# PA198
# Augmented Reality Interfaces

Lecture 8

Wearable Augmented Reality

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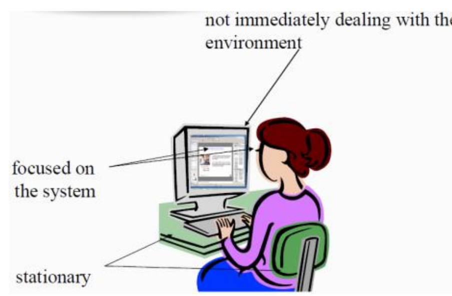
# Introduction

## Intro to Wearable Computing (WC)

- Technology which allows for the human and computer to interact, process data, and perform tasks as one unit
- The concept of wearable computers attempts to bridge the 'interaction gap' between the computer and a human
- Wearable computing promotes devices that should be as natural to the user as wearing sunglasses or clothes

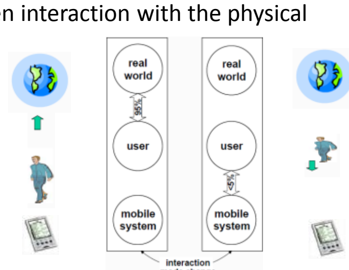
## Conventional Computer




Roadmap: Wearable Computing 2020, Wear it at work.

## Today's Mobile Interaction

- Unusable when interaction with the physical world needed

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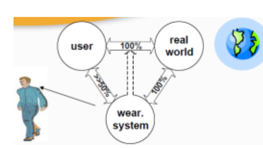
## The Wearable Vision

- Non disruptive interaction
- Environment oriented
  - Context recognition
  - Augmentation
- Physically unobtrusive
- Seamlessly connected

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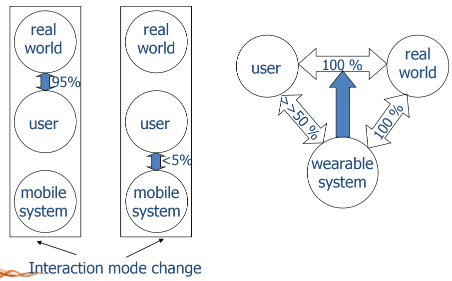
## Wearable vs. Mobile Computing

- Focus on the interaction of user/system

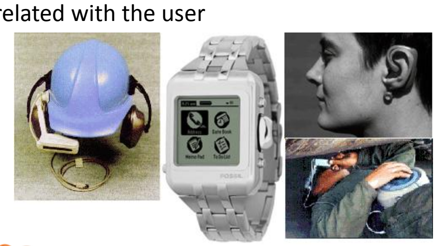



## What is a Wearable Computer?

- A computer that is subsumed into the personal space of the user
- Controlled by the user, and always with the user – it is always on and always accessible
  - Operational and interactional consistency


## Wearable Computer Definition

- A wearable computer offers all the features of a regular computing system, but is also totally related with the user



Ganguly, K. A Study on Wearable Computing, CS898A - Mobile / Wireless Communications

## Fundamentals of Wearable Computing

- Humanistic Intelligence (HI)
- Human-Computer Interaction (HCI)
- Mediated Reality

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## Humanistic Intelligence (HI)

- HI is the intelligence that arises when a human is part of the feedback loop of a computational process in which the human and computer are linked
- This creates a far more powerful entity than the individual parts

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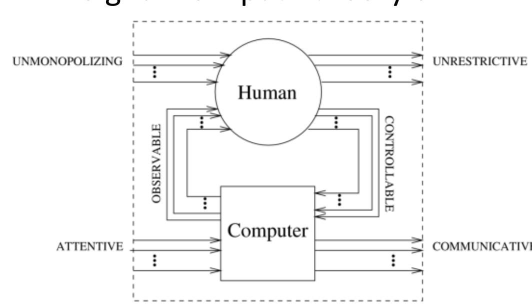
## Signal flow path theory of HI



## HCI

- HCI typically treats the human and computer as 2 separate entities
- Wearable computing extends the HCI concept
  - The computer can be regarded as a second brain, with it's sensory modalities and additional senses adding to the wearer's (paradigm shift)
- Idea is to move the tools of augmented intelligence and communication directly onto the human body

