PA198
Augmented Reality Interfaces

Lecture 9

Wearable Augmented Reality

Fotis Liarokapis
liarokap@fi.muni.cz

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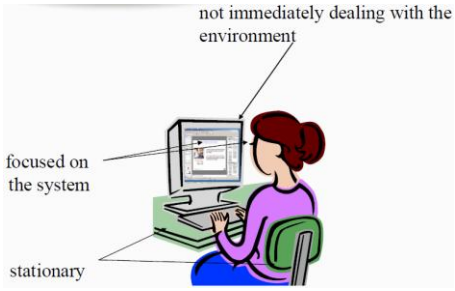
Introduction

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

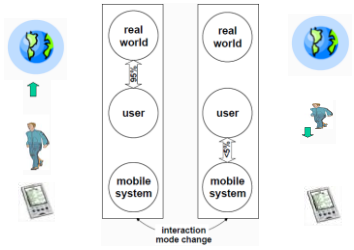
Conventional Computer



Roadmap: Wearable Computing 2020, Wear it at work.

Today's Mobile Interaction

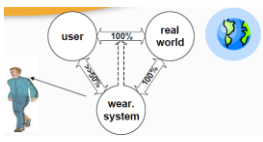
- Unusable when interaction with the physical world needed



Roadmap: Wearable Computing 2020, Wear it at work.

The Wearable Vision

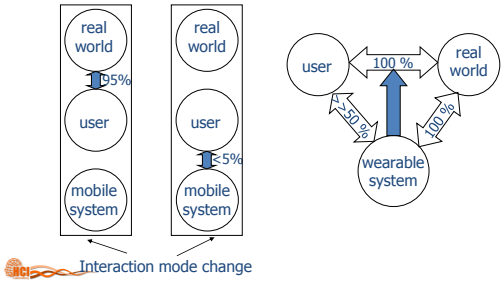
- Non disruptive interaction
- Environment oriented
  - Context recognition
  - Augmentation
- Physically unobtrusive
- Seamlessly connected



Roadmap: Wearable Computing 2020, Wear it at work.

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

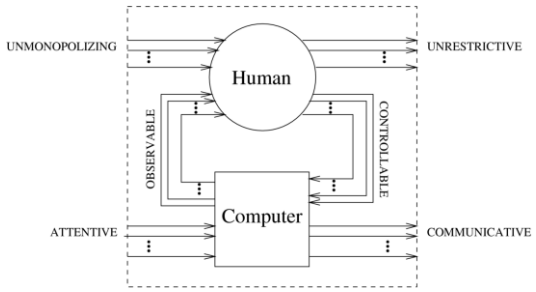
Fundamentals of Wearable Computing

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

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

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

Mediated Reality

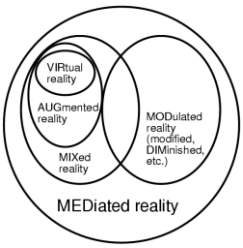
- Refers to the ability to add to, subtract information from, or otherwise manipulate one's perception of reality
  - Through the use of a wearable computer or hand-held device
- Typically, it is the user's visual perception of the environment that is mediated

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

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

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

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

Father of Wearable Computing

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

Wearable Devices




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

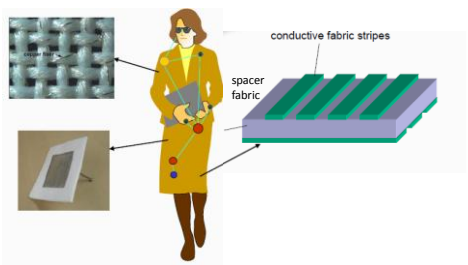
Architecture

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

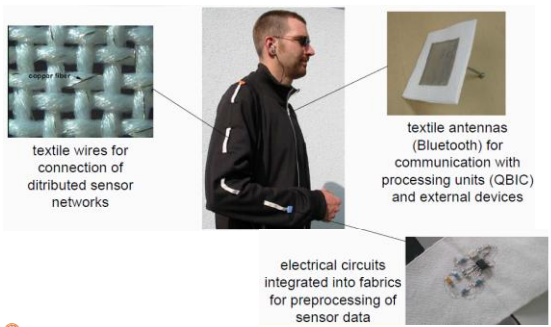
Roadmap: Wearable Computing 2020, Wear it at work.

Layer 1: Functional Textiles



Roadmap: Wearable Computing 2020, Wear it at work.

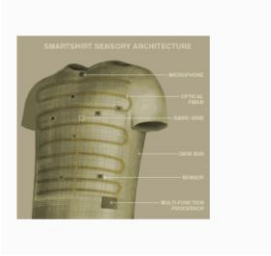
Simple Functions in Textiles



Roadmap: Wearable Computing 2020, Wear it at work.

