Introduction to Wearable Computers

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Georgia Tech

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Ricoh Innovations

Science Is Beginning to Look Like Science Fiction

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

Georgia Tech/MIT Cyborgs: a living experiment

Outline

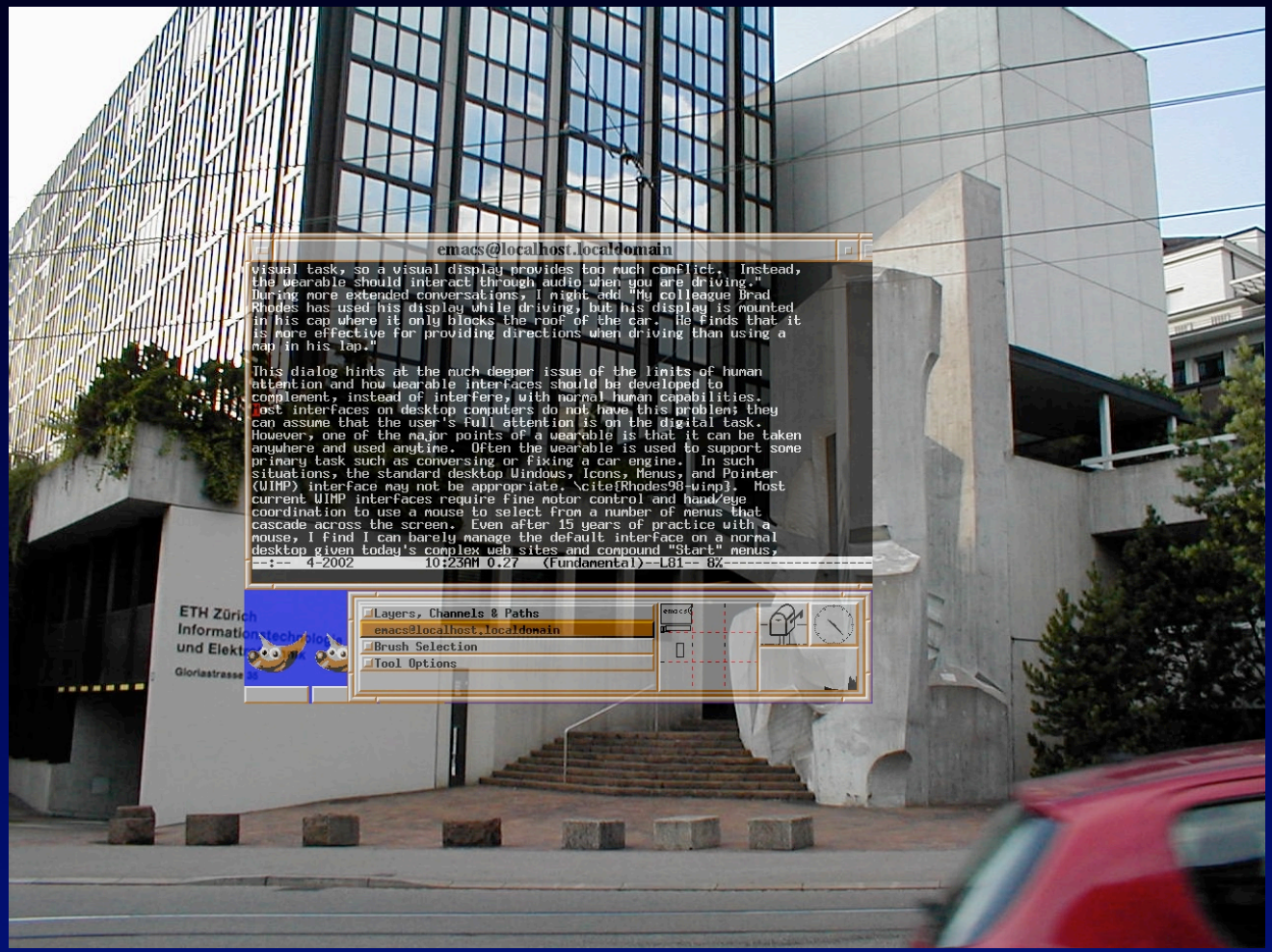
- The Toys
- Comparisons to past and current technology
- Applications: current state of industry
- The Vision
- Man-machine symbiosis
- Augmented reality
- Perception
- Challenges

The Toys

Miniature Head-up Displays

MicroOptical prescription display eyeglasses

Teleprompter



Keyboards

- Twiddler
  - Chording
  - In 5 min. alphabet
  - In 1 hr touch typing
  - Speed of 70 wpm (3-7x mobile phone)
- Half QWERTY
- Embroider in a jacket

CharmIT Wearable Computer

- 266MHz Intel Pentium or 800MHz Transmeta Crusoe

(www.charmed.com)

Questions About Hardware…?

- How can I see with that thing in front of my eye?
- Eye strain?
- Isn’t it socially interruptive?
- Why do they cost so much?
- Isn’t that bad on your hands?
- Why do you tuck the display into your shirt pocket?
- …

Why Wear?