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## Mediated Reality

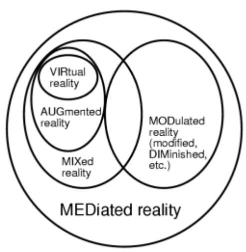
- Refers to the ability to add to, subtract information from, or otherwise manipulate one's perception of reality
  - Through the use of a wearable computer or hand-held device
- Typically, it is the user's visual perception of the environment that is mediated

Displays what's really there and then this allows a computer to be inserted into the "reality stream" to modify it

https://en.wikipedia.org/wiki/Computer-mediated_reality

## Mediated Reality .

- Mixed reality and augmented reality are special cases of mediated reality




https://en.wikipedia.org/wiki/Computer-mediated_reality

## Goal of Wearable Computing

- Main goal of the wearable computing paradigm is to produce a symbiotic relationship between the human and computer
  - Rather than attempting to emulate human intelligence
- The computer simply performs tasks at which it is much better and faster at doing

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## Communications

- Wireless communication is an integral part of wearable computing
  - Extremely important!
- Nowadays WC's use communication protocols such as:
  - 802.11x
  - Bluetooth
  - Infra-red

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## Hardware

- Small size and light-weight
  - Getting better and better
  - Innovative design of components
- Functionality is decided by where on the body it is worn
  - Head-mounted are the most common
- Multiple standard connectors
  - i.e. USB
- Innovative power use
  - Batteries are still a problem

## Software

- Common Operating Systems:
  - Windows
  - Linux (popular)
  - MS-DOS
- GUIs are typically minimal
- Installed applications depend on the function of the device
- Use of Agents is mandatory, not optional
  - i.e. Remembrance agent, context-aware agent, etc

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## Why Use Wearables

- Since they are wearable they are always with you
  - Difficult to loose
- Instant access, information anywhere and at anytime
  - Laptops require preparation time
  - PDAs require both hands
- Can become very personal items
  - Transparent use

## Who Uses Wearables

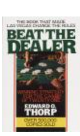
- Researchers
  - i.e. Augmented reality
- Field workers
  - Access to information given by remote experts
- Technicians
  - Blueprints
- Military
  - Soldiers monitoring health and equipment

## Characteristics of Computing Devices

| Device Type | Form Factor | Highest Degree of Mobility | Mode of Interaction | Modularity |
|---|---|---|---|---|
| Desktops | Large | Fixed | Stationary only | Fully modular input/output mechanisms |
| Laptops | Medium | Transportable | Stationary only | Single unit device with optional external output mechanisms (audio) |
| Palmtops | Small | Transportable | Stationary, with minor exceptions | Single unit device with optional external output mechanisms (audio) |
| Handhelds | Medium to small | Fully mobile | Mobile interaction enabled | Single unit device with optional external input/output mechanisms |
| Wearables | Small | Fully mobile | Mobile interaction enabled | Fully modular input/output mechanisms |

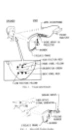
[L. Gorlenko and R. Merrick, No wires attached: Usability challenges in the connected mobile world]

## Brief History

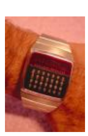


1961

1966



1968



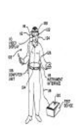
1977

1980

1981

1991

1991



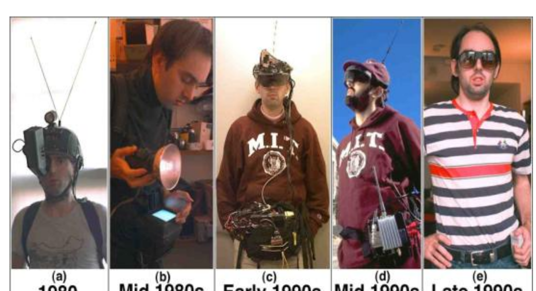
1992

1993

1993

1996

## Evolution of Wearable Computers



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## Father of Wearable Computing

https://www.youtube.com/watch?v=jhTchUYEldU

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## Wearable Devices


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# Architecture

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## Key Architecture Question

- What does integration with the outfit mean ?
- Observation:
  - Clothing is a heterogeneous, distributed, dynamically reconfigurable system
    - Function
    - Technology
    - User expectation
- Solution:
  - 4 layers of integration reflecting relation between clothing and electronic

Roadmap: Wearable Computing 2020, Wear it at work.