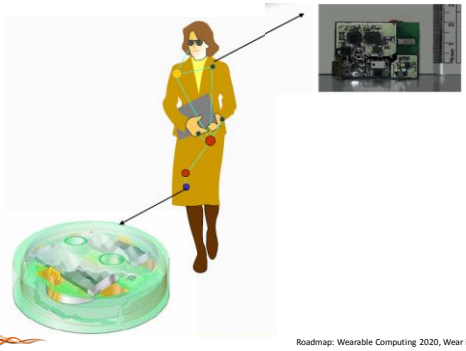
Smart Shirts

- Wearable Motherboard, Smart Shirt (GATECH)



Roadmap: Wearable Computing 2020, Wear it at work.

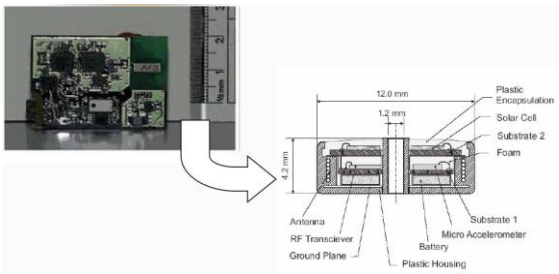
Layer 2: Embedded Microsystems



Roadmap: Wearable Computing 2020, Wear it at work.

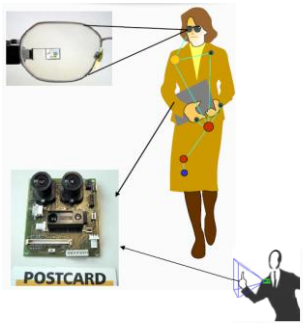
Miniaturized Sensors

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



Roadmap: Wearable Computing 2020, Wear it at work.

Layer 3: Attachable Peripherals



Roadmap: Wearable Computing 2020, Wear it at work.

Augmented Reality

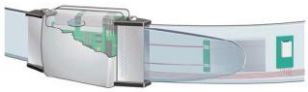
Roadmap: Wearable Computing 2020, Wear it at work.

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

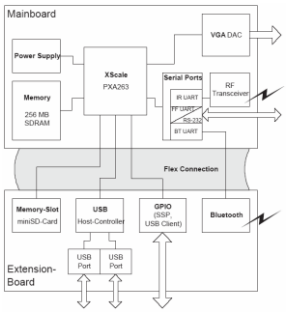
Sensor Based Interfaces

ETH QBIC: Belt Integrated System

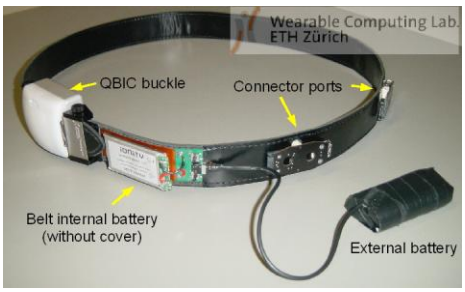
- Buckle as computer housing
- Belt as peripheral bus
  - Connectors
  - Batteries
  - Wireless adapter, storage etc



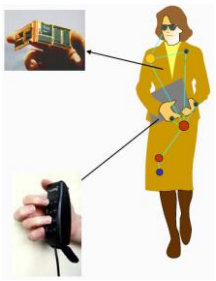
QBIC



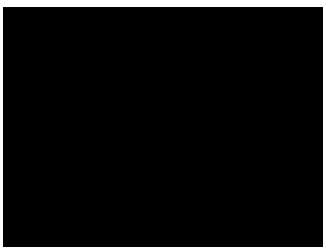
ETH QBIC



Layer 4: Carry On Devices



Wearable Computer New Scientist



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

Design Guidelines

How To Design This?

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

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.

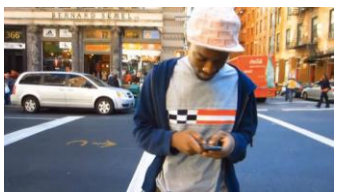
Designing for Wearables

- 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

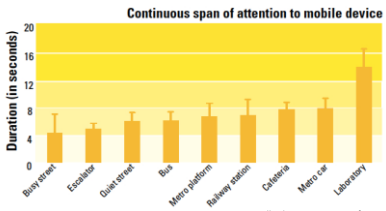
- Using mobile phone people split their attention between the display and the real world



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



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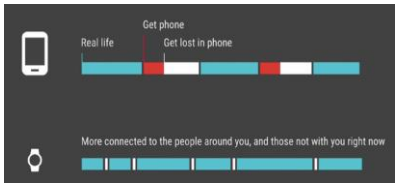
Using Micro Interactions

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

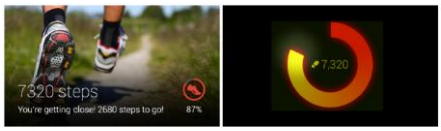


Like A Rear View Mirror

- 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

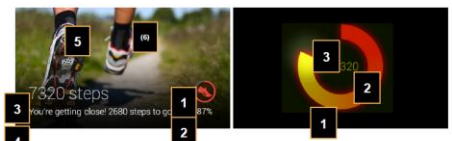


Bad Good

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

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

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

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

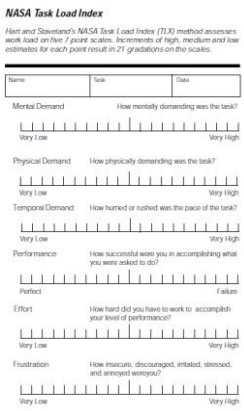
Important Note

- 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/



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

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

How To Take A Note?