- Computing in the wild
  - Hands, eyes, ears or brain is busy
  - Secondary and support tasks
- Always on / continuous use
  - Constant recording (medical, environmental)
  - Monitoring & alert (military, medical, phone)
- Instant and integrated use
  - Integrated with real-world task
  - Time-critical
  - Minor, secondary tasks

Wearable Computer (simple definition)

- Pocket or clothing based computing
- Peripherals distributed around the sensors and actuators of the body, connected wirelessly
- Runs entire day

Wearable Computer (formal definitions)

- Rhodes [Rhodes97]
  - Portable while operational
  - Enable hands-free or hands-limited use
  - Capable of getting user's attention
  - Always "on"
  - Sense the user's context in order to serve him better
- Starner [Starner99]
  - Persists and provides constant access
  - Senses and models context
  - Augments and mediates
  - Interacts seamlessly

Comparison To Other Technology

Human-computer evolution

- Mainframe -> mini -> PC -> wearable
- Initially lose on features
  - Less CPU capacity
  - Lower bus speed
  - Less disk storage
- Gain on interface
  - Personalization
  - Interactivity

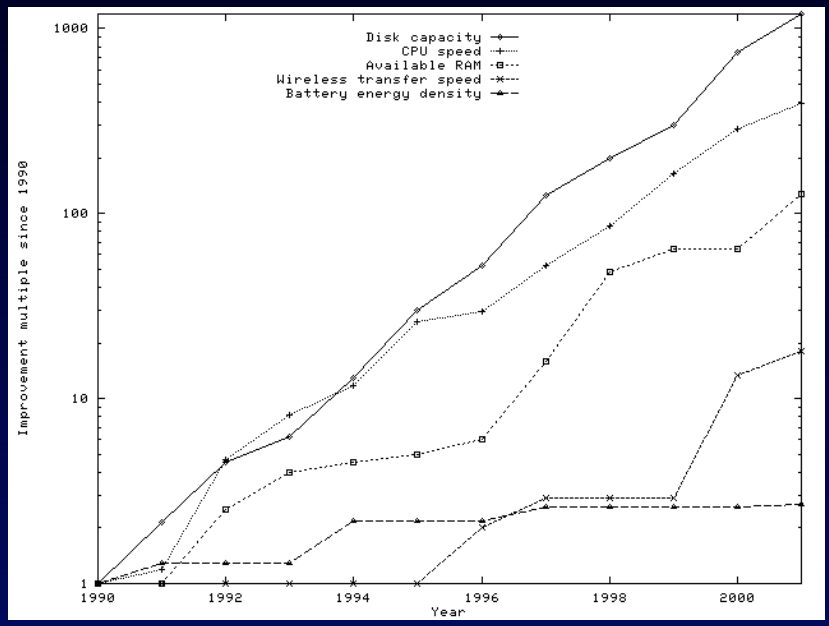
(Starner PhD 1999)

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

Why Not a Thin-Client?

- 100X RAM
- 400X CPU
- 1200X disk (>Moore's Law)
- 20X wireless speed
- 3X battery



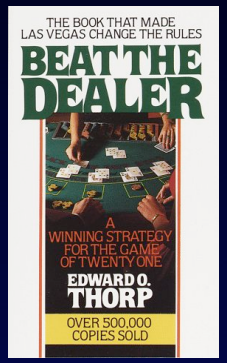
Exponential improvement in mobile tech since 1990

Current "General Purpose" Commercial Systems

- CharmIT & CharmIT Pro (R&D)
- Hitachi WIA/POMA
- Via series
- Xybernaut MA series
-
- Mentis?
- Past systems: Reddy Systems, Park Engineering, …

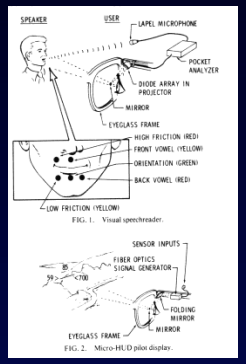
Applications: Current State of the Industry

Brief History



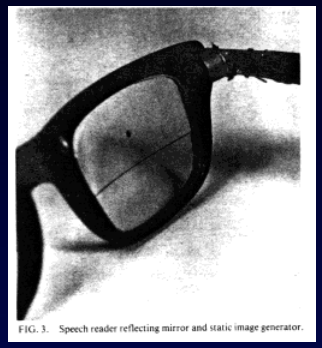
1961

1966



1968

1977

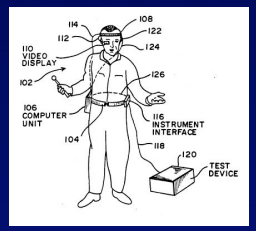


1980

1981

1991

1991



1992

1993

1993

1996

Application Areas

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

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

Vocollect Series

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

CharmBadge

- One of the simplest wearable computers
- Exchange business card information between attendees at conferences
- Allows attendees to sort conference contacts by length of conversation
- Similarly, product information can be remembered and sorted based on interaction time

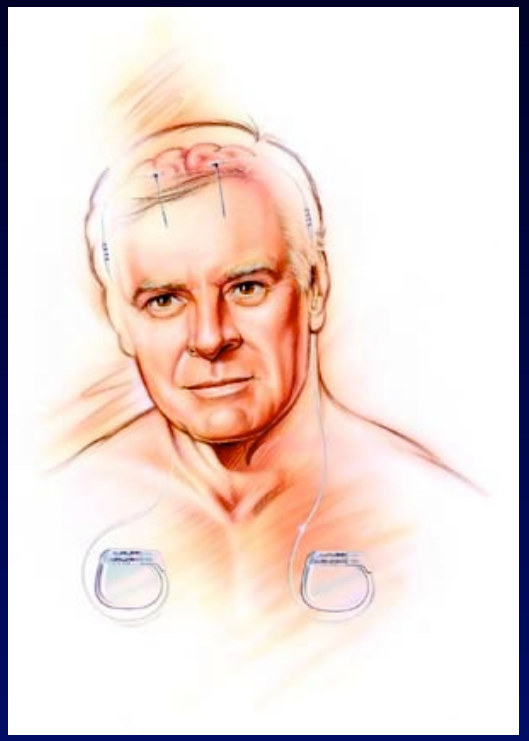
(www.charmed.com)

Portable Entertainment Systems

- MP3 players
  - iPod: 23,000/week
  - Wearables or not?
  - $4.2 billion/year
- Video
- Portable phones/games/…

Medical and Fitness Systems

FitSense



Medtronic

Fashion

Music Jacket

(MIT)

Galvactivator

(MIT)

The Visions

Convergence

Phone
(networking)

PDA
(computation)

Music
(storage)

