconds)

Device	Retrv.	Navig.	Retrv. + Navig.	Entry	Total
Scrap	17.8		17.8	18.1	35.9
Planner	11.8	7.6	19.4	12.5	31.9
PDA	11.0	12.7	23.7	14.0	37.7

Thad Starner, GVU Center, Georgia Tech ICAT2004

Timing (in seconds)

Device	Retrv.	Navig.	Retrv. + Navig.	Entry	Total
Scrap	17.8		17.8	18.1	35.9
Planner	11.8	7.6	19.4	12.5	31.9
PDA	11.0	12.7	23.7	14.0	37.7

Timing (in seconds)

Device	Retrv.	Navig.	Retrv. + Navig.	Entry	Total
Scrap	17.8		17.8	18.1	35.9
Planner	11.8	7.6	19.4	12.5	31.9
PDA	11.0	12.7	23.7	14.0	37.7

Thad Starner, GVU Center, Georgia Tech ICAT2004

Timing (in seconds)

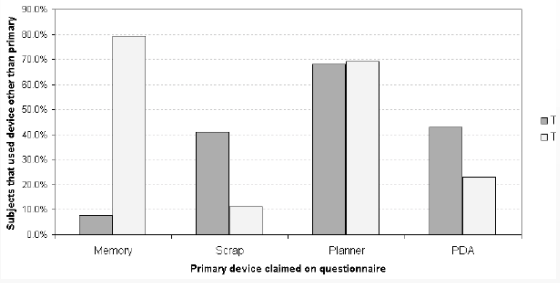
Device	Retrv.	Navig.	Retrv. + Navig.	Entry	Total
Scrap	17.8		17.8	18.1	35.9
Planner	11.8	7.6	19.4	12.5	31.9
PDA	11.0	12.7	23.7	14.0	37.7

Thad Starner, GVU Center, Georgia Tech ICAT2004

Actual vs. Claimed Usage

	Memory	Scrap	Planner	PDA	Other	# Used
Memory	24	9	16	4	4	57
Scrap	1	13	13	1	4	32
Planner			14	1	1	16
PDA				8		8
Other	1		1		6	8
#Claimed	26	22	44	14	15	121

Abandonment by Task



Buffering Information for Later Entry

- 42% of scrap and memory users said they would later enter appointment in another system for first ("next week") appointment
- 86% for second (3 months away) appointment
- Reduce cognitive load? Social effect?

Summary

- Overall usage speed is similar between methods
- Users tend to switch to faster access systems when scheduling appointments when mobile
- Appointments buffered for later entry
  - Even though 2X in overhead (waste a minute later to save a second during conversation)
  - Transfer to more formal devices for more distant events
- Future work: Larger study on office workers

Just-in-time Information Retrieval

- Automatically provide information
- Based on local environment
- Do it without driving people nuts

Speech Agent Experiment

- What if you wanted a speech-enabled agent running all the time?
- What would you do with it?
- How would you implement it?

The Jane Experiment

- Continuous audio-based agent
  - Inspired by Card's "Ender's Game"
  - Access to user's e-mail
  - Internet search engines
- Wizard of Oz experiment failed:
  - "Agent" could not respond quickly enough
  - Audio output was interruptive
  - Not enough context to be pro-active
  - Context could not accumulate due to experimental

Vocollect Series