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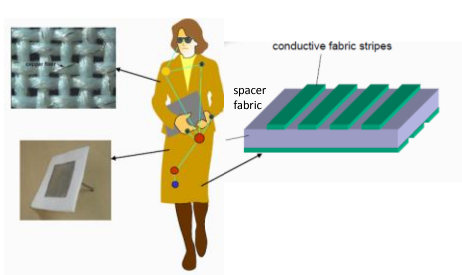
## Layer 1: Functional Textiles

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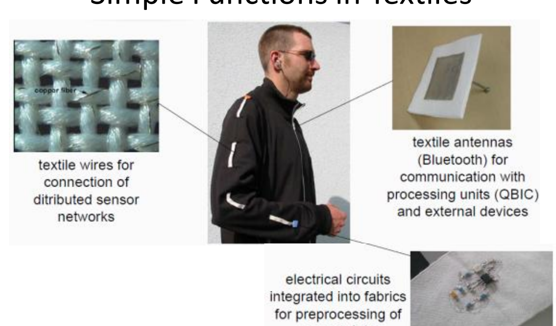
## Simple Functions in Textiles

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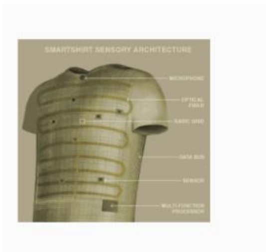
## Smart Shirts

- Wearable Motherboard, Smart Shirt (GATECH)



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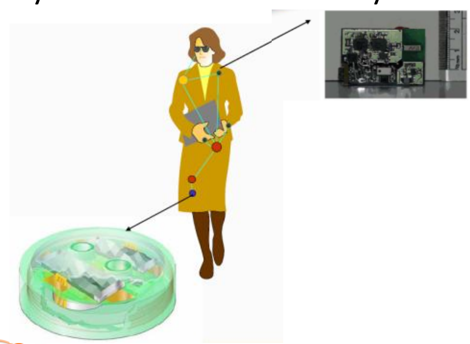
## Layer 2: Embedded Microsystems



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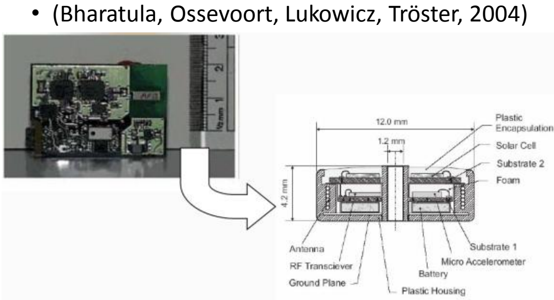
## Miniaturized Sensors

- (Bharatula, Ossevoort, Lukowicz, Tröster, 2004)

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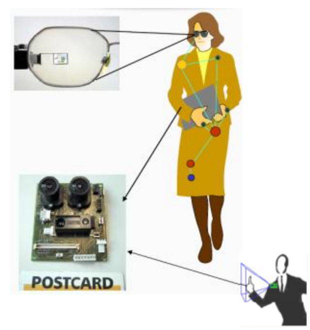
## Layer 3: Attachable Peripherals

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## Augmented Reality

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Billinghurst, M. Designing for Wearables, AWE Asia 2015.

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## Sensor Based Interfaces


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## ETH QBIC: Belt Integrated System

- Buckle as computer housing
- Belt as peripheral bus
  - Connectors
  - Batteries
  - Wireless adapter, storage etc

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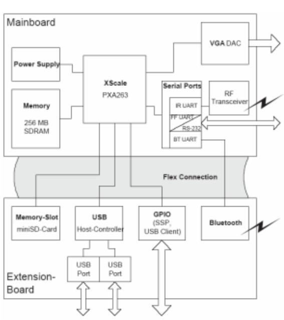
## QBIC





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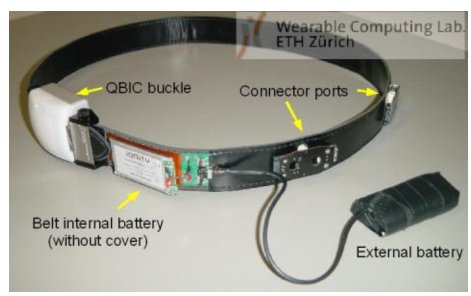
## ETH QBIC

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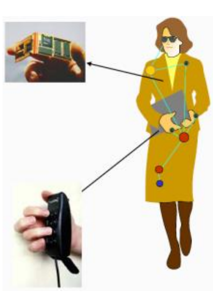
## Layer 4: Carry On Devices



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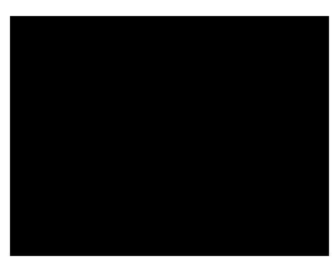
## Wearable Computer New Scientist



https://www.youtube.com/watch?v=9DNXLAogM7Q

# Design Guidelines

## How To Design This?

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## Universal Design Principles

- Flexibility
- Equitable use
- Easy to perceive
- Simple and intuitive
- Low physical effort
- High tolerance for error

Billinghurst, M. Designing for Wearables, AWE Asia 2015.