Computation in the Wild

- Hostile or uncontrolled environments
- Continuous monitoring

Personal Server (Intel)

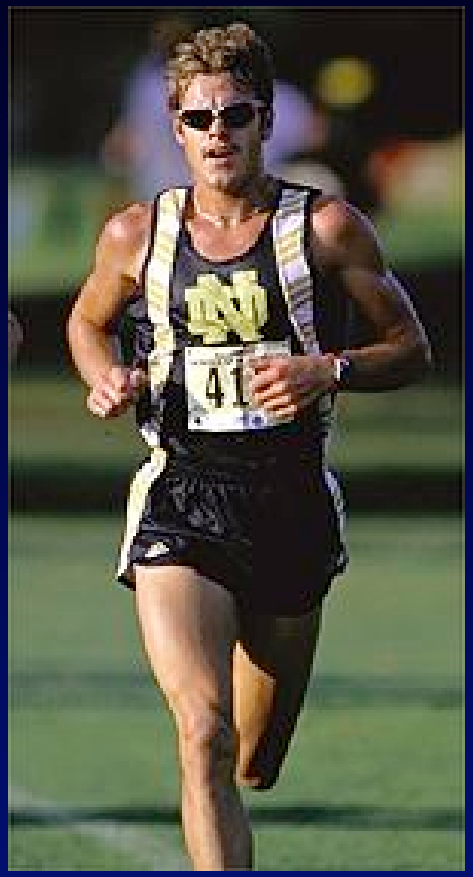
- Always with you
- Uses outside interfaces
- Represents you to ubiquitous computing world

Interaction Lifestyle

- Seamless integration into everyday life
- Augment the senses and the mind
- See as you see, hear as you hear

Man-Machine Symbiosis

Intelligence Enhancement



- "Strengthen" the mind
- Train how to use the mind more effectively

Smart foods, brainstorming techniques, memory tricks, etc.

Intelligence Augmentation

- Support mental task
- Constrain thinking
- Maintain flexibility

Not a New Concept

- Douglas Engelbart (1962)
  - Intelligence augmentation
- JCR Licklider (1960)
  - Man-computer symbiosis

Intelligence Augmentation

- Human Intelligence (normal thinking)
- Artifacts (autonomous systems)
- Combination (intelligence augmentation)

Man-Computer Symbiosis

JCR Licklider, 1960

"Man-computer symbiosis… will involve very close coupling between the human and the electronic members of the partnership."

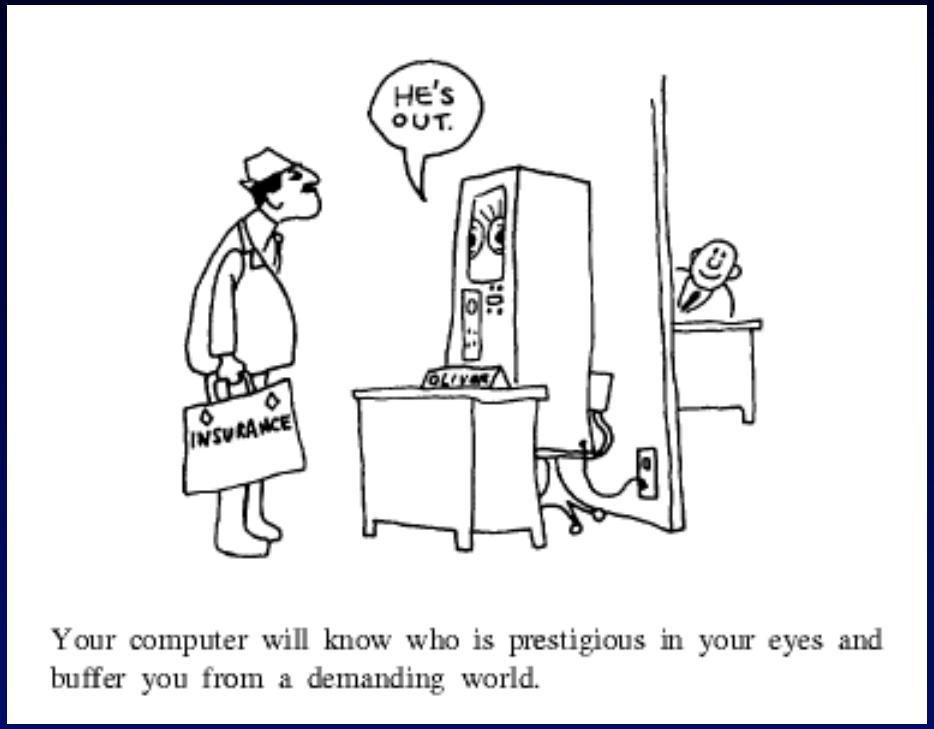
"[A person could] in general interact with [a computer] very much as he would with another engineer, except that the 'other engineer' would be a precise draftsman, a lightning calculator, a mnemonic wizard, and many other valuable partners all in one."

"[In his self-study] Much more time went into finding or obtaining information rather than digesting it"

Software Agents

- Personalized
- Autonomous
- Sense the environment
- Act on your behalf

Communications Filtering Agent



Your computer will know who is prestigious in your eyes and buffer you from a demanding world.