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

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

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

Important Note

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

Design For Device

- Simple, relevant information
- Complement existing devices

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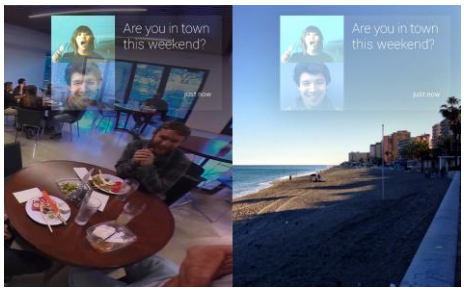
Glass User Interface

Test Indoors & Outdoors



Design for Context

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

Interface Guidelines

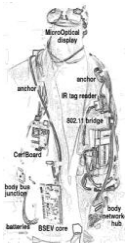
- Design for device
- Use multiple input options
- Do one thing at a time
- Consider user context
- Design for indoor and outdoor use
- Design for device ecosystem

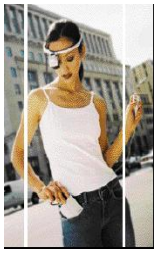
Social Acceptance

- 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

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?

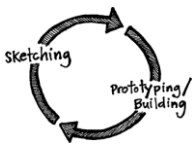
Prototyping

Main Goal

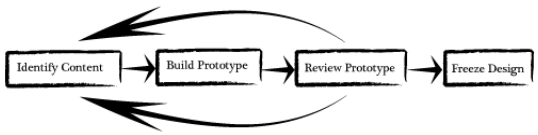
- How can we quickly prototype wearable computing applications with little or no experience
- Understand the market and user needs first

Why Prototype?

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



Prototype Design Process



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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

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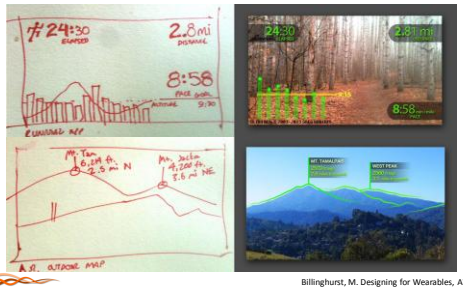
Sketched Interfaces

- Sketch + Powerpoint/Photoshop/Illustrator



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

Paper Prototype

- Use sketched interface in template

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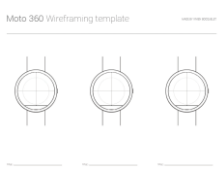
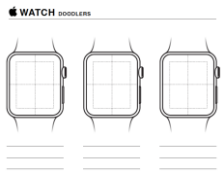
Smart Watch Templates

- 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 .

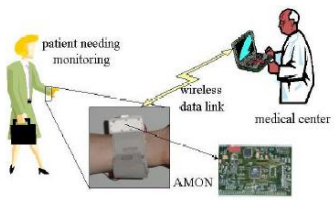
- MIT Media Lab has developed handbags that alert you when you leave
  - Things behind, your wallet, or an umbrella if you need one
- Oakley has developed the first digital music eyewear
  - The Oakley Thump, comes equipped with a solid state hard drive, for skip free listening

Intel Wearable Video

https://www.youtube.com/watch?v=iw5pn7H7vKg

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

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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

Major Subsystems and Components

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

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Helmet Subsystem

Helmet subsystem
- Helmet-mounted display, speaker, and microphone
- Provides soldier audio and video interfaces

Soldier control unit and communication subsystem
- Provides system controls and soldier radio
- Power on, smart card login, joystick, volume control, brightness control, and push-to-call
- Soldier radio
- Communications processor

Weapon subsystem
- Weapon user input device, day video sight, thermal sight, multifunctional laser, and compass
- Provides the soldier with sensors and controls for aiming, target location, and target identification

System power
- One battery on each side of the soldier
- Rechargeable or disposable smart batteries

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Computer Subsystem

Computer subsystem
- Manages system configuration, messages, and alerts
- Stores standard map product, mission data, and manuals
- Generates map with graphical overlay of position and situation

Navigation subsystem
- Provides GPS and magnetic heading
- Utilizes dead reckoning device when GPS signal is not present
- Provides soldier location and heading to computer for map display, automatic position reporting, and target location calculation

Soldier equipment
- Clothing, boots, gloves
- Assault helmet
- Modular lightweight load-bearing equipment, and ruck sack
- Hydration system
- Body armor

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Land Warrior Video

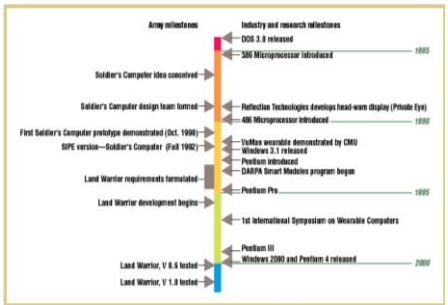
https://www.youtube.com/watch?v=dDrvZzfmuk4

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

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