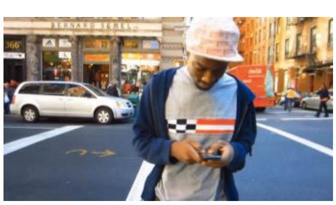
## Designing for Wearables

- Wearables are intimate on-body devices, so interface design for wearables, means:
  - Designing for Attention
  - Designing for Interruption
  - Designing for User Experience
  - Designing for Social Interaction

Billinghurst, M. Designing for Wearables, AWE Asia 2015.

## Micro-Interactions

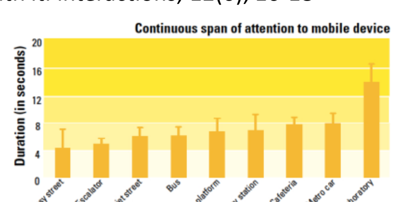
- Using mobile phone people split their attention between the display and the real world



Billinghurst, M. Designing for Wearables, AWE Asia 2015.

## Time Looking at Screen

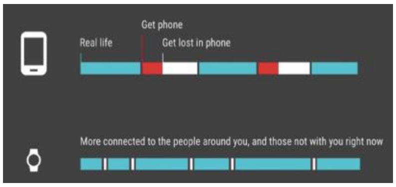
- Oulasvirta, A. (2005). The fragmentation of attention in mobile interaction, and what to do with it. interactions, 12(6), 16-18




Billinghurst, M. Designing for Wearables, AWE Asia 2015.

## Using Micro Interactions

- Quick micro-interactions reduce divided attention and allow people to spend more time in real world





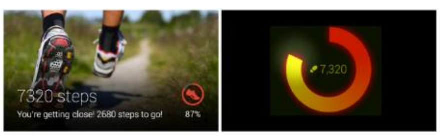

## Like A Rear View Mirror

- Don't overload the user
- Stick to the absolutely essential
  - Avoid long interactions
- Be explicit



## Make it Glanceable

- Seek to rigorously reduce information density
- Successful designs afford for recognition, not reading




Bad Good

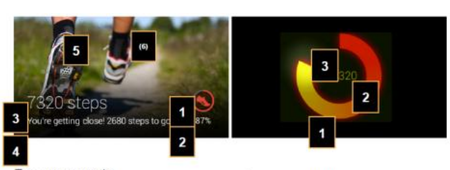


## Reduce the Number of Info Chunks

- Designing for recognition, not reading
- Reducing the total # of information chunks will greatly increase the glance ability of the design




## Design Single Interactions < 4 sec




Eye movements
For 1: 1 230ms
For 2: 1 230ms
For 3: 1 230ms
For 4: 3 690ms
For 5: 2 460ms

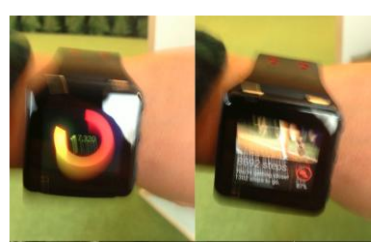
**~1,840ms**

Eye movements
For 1: 1-2 460ms
For 2: 1 230ms
For 3: 1 230ms

**~920ms**



## Test the Glanceability of Your Design



## Design for Micro-Interactions

- Design interactions less than a few seconds
  - Tiny bursts of interaction
  - One task per interaction
  - One input per interaction
- Benefits
  - Use limited input
  - Minimize interruptions
  - Reduce attention fragmentation

Billinghurst, M. Designing for Wearables, AWE Asia 2015.

## Important Note

- Design for limited attention/micro-interactions
- No more than 4 seconds to complete a given step in the interaction

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## Designing for Interruptions

- Assume user is engaged in critical real world task
- Use context to filter interruptions
  - Is it necessary?
- Interrupt in way that consumes least attention
- Allow user to dismiss interruption with minimal effort
- Progressively disclose information and increase interaction

Billinghurst, M. Designing for Wearables, AWE Asia 2015.