[JCR Licklider, "The computer as a Communications Device," Science and Technology, April 1968]

Nomadic Radio

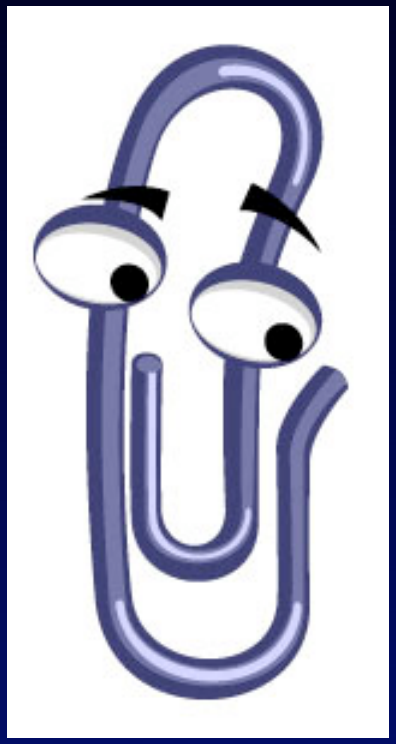
(Sawhney, MIT Media Lab)

- Audio interface
  - Voicemail, news, email
- Dynamic interruption
  - Importance of info
  - Personal profile
  - Conversation detection

Software Agents

- Effective
  - Well defined task
  - Necessary information available to agent
- Break down
  - Open-ended task
  - Require “mind reading”

The Annoying Intern



- Help task too open-ended
- Need to know user's intent

Communication between user and agent is too distracting!

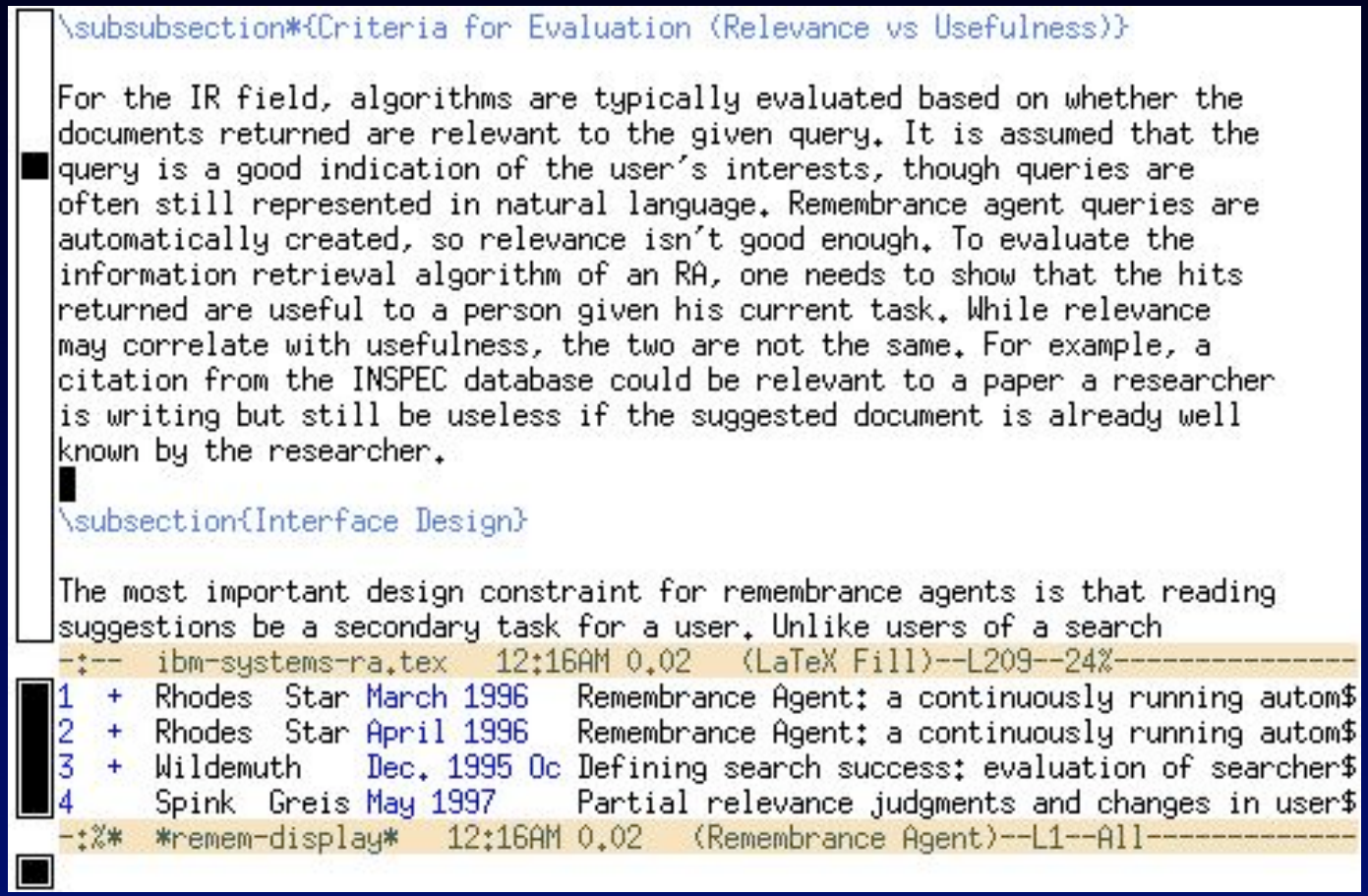
Prosthesis For The Brain

- *Less* autonomy
- Constant, low-load communication
- Tight integration with environment and task

Just-in-time Information Retrieval

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

Remembrance Agent



JITIR Interfaces

- Progressive disclosure (Ramping interface)
  - Low-cost false positives
  - Lots of opportunities to bail out
  - Allow control over when information is viewed
- Follow *proximity compatibility* principle
  - Use local environment as part of interface
- Two-second rule (Miller, 1968)

Jimminy (Wearable RA)

Jimminy

- Environment automatically sensed
  - Location
  - People in area
  - “Subject”
  - Notes being taken
- Output too dense for conversational speeds
- Physical context not good marker for “useful information”

Looking at the Feature Set

Features	% Good
All Features	56%
Note Text	50%
Subject	24%
Location	12%
Person	8%
Random	0%

Augmented Reality

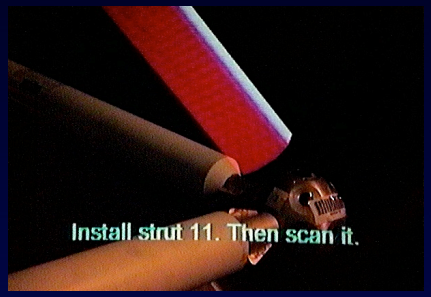
What Is Augmented Reality?