## Interruptions on Glass Example

- Receiving SMS on Glass
  - Gradually increase engagement and attention load
  - Respond to user engagement


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## Important Note

- Design carefully for interruption
- Low cognitive load that can be increased as needed
  - i.e. NASA TLX

## NASA TLX

- A subjective workload assessment tool
- Allows users to perform subjective workload assessments on operator(s) working with various human-machine systems
- A multi-dimensional rating procedure that derives an overall workload score based on a weighted average of ratings on six subscales

http://humansystems.arc.nasa.gov/groups/tlx/

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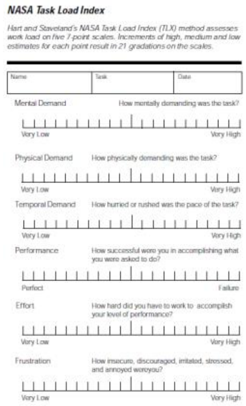
**NASA Task Load Index**

*Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales.*

| Name | Task | Date |
|---|---|---|
| | | |

Mental Demand — How mentally demanding was the task?
Very Low — Very High

Physical Demand — How physically demanding was the task?
Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?
Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?
Perfect — Failure

Effort — How hard did you have to work to accomplish your level of performance?
Very Low — Very High

Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou?
Very Low — Very High

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## Consider Your User

- Wearable User
  - Probably Mobile
  - One/no hand interaction
  - Short application use
  - Need to be able to multitask
  - Use in outdoor or indoor environment
  - Want to enhance interaction with real world

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## How To Take A Note?

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## Glass Pictures Example

- On Glass there are three ways to take a picture
  - Voice commands – “Ok Glass, Take a Picture”
  - Touch navigation through menu
  - Winking with right eye
- Which you use depends on context
  - Riding a bike outdoors – voice commands
  - During a meeting – winking


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## Important Note

- Provide many different ways of accessing functionality
- Each person is different!

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## Design For Device

- Simple, relevant information
- Complement existing devices


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## Glass User Interface


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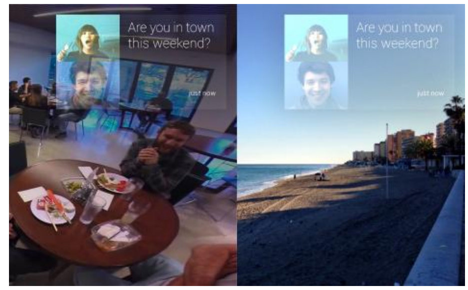
## Test Indoors & Outdoors




Billinghurst, M. Designing for Wearables, AWE Asia 2015.

## Design for Context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## Design for Ecosystem of Wearables

- User have multiple devices
  - Phone, watch
  - Fitness band, HMD
- Each device should be used when it's most relevant and when it's the easiest interaction available

Billinghurst, M. Designing for Wearables, AWE Asia 2015.

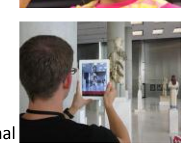
## Interface Guidelines

- Design for device
- Use multiple input options
- Do one thing at a time
- Consider user context
- Design for indoor and outdoor use
- Design for device ecosystem

Billinghurst, M. Designing for Wearables, AWE Asia 2015.

## Social Acceptance

- People don't want to look silly
  - Only 12% of 4,600 adults would be willing to wear AR glasses
  - 20% of mobile AR browser users experience social issues
- Acceptance more due to social than technical issues
  - Needs further studies
    - Ethnographic, field tests, longitudinal



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## Social Implications

- Freak or Trendy?

## Social Implications Questions

- Will the use of wearable computers become a symbol of elitism or will they become accepted as part of the daily routine?
- Is the integration of computer equipment into the body more acceptable than a wearable computer module?

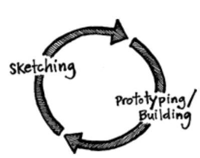
# Prototyping

## Main Goal

- How can we quickly prototype wearable computing applications with little or no experience
- Understand the market and user needs first

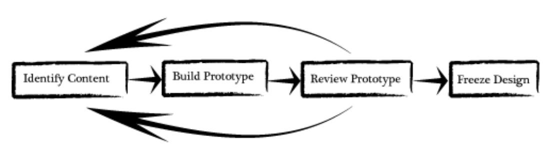
## Why Prototype?