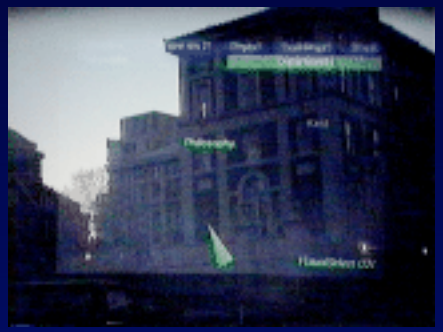
The overlay of graphics (or sounds) on top of the real world such that they seem to be a part of the physical space.

- Uses real world (context) as part of message
- Information where needed most

Columbia University Augmented Reality (1993)

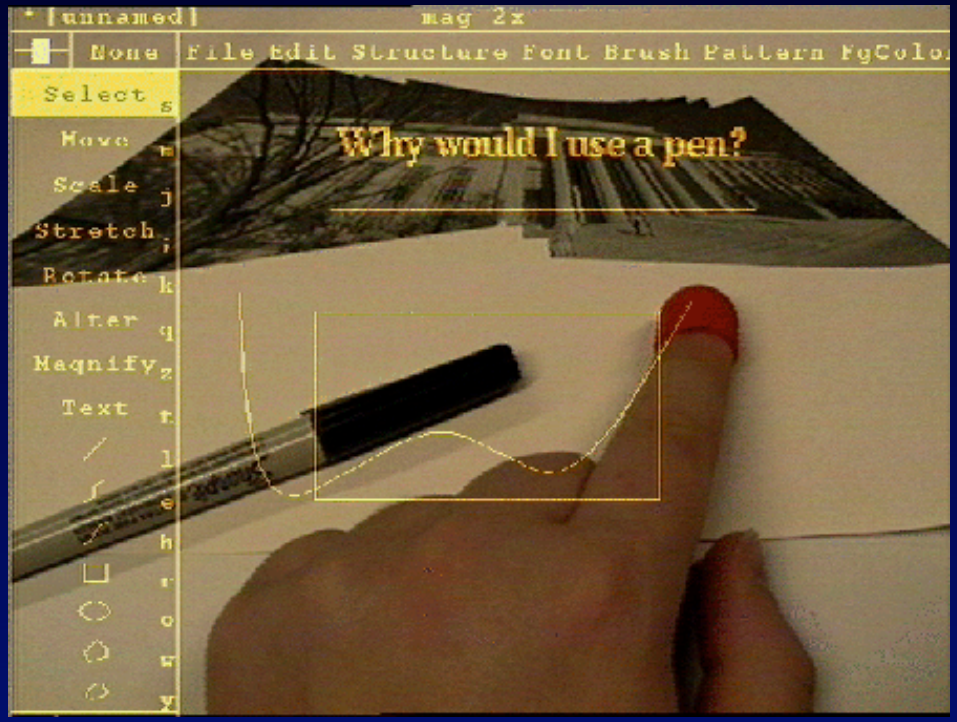
- Applications
  - Instruction
  - Mobile information
- Focus on graphics, speed
- Good evaluation
- Wired ultrasonic sensors

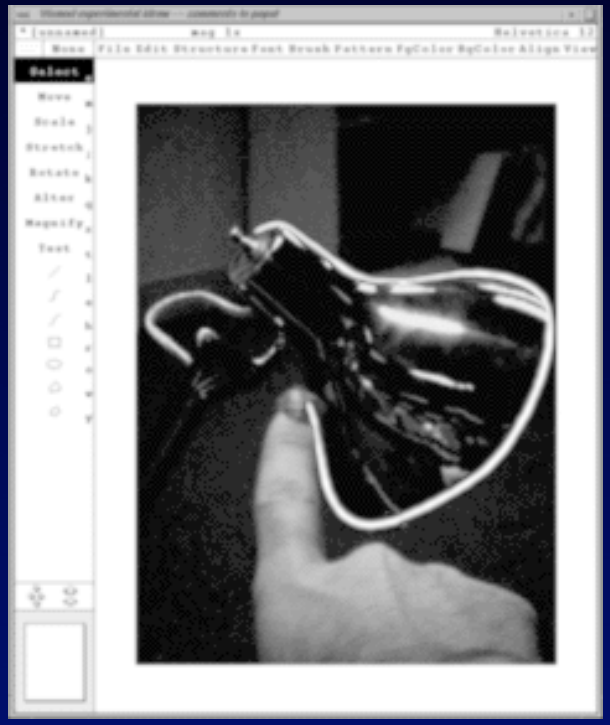




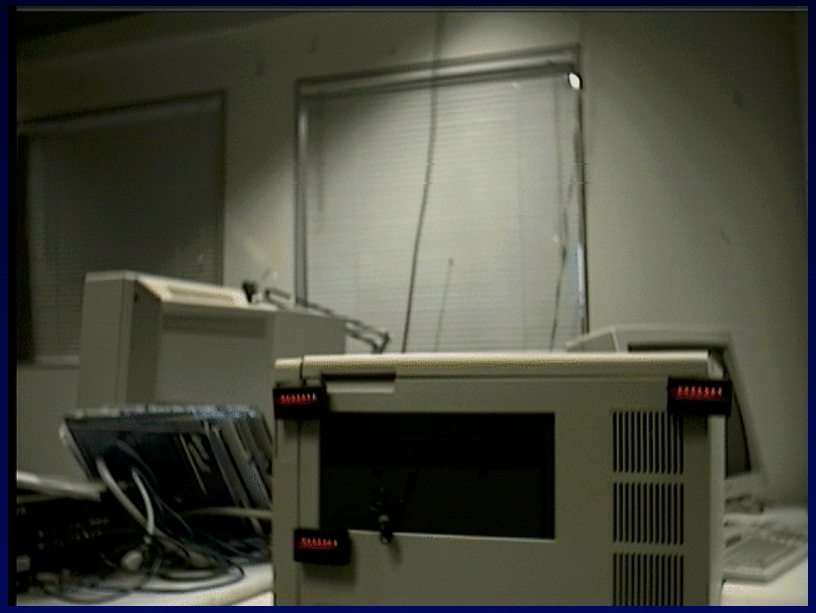
http://www.cs.columbia.edu/graphics/

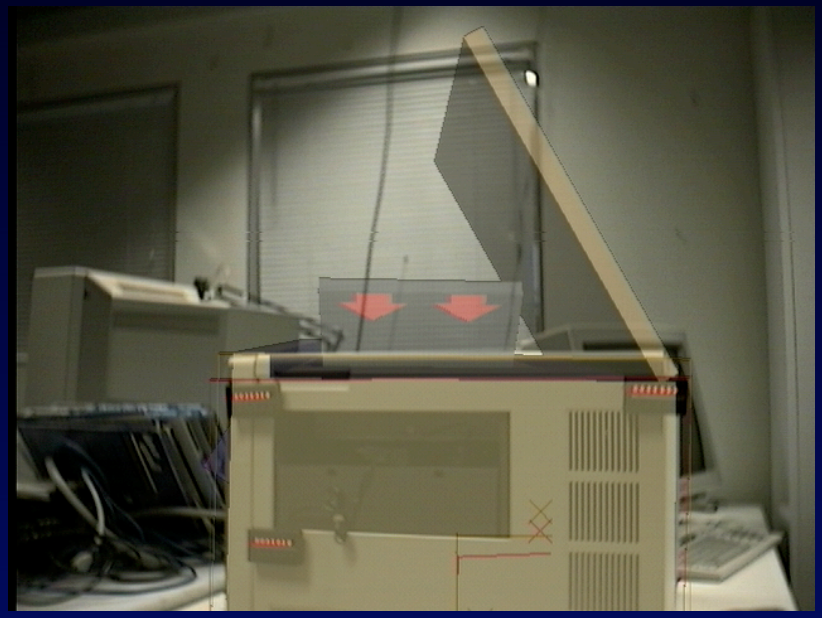
Vision-based AR: finger as mouse (1995)





Repair/Inspection/Maintenance

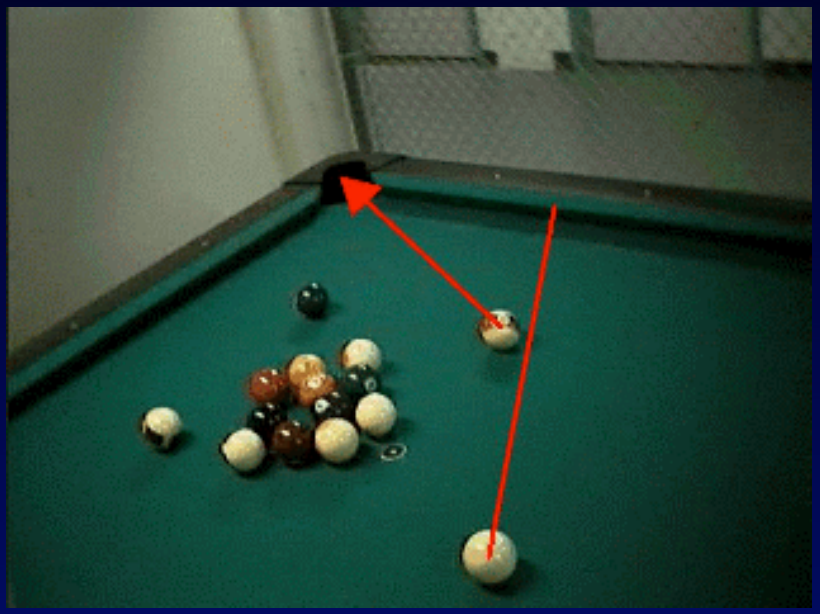




Other Examples

Wiring AR System

(Mizell, Boeing)

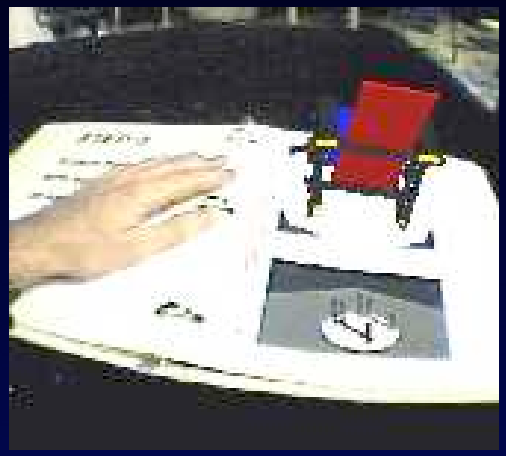


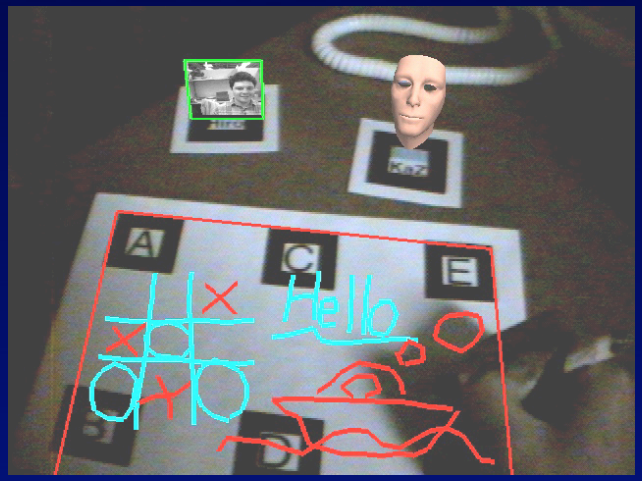
Billiards Assistant

(Jebara, MIT Media Lab)