- Quick visual design
- Capture key interactions
- Focus on user experience
- Communicate design ideas
- Learn by experience




Billinghurst, M. Designing for Wearables, AWE Asia 2015.

## Prototype Design Process



## Typical Development Steps

- Sketching
- Storyboards
- UI Mockups
- Interaction Flows
- Video Prototypes
- Interactive Prototypes
- Final Native Application

**Static**
**Low fidelity**

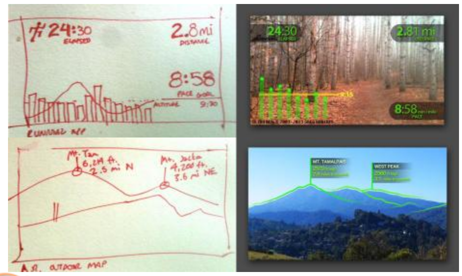
*Increased Fidelity & Interactivity*

**Interactive**
**High fidelity**

Billinghurst, M. Designing for Wearables, AWE Asia 2015.

## Sketched Interfaces

- Sketch + Powerpoint/Photoshop/Illustrator



Billinghurst, M. Designing for Wearables, AWE Asia 2015.

## Paper Prototype

- Use sketched interface in template

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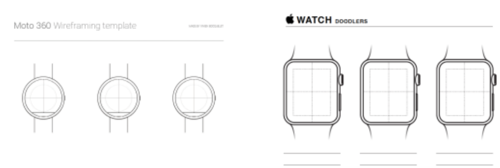
## Smart Watch Templates

- https://dribbble.com/jaysuthar/buckets/260235-watch

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# Wearables Today

## Application Areas

- Warehouse picking
- Inspection
- Maintenance
- Repair
- Medical
- Security
- Military

## A Prototypical Wearable Device

- Hearing aid computer
- Permanently useful
- Augments user's perception
- Situation sensitive
  - Adjusts amplification to the situation
- Virtually unnoticeable

Roadmap: Wearable Computing 2020, Wear it at work.

## Consumer Applications

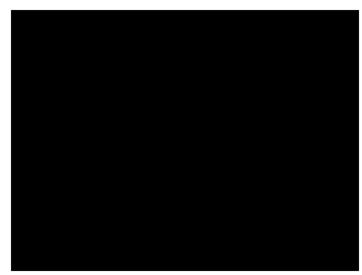
- Fossil has created the wrist PDA, it uses the Palm OS, and has almost all the functionality of a standard Palm Pilot

- Accenture Technology Labs has created a device that uses two small microphones, and a camera to assist in remembering a persons name

## Consumer Applications .

- MIT Media Lab has developed handbags that alert you when you leave
  - Things behind, your wallet, or an umbrella if you need one
- Oakley has developed the first digital music eyewear
  - The Oakley Thump, comes equipped with a solid state hard drive, for skip free listening

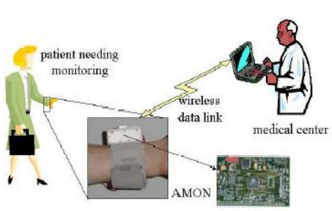
## Intel Wearable Video



https://www.youtube.com/watch?v=iwSpn7H7vKg

## Medical Applications

- Wrist worn medical monitoring devices




## Medical Applications .

- The C-Leg
  - Uses the C programming language to do all of the calculations required to function, hence "C"-leg
  - Sensors from the foot and ankle get load information, sensors from the knee get the precise angle of the leg and swing speed, this is all sent to a microprocessor for processing

Ottobockus.com

## C-Leg Video

https://www.youtube.com/watch?v=F0bpXmzCw7A

## Personal/Recreational Use

- Web surfing
- Email/Text/Video Messaging
- Note taking
- Audio/Video Entertainment


## Hiris Video

https://www.youtube.com/watch?v=VF9Qkt89u30

# Military Wearables

## Early Years - The Soldier's Computer

- James Schoening, Matt Zieniewicz 1989, John Flatt, Sal Barone, and Almon Gillette, 1990
- Schoening:
  - small wearable computer, integrated with a wireless link and HMD
- Matt Zieniewicz:
  - wireless data transmission, image capture, integrated Global Positioning System (GPS) receivers, and menu-driven software