Physical World Wide Web

ARToolkit (Billinghurst)





Perception

From Sensors To Perception

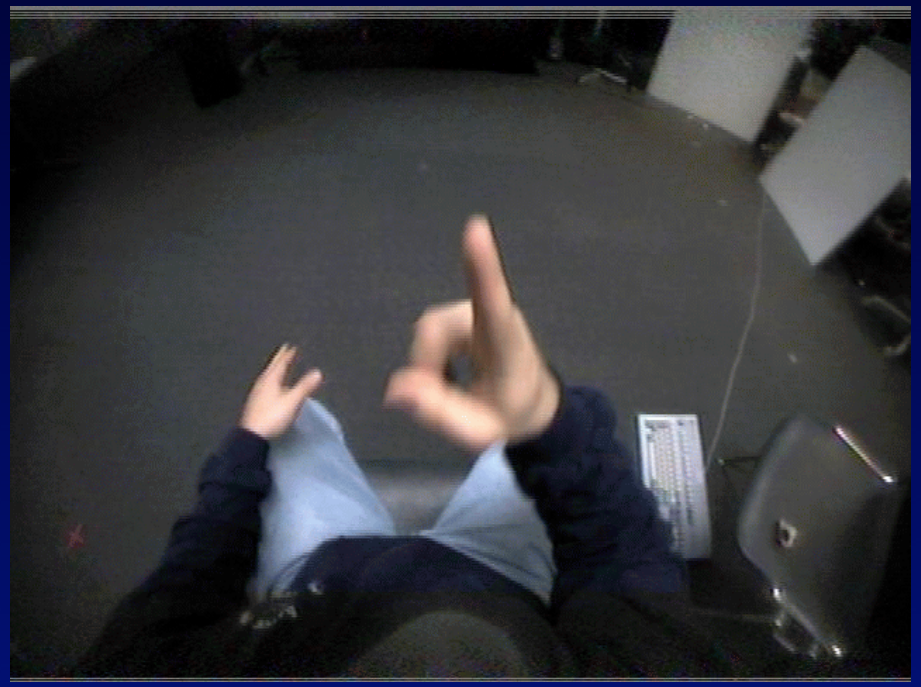
ASL translator
(MIT)

Sensate Liner
(Georgia Tech)

Blood pressure sensor earing
(MIT)