Zieniewicz, M.J., Johnson, D.C., Wong, D.C., Flatt , J.D. The Evolution of Army Wearable Computers, Research, Development, and Engineering Center, US Army Communications Electronic Command

## Army Material Command's - First Trade Show

- Agilis bricktype 386-based computer
- Software:
  - Creating reports, displaying battlefield situation maps
  - Could enter and transmit simple reports to other units
- HMD:
  - 14-inch monochromatic display
- Interaction:
  - Trackball for input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## The SIPE project

- Spring of 1990
  - Led by Carol Fitzgerald
- New digitized battlefield concept:
  - portable, wearable battery-powered computer
- Computer needed to include:
  - Image capture
  - Integrated radio
  - Portable display unit

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## SIPE Requirements

- Challenges
  - Integrate these components into a lightweight package
  - Bring computing devices to the individual soldier
- None of the functions were commercially available
- Software:
  - Developed in C

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## SIPE Functionality

- The new system aimed to digitize basic battlefield operations to help soldiers
  - Read maps, navigate, and maintain situation awareness
  - Receive, prepare, and send written field reports
  - Capture and transmit color still images for reconnaissance purposes
  - Access battlefield operations reference material

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## SIPE System Architecture

- Computer processor with memory
- GPS receiver and a digital compass
- Data radio
- Video capture system
- A miniature color camera
- A video controller subsystem
- An HMD
- A power supply subsystem
- Wiring harnesses and packaging

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## Feedback From Soldiers

- Operate longer on a set of batteries
- Computer-radio-GPS:
  - 18 pounds
- HMD into helmet
  - nearly 8 pounds
- CRT display
  - 15 pounds
- Drawback
  - Delay in capturing and sending a still video image

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## Land Warrior Project

- Land Warrior requirements:
  - Integrate small arms with high-tech equipment
  - Provide communications and command and control at the infantry soldier level
  - Look at the individual infantry soldier as a complete unit rather than as a segment of a larger force
- Cancelled in 2007, but restarted in 2008

https://en.wikipedia.org/wiki/Land_Warrior

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## Major Subsystems and Components

- Computer subsystem
- Helmet subsystem
- Control and communications subsystem
- Weapons subsystem
- Navigation system

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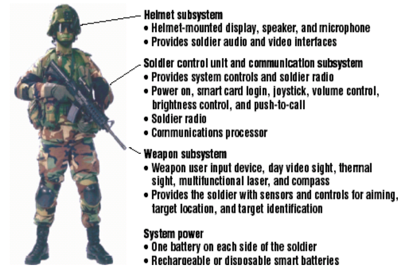
## Helmet Subsystem

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## Computer Subsystem


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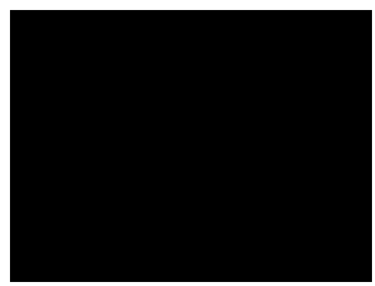
## Land Warrior Video



https://www.youtube.com/watch?v=dDrvZzfmuk4

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## 21st-Century Soldier

- 21st-Century Soldier (Czech: Voják 21. století) is a Czech Future Soldier military project
- The agreement of Czech Ministry of Defence and VOP-026 Šternberk about the future soldier program was signed in 2004
- A functional prototype was created at the end of 2005
  - Expected to be operation in 2012

https://en.wikipedia.org/wiki/21st-Century_Soldier

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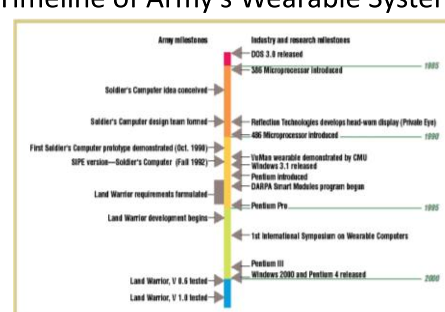
## Timeline of Army's Wearable Systems

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## Military Suit & Suspended Armor

https://www.youtube.com/watch?v=Ix_KVBLrEdo

## Conclusions

- Wearables mainly used by Universities
  - Industrial applications are catching up
- Major obstacles
  - Power, cooling, processing power, lightweight components, displays, graphics
- Future:
  - A single wearable will replace all separate devices we carry and use on a daily basis

## Questions