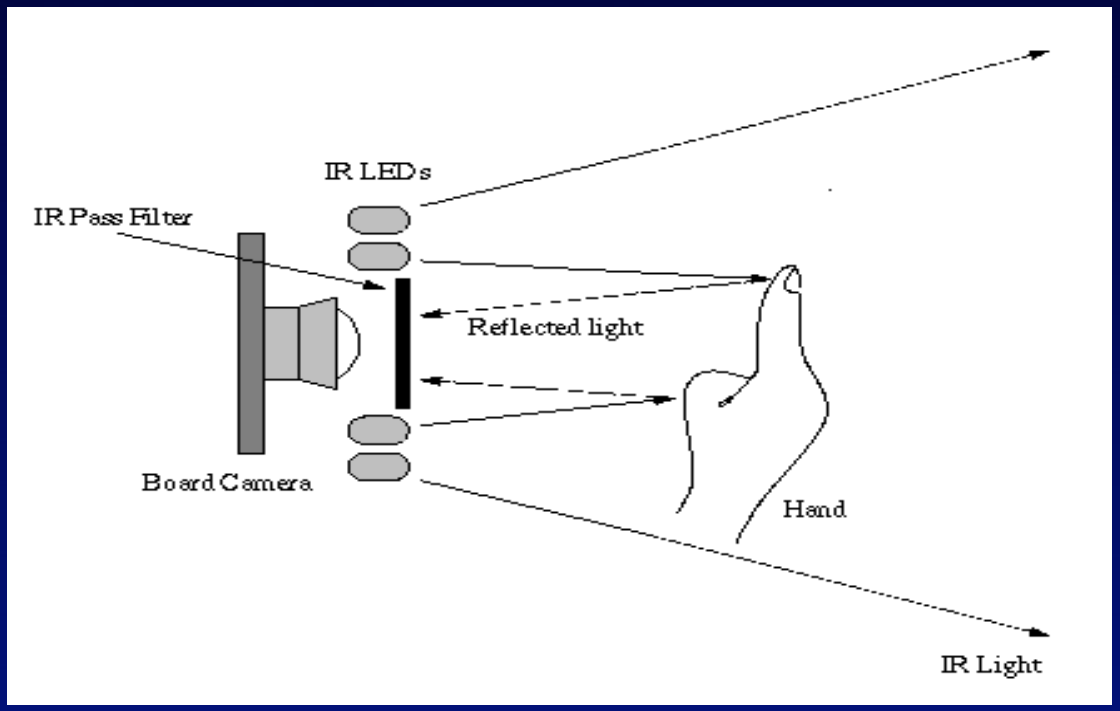
Recognizing Gesture

- Wearable American Sign Language recognition: 97% accuracy

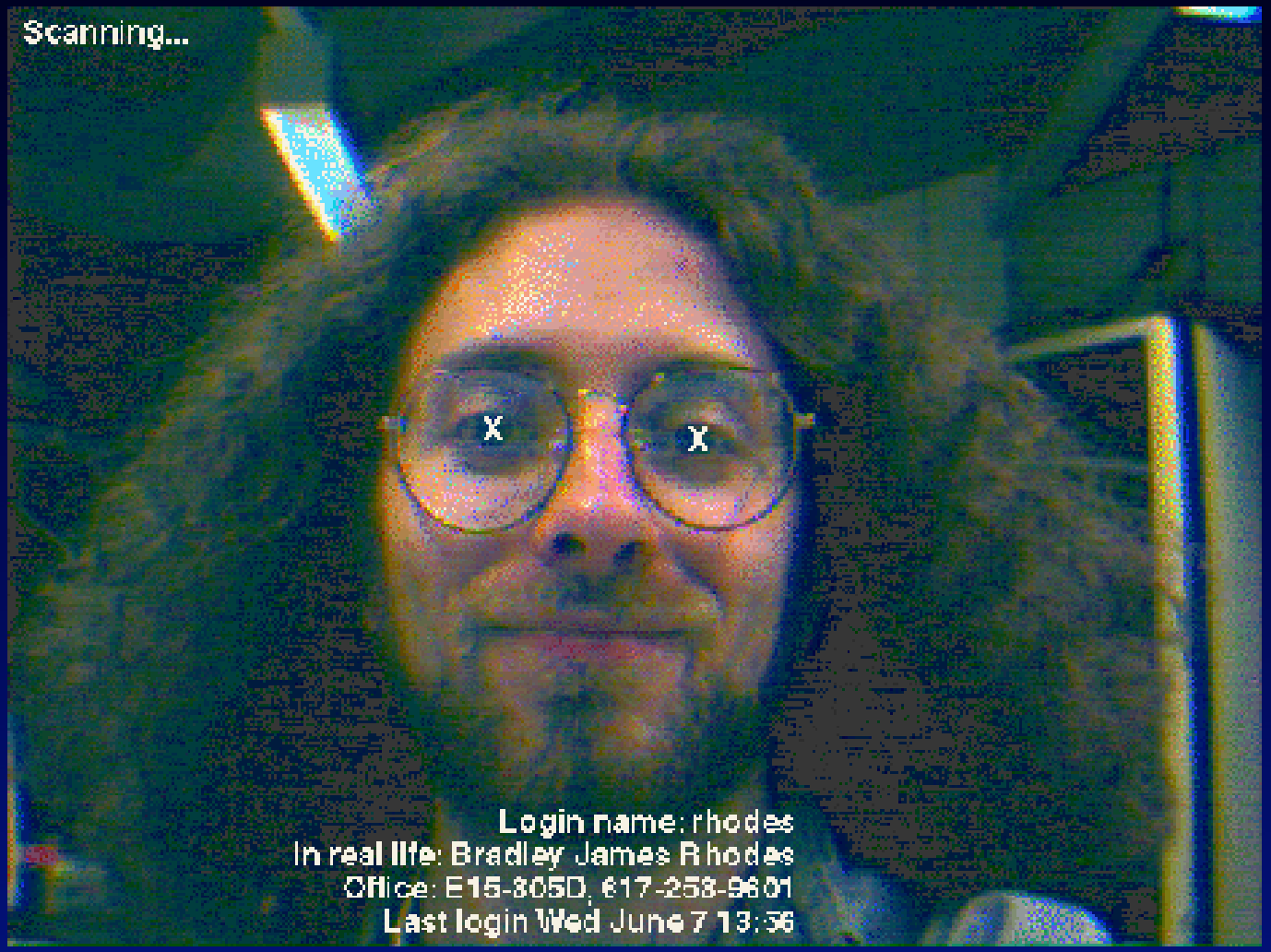


Gesture Pendant

- Home appliance control
- Medical monitoring



Face Recognition



Location

- GPS
- Ultrasound, RF, IR Beacons
- Fiducials & Barcodes
- Machine Vision
- Accelerometers & Dead Reckoning

Activity

- Accelerometers
  - running, sitting, shaking hands
- Bio Sensors
  - interested, confused, asleep, wounded
- Microphones
  - in a conversation, talking about a topic
- Location Sensors
  - activity appropriate for that location

Privacy Issues

- Big vs. Little Brother
- Controlling your bits
- Lifelog vs. Environmental sensing
  - noise canceling microphone
  - fish-eye video
- Legislation

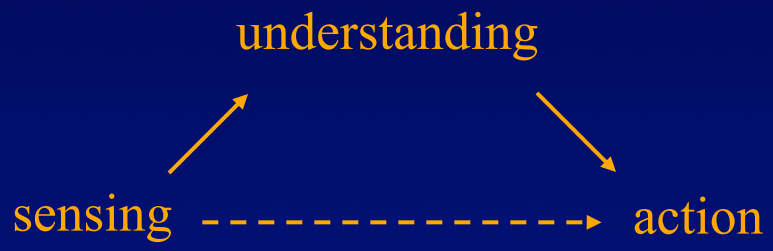
Challenges

Human/Machine Interface Bottleneck (HCI)

- Automate when possible
- Progressive disclosure
  - Easy to use
  - Easy to ignore
- Use context
  - Disambiguate instruction for the computer
  - Explain output for user

Machine Understanding of Context (AI)

- Sensors are easy, mind-reading is hard
- Proxies for context
  - "in my office" implies I'm working
  - "talking" implies not to be disturbed
- Proxies can only go so far



Integration With The Task (Activity Theory)

- The details matter
- Need to combine
  - Cognitive
  - Ergonomic
  - Social
  - Practical
  - Environmental
- Can we be integrated and still general?

Wearable Trade-offs

- Power and heat (mips/watt)
- On and off-body networking (bits/joule)
- Privacy vs using environment's resources
- Capability vs. load
  - User Interface (cognitive load)
  - Machine understanding of context (application scope)
  - Ergonomics/human factors (weight, heat, etc.)

Resources

- Charmed Technologies (www.charmed.com)
  - Inexpensive wearables for prototyping
- IEEE Wearable Information Systems Technical Committee (computer.org)
- www.cc.gatech.edu/~thad
- www.bradleyrhodes.com
- Research mailing list: wearables@cc.gatech.edu